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Long-Term Results of *In Situ* Saphenous Vein Bypass

Analysis of 2058 Cases

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Objective
The authors evaluated the long-term patency and outcome of patients undergoing infrainguinal reconstruction using the *in situ* saphenous vein.

Summary Background Data
The *in situ* saphenous vein bypass has demonstrated excellent patency and limb salvage rates in numerous studies. The authors previously reported their early results with these bypass procedures, and this article represents their long-term experience with 2058 *in situ* saphenous vein bypasses during a 20-year period. This comprises the largest series with long-term follow-up of *in situ* saphenous vein bypasses in the literature.

Methods
From 1975 to 1995, 3148 autogenous vein bypasses were performed at the authors' institution, of which 2058 used the saphenous vein *in situ*. The indication for operation was limb-threatening ischemia in 1875 of 2058 patients (91%). In 88% of patients with an intact ipsilateral saphenous vein, an *in situ* bypass was completed successfully. One thousand twenty-three bypasses (69%) were terminated at the infrapopliteal level. Of these bypasses, 1562 of 2058 (76%) were completed using the closed *in situ* technique.

Results
The 30-day patency rate was 96%, and the cumulative secondary patency was 91%, 81%, and 70% at 1, 5, and 10 years, respectively. Limb salvage rates using the *in situ* bypass were 97%, 95%, and 90% at 1, 5, and 10 years, respectively.

Conclusion
The infrainguinal inflow source, length of bypass, specific outflow vessel, or vein diameter did not have a significant effect on immediate or long-term bypass performance. These data suggest that the *in situ* saphenous vein is an excellent conduit for femoropopliteal and femoral to infrageniculate bypasses for limb salvage.

Over the past 20 years, vascular surgeons have seen a remarkable evolution in the treatment of infrainguinal occlusive disease. The expectations of surgeons and patients have been elevated as infrainguinal bypass procedures and resultant limb salvage have become increasingly successful. This improvement has been achieved through a gradual accrual of surgical knowledge of the factors that significantly affect bypass func-

Table 1. PATIENT DEMOGRAPHICS

Group	No. (%)
Males	1325 (64)
Females	733 (36)
Diabetics	1067 (52)
Mean age (yr) (range)	68 (12–99)

tion and longevity. In particular, an appreciation of the superiority of autogenous vein as a bypass conduit and the importance of vein quality and minimally traumatic preparation have been documented in several large series.[1–13] Knowledge of the use of more distal inflow and outflow arteries may also be gained from these types of series.[1–22]

Theoretically, the ideal conduit for infragenicular arterial reconstruction should consist of an antithrombogenic autogenous tube lined by normally functioning endothelium matched in size to the vessels it connects. Use of the greater saphenous vein (GSV), prepared atraumatically *in situ,* appears to be the most reliable method of achieving this end.[23–30] After early skepticism and some technical modifications, we and others have adopted the use of the saphenous vein *in situ* as the preferred conduit for treatment of critical lower limb ischemia.

The evolution of the modern *in situ* bypass has provided knowledge not only about a method of vein preparation but also about a myriad of aspects important to the salvage of ischemic limbs. Our purpose in this report was to summarize these findings within the context of a 20-year series involving several thousand distal bypasses.

METHODS

Between 1975 and 1995, 3148 infrainguinal arterial bypasses were performed at Albany Medical Center Hospital. *In situ* saphenous vein bypass with use of the atraumatic valve incision technique, as described previously, was attempted in all patients in whom a vein was not previously harvested, ligated, absent secondary to previous stripping, or needed for future use. A complete *in situ* bypass was performed in 2058 procedures. Partial *in situ* bypass was performed in 182 procedures, a vein excised in 518, and a prosthesis used in 390. Patients were predominantly elderly men, and 52% had a history of diabetes (Table 1). Limb salvage was indicated for 91% of the bypasses performed (Table 2). An *in situ* bypass was not performed in 908 patients. One hundred ten of these patients (12%) had an inadequate vein, 590 (65%) had no usable vein, and 208 (23%) had a vein that was spared. The most common site of proximal anastomosis was the femoral artery, and distal anastomosis was predominantly to a tibial artery (Table 3).

Preoperative biplanar angiography was obtained for all patients (digital subtraction in the later period). In addition, saphenous veins were studied preoperatively with a venogram or duplex ultrasonography. All *in situ* bypasses were performed with the atraumatic valve incision method.

The technical approach has remained unchanged since the introduction of the valve cutter in 1981.[31] In brief, the proximal GSV and inflow artery are isolated. Concurrently, a separate incision is made below the

Table 2. INDICATIONS FOR *IN SITU* BYPASS

	No. (%)
Limb salvage	1875 (91)
Rest Pain	623
Tissue necrosis	1252
Claudication	114 (6)
Aneurysm	44 (2)
Trauma	25 (1)

Table 3. INFLOW AND OUTFLOW ARTERIES

Artery	No.
Inflow	
Common femoral	718
Superficial femoral	767
Profunda femoris	434
Popliteal	62
Tibial	5
Graft/iliac	72
Outflow	
AK popliteal	48
BK popliteal	587
Tibioperoneal trunk	54
Proximal anterior tibial	195
Distal anterior tibial	115
Dorsalis pedis	152
Proximal posterior tibial	269
Distal posterior tibial	123
Proximal peroneal	413
Distal peroneal	102

AK = above knee; BK = below knee.

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knee, and a side branch of the GSV is identified when the two-team approach is used. After heparinization (30 units/kg), the proximal GSV is transected and the proximal valves are excised or divided with fine scissors or a retrograde valvulotome. A 1-mm embolectomy (#3 Fogarty) catheter is then introduced through the side branch at the knee and passed proximally through the divided end of the vein. The catheter is divided, and the cutter and following irrigation catheter are secured to it. This mechanism is drawn distally with a solution of dextran/heparin/papaverine infused at a constant pressure (>300 mm Hg) to dilate the vein. This floats the cutter and presents a functionally closed valve so that the blade can engage and bisect the leaflets. The cutter is withdrawn at the proximal end and detached, and the Fogarty catheter is withdrawn distally. The use of this cutter is confined to the thigh portion of the vein.

The proximal anastomosis is performed and arterial flow is introduced in the saphenous vein. The resultant palpable pulsation demonstrates the next competent valve. The site of distal anastomosis is identified, dictating the length of the distal mobilized segment needed. The remaining valves are divided with the retrograde Mills valvulotome. Before construction of the distal anastomosis, the absence of a flow-limiting lesion or fistula in the conduit is best determined by observation of free flow through the distal divided end of the arterialized *in situ* vein. At completion of the bypass, the conduit and outflow tract are examined with a hand-held Doppler ultrasound and/or intraoperative angiography. Whenever possible, the bypasses were completed using this modified closed technique, which was possible in 75% of the cases. Hemodynamically significant fistulas were localized by intraoperative arteriogram or Doppler ultrasound and ligated.

When the vein was complex or of smaller diameter, the open method was used. The vein was exposed throughout its entirety and the intraluminal valve cutter was not used. The GSV and inflow artery were identified, the first and second valves were incised or excised in the usual manner, and the proximal anastomosis was performed. An incision was then made along the length of the vein to identify the next valve and fistula. Before any distal manipulation was performed, the vein was prepared with the dextran/heparin/papaverine solution to gently dilate the vein and avoid endothelial damage. The fistulas were ligated in continuity and the valves were incised with the retrograde valvulotome through a distal side branch. The rest of the procedure was completed in the same manner as the closed method.

In the postoperative period, bypass patency and limb salvage were determined at 2 weeks, 3 months, 6 months, 9 months, 12 months, and every 6 months thereafter. Assessment included physical examination, pulse volume recordings, segmental limb pressures, and duplex ultrasonography. Recurrence of symptoms, deterioration of pulse volume reading waveforms, or decreased conduit flow velocities and reactive hyperemia as determined by duplex scanning led to further investigation by angiography. Follow-up was completed for 95% of the patients. Graft patency and limb salvage data were calculated according to life-table methods. In addition to the type of conduit used, bypasses were also evaluated according to the length of the bypass and vein size. Long bypasses were those with the inflow originating from within 10 cm of the femoral bifurcation and terminating within 10 cm of the ankle, and short bypasses were those with the inflow originating from the popliteal or tibial arteries. Vein size was also measured after arterialization with a Vernier caliper. All operations, complications, and follow-up data were recorded prospectively in our computerized vascular registry, and statistical comparisons were performed with use of Wilcoxon's analysis with a biomedical statistical software package.

Table 4. PRIMARY PATENCY OF 2058 *IN SITU* BYPASSES

Interval (mo)	Bypasses at Risk	Occlusions	Interval Patency	Cumulative Patency
0–1	2058	134	0.931	0.931
2–12	1718	142	0.900	0.838
13–24	968	41	0.951	0.797
25–36	659	20	0.965	0.769
37–48	455	12	0.970	0.746
49–60	336	12	0.959	0.715
61–72	231	10	0.951	0.680
73–84	169	6	0.960	0.652
85–96	123	3	0.972	0.634
97–108	88	4	0.948	0.601
109–120	62	4	0.917	0.551

RESULTS

Cumulative primary and secondary patency rates for the total series of *in situ* bypasses are listed in Tables 4 and 5. The primary patency rate was 84% at 1 year, 72% at 5 years, and 55% at 10 years. The secondary patency rate was 91% at 1 year, 81% at 5 years, and 70% at 10 years. When the *in situ* bypasses were evaluated for primary and secondary patency based on inflow and outflow, no statistically significant differences in patency were found in the long or short term (Tables 6 and 7). Patency was also assessed based on the diameter of the distal vein as measured at the time of operation (Table 8). Bypasses were divided into two groups of vein size: larger than or equal to 4.0 mm and smaller than 4.0 mm

Table 5. SECONDARY PATENCY OF 2058 *IN SITU* BYPASSES

Interval (mo)	Bypasses at Risk	Occlusions	Interval Patency	Cumulative Patency
0–1	2058	79	0.960	0.960
2–12	1765	76	0.947	0.909
13–24	1051	29	0.968	0.880
25–36	737	13	0.980	0.862
37–48	520	16	0.965	0.832
49–60	382	7	0.979	0.814
61–72	275	7	0.971	0.791
73–84	204	5	0.972	0.769
85–96	148	2	0.985	0.757
97–108	110	5	0.949	0.718
109–120	81	2	0.969	0.696

at the outside diameter (OD). Nine hundred thirty-six bypasses were performed with veins smaller than 4.0 mm, and 1122 were performed with veins measuring 4.0 mm or larger. Primary patency was virtually identical for the two groups at 10 years. Primary and secondary patency was also analyzed based on sex and diabetic status. Again, there was no difference in patency up to 10 years in either of these groups (Tables 9 and 10). The length of the bypass did not appear to affect long- or short-term patency, although these results are difficult to compare due to the relatively small number of short bypasses (Tables 11 and 12). Limb salvage rates were 99% at 30 days, 97% at 1 year, 95% at 5 years, and 90% at 10 years (Table 13). No difference in patency was found regardless of whether an open or closed technique was used (Table 14). Revisions of the *in situ* bypasses are listed in Table 15. One hundred eleven fistulas were ligated postoperatively in 107 bypasses without any failures. Thirty-one retained valves were excised, with a continued patency of 28 of these 31 cases. There were 42 proximal arterial revisions, with continued patency of 38, and 64 distal arterial revisions, with continued patency of 49. There were 34 proximal vein revisions, 31 of which remained patent; 38 midvein revisions, 36 of which remained; and 44 distal vein revisions, of which 35 remained patent. There were eight aneurysm formations of *in situ* veins. The operative mortality rate was 3.7% (77/2058). Cumulative patient survival is presented in Table 16.

Table 7. PATENCY BASED ON OUTFLOW

Artery	No.	30 days	1 year	5 years	10 years
Primary patency					
AK popliteal	48	0.956	0.880	0.710	*
BK popliteal	587	0.926	0.839	0.720	0.532
Tibioperoneal	54	0.942	0.777	0.744	*
Proximal anterior tibial	195	0.963	0.871	0.784	*
Distal anterior tibial	115	0.943	0.873	0.772	*
Dorsalis pedis	152	0.916	0.821	0.680	*
Proximal posterior tibial	269	0.948	0.804	0.658	0.498
Distal posterior tibial	123	0.915	0.811	0.719	*
Proximal peroneal	413	0.931	0.853	0.723	0.461
Distal peroneal	102	0.877	0.812	0.663	*
Secondary patency					
AK popliteal	48	0.956	0.930	0.762	*
BK popliteal	587	0.954	0.910	0.826	0.705
Tibioperoneal	54	0.981	0.887	0.855	*
Proximal anterior tibial	195	0.979	0.946	0.860	*
Distal anterior tibal	115	0.962	0.948	0.876	*
Dorsalis pedis	152	0.958	0.919	0.771	*
Proximal posterior tibial	269	0.980	0.910	0.794	0.595
Distal posterior tibial	123	0.940	0.858	0.764	*
Proximal peroneal	413	0.957	0.903	0.817	0.633
Distal peroneal	102	0.928	0.862	0.771	*

AK = ??? BK = ???
* Insufficient data for analysis.

Table 6. PATENCY BASED ON INFLOW

Interval	CFA (n = 718)	SFA (n = 767)	PFA (n = 434)	POP (n = 62)	TIB (n = 5)	Graft/Iliac (n = 72)
Primary patency						
30 days	0.931	0.929	0.930	0.983	1.000	0.922
1 yr	0.826	0.849	0.844	0.839	1.000	0.789
5 yr	0.694	0.753	0.686	0.839	*	0.623
10 yr	0.581	0.509	*	*	*	*
Secondary Patency						
30 days	0.959	0.949	0.973	0.983	1.000	0.969
1 yr	0.906	0.910	0.916	0.909	1.000	0.879
5 yr	0.792	0.846	0.805	0.909	*	0.750
10 yr	0.710	0.700	*	*	*	*

CFA = common femoral; SFA = superficial femoral; PFA = profunda femoris; POP = popliteal; TIB = tibial.
* Insufficient data for analysis.

Table 8. PRIMARY PATENCY BASED ON VEIN SIZE

Interval	<4.0 mm (n = 936)	≥4.0 mm (n = 1122)
30 days	0.899	0.959
1 yr	0.770	0.897
5 yr	0.655	0.766
10 yr	0.534	0.540

Table 10. SECONDARY PATENCY BASED ON SEX AND DIABETES STATUS

Interval	Males (n = 1325)	Females (n = 733)	Diabetics (n = 1067)	Nondiabetics (n = 991)
30 days	0.964	0.952	0.964	0.954
1 yr	0.910	0.907	0.919	0.899
5 yr	0.789	0.859	0.840	0.797
10 yr	0.673	0.734	0.778	0.659

DISCUSSION

In its original incarnation, the *in situ* bypass as performed in the 1960s was an inferior technique to reversed vein bypass techniques.[10,32–34] No form of distal bypass in the 1960s and 1970s delivered results comparable to those achievable today.[1–5] The inflow vessel was almost always the common femoral artery; bypasses below the knee were considered to have an unlikely chance for success, especially if they involved tibial arteries. The peroneal and pedal arteries were dismissed as viable outflow options. Veins were thought to be usable if they were at least 4 mm in diameter. The intactness of the distal pedal arch and bypass flows of more than 100 mL/minute were regarded as significant factors for bypass patency. Most importantly, countless limbs were amputated, simply because many surgeons did not have an expectation of success.

The method of valve incision for *in situ* bypass was discovered accidentally. However, the information gained in performing the next 2000 of these procedures has contradicted the teachings of the past and has raised the surgeon's expectation of success when presented with a critically ischemic limb.

The superiority of autogenous vein for distal bypass is most likely derived from the antithrombogenic properties of the endothelial layer, especially as compared with either prosthetic material or endarterectomized artery. The appreciation of the endothelium as a uniquely important organ in its own right has been supported by a tremendous amount of work in cell biology over the past two decades.[11,23,24,26,28–30] An understanding of the sensitivity of the functional monolayer to warm ischemia, surgical manipulation, and injudicious handling, which was derived in part from this series, has radically changed vein preparation techniques. One can oxygenate the endothelium by not interrupting the vasa vasorum and/or by rapidly perfusing the conduit with arterial blood.[11,23,24] The interior of the vein and both arteries should be subjected to a minimum of direct trauma from forceps, dilators, or catheters. To do this, the operator must handle the vein very gently; the use of loupe magnification and microsurgical techniques and instruments facilitate the operator's efforts to try to maintain the vein in as much of a living, functional form as possible. Vein dilatation should be performed with a limited, controlled pressure with a solution that does not injure the epithelium, such as heparinized blood or dextran. These principles can be applied to and are equally pertinent for *in situ* or reversed vein bypass techniques.

There is, however, a widely held misconception that all *in situ* bypass techniques produce comparable results. Since the resurrection of the *in situ* bypass by the introduction of valve incision as the least traumatic method of rendering the bicuspid venous valves incompetent, many surgeons have introduced their own variations of the technique.[34–40] However, common to virtually all of these techniques is the use of the Mills valvulotome and/or an obturator-style cutter/disruptor. Clearly, the Mills valvulotome is the safest instrument for valve incision,

Table 9. PRIMARY PATENCY BASED ON SEX AND DIABETES STATUS

Interval	Males (n = 1325)	Females (n = 733)	Diabetics (n = 1067)	Nondiabetics (n = 991)
30 days	0.933	0.928	0.944	0.918
1 yr	0.836	0.842	0.857	0.818
5 yr	0.692	0.755	0.751	0.685
10 yr	0.521	0.604	0.672	0.491

Table 11. PRIMARY PATENCY OF "LONG" *VERSUS* "SHORT" *IN SITU* BYPASSES

Interval	"Long" (n = 440)	"Short" (n = 67)
30 days	0.906	0.984
1 yr	0.825	0.847
5 yr	0.687	0.847
10 yr	0.545	*

"Long" = inflow proximal to popliteal, outflow to distal anterior tibial, distal posterior tibial, distal peroneal, or dorsalis pedis; "short" = inflow popliteal or tibial.

Table 12. SECONDARY PATENCY OF "LONG" *VERSUS* "SHORT" *IN SITU* BYPASSES

Interval	"Long" (n = 440)	"Short" (n = 67)
30 days	0.944	0.984
1 yr	0.791	0.914
5 yr	0.775	0.914
10 yr	0.633	*

"Long" = inflow proximal to popliteal, outflow to distal anterior tibial, distal posterior tibial, distal peroneal, or dorsalis pedis; "short" = inflow popliteal or tibial.

largely due to the limited contact area of this instrument with the endothelium. This is borne out by the excellent results achieved, that is, less than a 5% 30-day failure rate, whether used with the vein exposed or with angioscopic guidance.[1,2,4,9,35] In Europe, *in situ* bypass has been performed largely by means of retrograde sequential valve disruption with the instruments of Hall/Gruss, Cartier/Chevalier (Langeron), and LeMaitre.[32–40] These instruments have a major disadvantage in that they are usually introduced and withdrawn through the distal divided end of the vein, which is invariably the portion of the vein smallest in diameter and most likely to be further narrowed by spasm when manipulated. These factors conspire to increase the likelihood of circumferential endothelial injury. Although the use of such instruments appears simple, when analyzed, femoropopliteal bypasses using >4.0 mm OD veins and longer, low-flow bypasses carried out to the crural arteries for limb salvage have a 15% to 20% 30-day failure rate.

With the successful development of the instruments and techniques required for minimally traumatic valve incision, the *in situ* technique was progressively applied in more extreme settings.[1,5,6,14,16,19,41,42] The use of smaller-diameter veins (<4.0 mm OD) made expectation of success commonplace; no longer did a small vein consign the limb to primary amputation. Use of these smaller veins in either an *in situ* or excised configuration generally has been accepted among vascular surgeons.[14,20,43] It is difficult to account for the success of these smaller veins as bypass conduits, but it probably reflects the appreciation of the delicacy of the vein preparation and the development of appropriate handling techniques mentioned previously.

Table 13. CUMULATIVE LIMB SALVAGE OF *IN SITU* BYPASSES

Interval	All (n = 2058)	Popliteal (n = 635)	Tibial (n = 1423)	Peroneal (n = 515)
30 days	0.991	0.988	0.992	0.992
1 yr	0.972	0.971	0.972	0.973
5 yr	0.950	0.961	0.943	0.943
10 yr	0.901	0.961	0.857	0.844

Table 14. SECONDARY PATENCY OF "OPEN" *VERSUS* "CLOSED" METHODS

Interval	"Open" (n = 496)	"Closed" (n = 1562)
30 days	0.952	0.962
1 yr	0.896	0.913
5 yr	0.799	0.822
10 yr	0.704	0.683

In addition to the emphasis on atraumatic vein preparation and anastomotic technique, work with the *in situ* vein in this series generated considerable information about the use of alternative inflow and outflow arteries. The common femoral artery had been regarded as the sole proper inflow vessel. However, because the saphenofemoral junction lies at a variable distance or distal to the end of the common femoral artery, use of the superficial and profunda femoris arteries as inflow arteries was studied. Although it was often technically easier to anastomose the proximal vein to these distal arteries, the fear of progression of disease limited its use by most surgeons. Data from this series and others have shown that, when properly selected, more distal inflow sites can be used successfully.[17,18,21,43] This not only helps to conserve the amount of vein necessary for the completion of the procedure, but also minimizes the extent of surgery whenever possible.

Armed with a reliable venous conduit, vascular surgeons extended the application of *in situ* and excised vein to more limited outflow tracts.[4–6,16,41–45] An appreciation of the utility of the peroneal artery for this purpose stems directly from the current paper. This is especially important in view of the frequency in which the peroneal vein is the only patent vessel left to the critically ischemic limb.[4,6,16,41–45] In addition, isolated tibial arteries or those without an intact pedal arch were used with impunity. That the bypasses remained patent bespoke of the improvements in vein preparation; the high rates of limb salvage with these types of bypasses was gratifying.[14,16,17,41] Further work by several investigators has demonstrated that perimalleolar and pedal arteries can be used successfully as outflow tracts.[1,4,5,17,19,20] No longer limited by previous constraints of vein diameter or bypass flow, surgeons can now perform these bypasses routinely.

In long-term follow-up, approximately 30% of *in situ* bypasses will fail during a 10-year period. Of these, approximately 10% can be salvaged with revision. Al-

Table 15. REVISIONS

Interval (mo)	A-V Fistula Ligation	Excision of Missed Valve	Proximal Artery	Distal Artery	Proximal Vein	Mid Vein	Distal Vein
0–1	34	27 (24)	7 (6)	27 (19)	2 (1)	8 (7)	17 (10)
2–12	68	4 (4)	20 (18)	16 (13)	18 (17)	19 (19)	22 (21)
13–24	6		3 (3)	5 (4)	7 (1)	4 (4)	3 (2)
25–36			5 (4)	4 (2)	1 (1)	5 (4)	1 (1)
37–48				1		1 (1)	
49–60	1		1 (1)	3 (3)	3 (3)	1 (1)	
61–72			1 (1)	4 (4)			
73–84			1 (1)	2 (2)			
85–96	1				1 (1)		
97–108							
109–120			1 (1)	1 (1)			
121–132	1		2 (2)		1 (1)		
133–144			1 (1)				
145+				1 (1)	1 (1)		1 (1)
Total revisions	111	31	42	64	34	38	44
Continued patency	111/111	28/31	38/42	49/64	31/34	36/38	35/44

Values in parentheses indicate successful revisions.

though there are many causes of failure, most of the revisions are performed to correct venous conduit problems. Early failures appear to be due to problems with vein preparation or to the use of poor-quality veins. Mid- and late failures appear to be more common secondary to fibrosis of the valve site or progression of disease. Most of these can be corrected easily, if found early, with the use of an interpositional venous graft or a vein patch angioplasty.[46–50] Occasionally in this series, ligation of small arteriovenous fistulas was required, virtually all within the first 24 months after surgery.[51,52] None of these contributed to failure of a bypass.

Selection of inflow arteries was based on initial angiographic and hemodynamic criteria, with any patent unobstructed artery acceptable. When stratified into groups based on inflow artery, no significant difference in patency was found when any particular femoral vessel or even distal vessels, such as the popliteal or tibial arteries, were used for *in situ* procedures. As has been found previously, if the vessel is hemodynamically stable and unobstructed, it can serve as an excellent inflow source. Proximal disease progression was noted equally among the groups, regardless of inflow vessel used. Remarkably, the *in situ* bypass remained patent despite complete occlusion of the inflow vessel in many cases. This only outlines the value of an intact biologically active endothelium in preserving these low-flow bypasses. Choice of outflow vessel was dictated by preoperative angiogram and operative exploration. Again, there was no difference in patency rates in terms of outflow vessel. This heightened our interest in using the peroneal artery as a significant outflow source. This artery tends to be disease free and can be exposed through the same medial incision that exposes the artery and vein throughout its length. Our results with the peroneal artery have been excellent, and we did not find this to be a disadvantageous outflow vessel compared with other tibial or pedal vessels.[1,4,14,16,41,44,45,53] Similarly, *in situ* bypasses to the dorsalis pedis, distal anterior tibial artery, and distal posterior tibial artery had a patency similar to bypasses to more proximal vessels.[1,4,5,41,53] Distal progression of disease and hemodynamic failures (<2%) were also similar. This led us to evaluate our results of long and short bypasses, which we found had no statistically significant difference in patency. However, this might not be true for reversed vein reconstructions.[18]

Table 16. CUMULATIVE PATIENTS SURVIVAL

Interval (mo)	At Risk	Deaths	Interval Survival	Cumulative Survival
0–1	2058	77	0.961	0.961
2–12	1765	159	0.893	0.858
13–24	1051	88	0.906	0.778
25–36	737	64	0.903	0.703
37–48	520	37	0.921	0.648
49–60	382	32	0.907	0.588
61–72	275	33	0.871	0.512
73–84	204	16	0.913	0.467
85–96	148	11	0.918	0.429
97–108	110	7	0.929	0.399
109–120	81	13	0.812	0.324

In addition, leaving the saphenous vein *in situ* allows for the natural taper of the vein, with the larger diameter of the vein anastomosed to the larger proximal arterial tree and the smallest diameter of the vein anastomosed to the smaller outflow tract. If rigorous technical details can be maintained in preparation of free or reversed vein grafts, excellent results can be achieved.[1,2,16,43] Generally, explantation of the vein subjects it to significant warm ischemia time. Reversal of the vein removes the natural taper matching the inflow and outflow arteries and allows for spasm and trauma during handling and exposure. The results of our excised vein bypasses during the same time period, using similar inflow and outflow arteries, remain significantly worse compared with *in situ* bypasses.[4,7] Conversely, *in situ* bypass, if not prepared adequately, may not produce optimal results.[33,54–56]

All patients undergoing elective surgery had their veins evaluated veins by venography or mapping. This aided in the planning of operative incisions and, most importantly, helped us to evaluate the veins before surgery. Thick-walled veins, sclerotic veins, and recanalized veins will have poor results regardless of bypass technique used. Preoperative evaluation has helped us choose the best vein for the bypass procedure and to delineate double systems or many of the venous anomalies that are anticipated with use of the GSV.[57,58]

Intraoperative and postoperative hand-held Doppler interrogation to evaluate these bypasses is very useful in localizing arteriovenous fistulas intraoperatively, evaluating the bypass itself, and evaluating the flow in the recipient artery. Determination of bypass patency by palpating the pulse alone is inadequate and may be misleading, because the best pulse will be felt proximal to a bypass stenosis/occlusion. Our postoperative follow-up protocol, particularly the use of duplex ultrasound, has improved secondary patency rates by approximately 10% by allowing us to identify those grafts that are failing, localize the problem area, and help direct subsequent treatment. Surveillance is useful in localizing arteriovenous fistulas and evaluating the bypass itself, the proximal and distal arteries, resting blood flow, and reactive hyperemia.[46,47,50,52] The consistent analysis of these bypasses is invaluable to maintaining a hemodynamically successful bypass and should be continued throughout the life of these patients for achievement of optimal results.

In conclusion, our data suggest that an *in situ* saphenous vein is a highly durable and excellent conduit for femoropopliteal and especially femoral to tibial artery bypasses. Lessons learned from this experience are applicable to any surgical procedure using a venous conduit. *In situ* bypasses require careful and meticulous preparation. Merely keeping the vein *in situ* does not have any protective merit unless the valves can be rendered incompetent atraumatically and the vein is prepared meticulously. These results show that the *in situ* saphenous vein bypass is an excellent venous conduit with optimum long-term patency and limb salvage rates and has withstood the test of time.

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Discussion

DR. G. MELVILLE WILLIAMS (Baltimore, Maryland): The Albany group, under the leadership of Drs. Shah and Leather, continue to lead the way in vascular reconstruction of the leg using the *in situ* saphenous vein. Their results are outstanding and unsurpassed. Of equal importance, the vein was found to be adequate in 88% of the patients, which would not be the case if they were to use reversed saphenous vein.