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Crural Artery Bypass with the Autogenous Greater Saphenous Vein

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Objective. *To evaluate the long-term outcome of greater saphenous vein (GSV) infrapopliteal revascularisation in a single centre over a 10 year period.*
Material and methods. *Fourty-one variables relating to a consecutive series of 90 crural artery GSV(76% in situ) bypasses in 81 patients (1990–2000) were analysed. The mean age of the 47 men and 34 women was 70 years. Limb-threatening ischaemia was present in 96% of cases, claudication in four patients. In 18 patients, surgery was 'redo'.*
Results. *The perioperative mortality was 3% ($n = 3$). Patient survival was 54% at 4 years. Independent risk factors affecting survival were chronic renal insufficiency ($p = 0.04$), hypertension ($p = 0.02$), and ischaemic heart disease ($p = 0.01$). Four bypasses thrombosed within 30 days. Three of them could be successfully reopened. Mean follow-up was 39 months. The primary patency rate at 4 years was 80%. Chronic renal insufficiency revealed to be the single independent risk factor for graft thrombosis ($p = 0.03$, $RR = 12.4$). The 4-year limb salvage rate was 88%. No independent risk factor affecting the limb salvage could be identified.*
Conclusion. *Crural artery revascularisation is a valuable option for the management of limb threatening infrapopliteal arterial occlusive disease.*

Key Words: Femorocrural bypass; Limb salvage; Graft patency; Lower limb revascularisation.

Introduction

Most vascular surgeons agree that femorodistal bypass with autogenous conduit remains the treatment of choice for patients with limb-threatening ischaemia.[1–8] Over the last decade, we pursued an aggressive policy of distal arterial reconstruction in elderly patients with threatening limb loss. The present study analyses the results obtained with distal infrapopliteal bypass surgery for limb salvage using the greater saphenous vein during the period 1990–2000.

Material and Methods

A database of vascular surgery has been prospectively maintained in our centre since 1988. A retrospective analysis of this computerized Vascular Surgery Registry revealed 90 infrapopliteal bypass grafts with the greater saphenous vein performed in the period of January 1990 to December 2000. This represents 7% of all infrainguinal revascularisations performed in the same time period. Endovascular procedures on the crural arteries are not performed in our centre. It concerns 81 patients of whom eight benefited bilateral tibial artery revascularisation and one had two distal bypass procedures on the same leg. There are 47 male and 34 female patients, with a mean age of 70 years (range: 37–93 years). For each case, a total of 41 variables were recorded. This includes 18 patient-related variables (demographic data, vascular risk factors, indications, past medical history, arterial run-off — summarised in Table 1), 16 procedure-related variables (graft material used, sites of anastomosis, type of surgical intervention, operative outcome), and seven follow-up variables, including patency rate, limb salvage, and survival. For follow-up, we gathered information from the out-patient clinic (at our centre or at another vascular centre) ($n = 75$) and from phone call to the general practitioner or to the patient if the last visit was 6 months or before ($n = 10$). Information gathered by phone call was limited to freedom of limb ischemia, freedom of amputation and survival.

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Table 1. Demographics and comorbidities of the 81 patients who benefited crural artery revascularisation.

Mean age	70 (range: 37–93 years)	
Men/women	47/34	
Smoking	45 (56%)	
Diabetes	35 (43%)	(17% insulin dependent) (26% non-insulin dependent)
Coronary artery disease	40 (49%)	
Hypertension	39 (48%)	
Hypercholesterolemia	35 (43%)	serum cholesterol values of 6.47 mmol/l or more or dyslipidemia requiring a lipid lowering drug regimen
Chronic renal insufficiency	16 (20%) (8 on dialysis)	persistent serum creatinine level greater than 0.15 mmol/l
Previous ipsilateral limb revascularisation	16 (20%)	

Patients were declared 'lost to follow-up' when no patient contact had occurred within 18 months.

All patients were preoperatively investigated by intraarterial angiography ($n = 75$) or by magnetic resonance angiography ($n = 15$). Arteriography revealed segmental to total occlusion of all three crural vessels in 17 limbs (19%). In three patients no distal outflow artery was visualised on angiography, but a patent distal crural vessel or pedal artery was evidenced by colour echoduplex scan, and this vessel was surgically exposed as target vessel. A single crural vessel was patent over its whole length in 47 limbs (52%), two vessels were patent in 18 legs (20%) and in eight legs (9%) all three crural vessels were patent. The indication for distal infrapopliteal bypass grafting was chronic critical limb ischemia in 96% of the cases (a case is defined as a revascularisation procedure, $n = 90$). It concerned ischemic rest pain (30%), ischemic non-healing ulceration (12%), toe gangrene (38%) and heel gangrene (15%). For four patients, the indication to tibial artery revascularisation was incapacitating claudication. For 20% of the operations, it concerned a secondary procedure, performed after a previous failed infrainguinal revascularisation. The procedures were preferentially done under locoregional anaesthesia (peridural in 54%, rachianaesthesia in 23%). In 23% of the operations, general anaesthesia was used. The most common technique was *in situ* greater saphenous vein (GSV) bypass grafting (68 procedures, 76%). A reversed GSV was used for 22 distal bypasses (24%), of which eight were done with the contralateral GSV.

During the same study period, 17 patients benefited crural artery revascularisation with other bypass material than the greater saphenous vein (seven spliced veins, eight cryopreserved arterial allografts, one lesser saphenous vein and one prosthesis). These cases are not included in this study. The number of primary major amputations for unreconstructable arterial disease could be limited to 28 cases over the same time period (it mainly concerned dialysed patients ($n = 21$)). This number was twice as high in the previous decade (58 primary amputations from 1980 to 1990).

The anastomotic sites are listed in Table 2. To obtain a tension-free proximal anastomosis of *in situ* grafts, we did not hesitate to select the proximal disease-free superficial femoral artery or the deep femoral artery as inflow source. In 16 patients, we preferred a short bypass graft, originating from the distal unobstructed superficial femoral artery ($n = 7$), the proximal popliteal ($n = 3$), or distal popliteal artery ($n = 6$). A reversed GSV was always used in these cases. The distal anastomotic site was chosen in function of the angiographic images, so that the revascularised target artery was directly on-line with the ischemic area. Ten patients had an inframalleolar arterial revascularisation. In 12 patients, two different distal anastomoses were performed with a bifurcated saphenous vein graft ($n = 7$) or with a vein segment sutured on the main graft ($n = 5$). Since 1998 we routinely used the pneumatic tigh tourniquet to exsanguinate the limb, in order to obtain a bloodless operative field and an atraumatic hemostasis for the distal anastomosis. This technique has been described in detail elsewhere.[9]

The revascularisation procedure was completed by a concomitant limited toe amputation in 17 cases, by a forefoot amputation in one case and by a free tissue transfer in four cases. The mean operating time was 230 min (range: 150–350 min).

Table 2. Anastomotic sites for crural artery revascularisation.

Proximal anastomosis ($n = 90$)	
Common femoral artery	26 (29%)
Proximal SFA	31 (34%)
DFA	17 (19%)
Distal SFA (above-knee)	7 (8%)
Proximal popliteal artery	3 (3%)
Distal popliteal artery	6 (7%)
Distal anastomosis ($n = 102$)	
Anterior tibial artery	26 (26%)
Posterior tibial artery	36 (36%)
Peroneal artery	30 (30%)
Dorsalis pedis artery	4 (4%)
Retromalleolar post-tibial artery	4 (4%)
Plantar artery	2 (2%)

NB: 12 patients had two distal anastomoses; SFA, supericial femoral artery; DFA, deep femoral artery.

At the end of the operation, a continuous wave Doppler investigation is made of the bypass graft. Patency and limb salvage rates were defined and presented in accordance with the recommendations of the Ad Hoc Committee on Reporting Standards of the Joint Council of the Vascular Societies.[10] Primary patency was defined as uninterrupted patency of the original graft without the need for any graft directed intervention. Assisted primary patency considers patency obtained with some graft revisions before occlusion. Secondary patency also includes reopened grafts. Limb salvage was defined as retention of a functional lower extremity without need for amputation proximal to the tarsal–metatarsal junction (freedom from transtibial or above-knee amputation).

During late follow-up graft patency was monitored by clinical examination, supplemented by segmental blood pressure measurements at the lower limb, at regular intervals (at 6 weeks, and every 4 months thereafter for the first year, and then biannually). Since 1999, all distal bypass grafts are routinely surveyed with colour duplex echography in the non-invasive vascular laboratory. When the segmental blood pressure decreased by 15 mmHg or more, compared to the postoperative value, or when focal flow disturbances (peak systolic velocity of 300 cm/s, or a decreased overall graft velocity of less than 45 cm/s), an arteriography was performed to investigate the causative stenosis.

Statistics

Results were expressed as mean ± S.E. (standard error) for quantitative variables and as counts and proportions (%) for categorical findings. Classical Kaplan–Meier survival curves and life-tables were used to display postoperative revascularisation results and primary outcome variables (patency, limb salvage and survival). Kaplan–Meier survival curves were associated with 95% confidence intervals. Subgroups were compared by the Log rank test.

To assess the predictive value of the variables (age, gender, smoking, diabetes, coronary artery disease, hypertension, hypercholesterolemia, renal insufficiency, type of graft material, site of distal anastomosis) that could affect mortality, graft thrombosis and amputation, a multivariate Cox proportional hazards regression analysis was done. Results were considered to be significant at the 5% critical level ($p < 0.05$) after adjusting for multiple testings. All calculations were performed using SAS (version 8.02 for Windows) and S-PLUS (version 6.1) statistical software package.

Results

The operative mortality rate was 3%. Of the three in-hospital deaths, two were related to cardiovascular disease (two myocardial infarctions). Another death was secondary to sepsis-induced multiorgan failure. No significant risk factor could be linked to the perioperative mortality.

Nine patients required an early reintervention in the postoperative period: thrombectomy in four patients (successful in three), ligation of an arteriovenous fistula of an *in situ* bypass graft in three and revision for bleeding from an eroded graft in two (one could be preserved by interposition of a new vein segment). Overall, two grafts were occluded when the patient left the hospital. One patient required early above-knee amputation for progressive infection of the heel necrosis, despite an open distal bypass graft. In all but five patients, the tissue loss or minor amputation healed within 2 months, as a result of the crural artery revascularisation.

The mean length of follow-up was 39 (range: 0–96) months. Three patients were lost to follow-up (at 6 weeks, 6 months, and 1 year, respectively). During follow-up, 12 reinterventions were done on the bypass graft (one thrombectomy, two fibrinolyses, five ligations of missed arteriovenous fistula of *in situ* GSV grafts, three prolongations of the bypass graft, and one vein patch). Nine of the late interventions were done on a failing graft to prevent thrombosis, while three revisions were done to reopen a thrombosed graft. Overall, four distal bypass grafts thrombosed during follow-up after a mean delay of 13 (range: 1–54) months. This results in a primary patency rate at 4 years of 80% (Fig. 1). The assisted-primary patency was 82% at 4 years and the secondary patency rate attains 86% at 4 years. The sole independent prognostic factor predictive for graft occlusion is chronic renal insufficiency ($p = 0.003$). For patients with renal insufficiency ($n = 16$, of whom 10 were on dialysis), the relative risk (RR) for graft thrombosis (early or late) is 12.4 (confidence interval 2.3–66.3). The primary patency rate was compared for the different levels of distal anastomosis (proximal versus distal crural artery, crural artery versus pedal artery), but no significant difference was observed ($p = 0.14$).

Overall, eight patients required major amputation (five below-knee, three above-knee) during follow-up, after a mean delay of 10.4 months (extremes 2 and 61 months). Five of the late amputations were the consequence of graft thrombosis. Of the four early postoperative graft thromboses, two ended up with amputation at 2 and 8 months, respectively. Of the four late graft thromboses, three ended up with amputation.

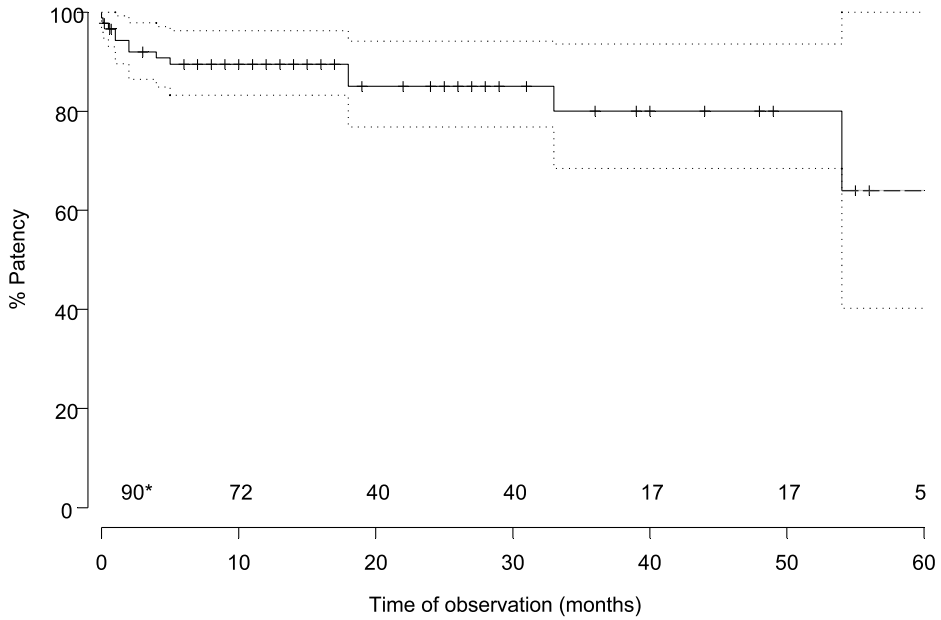

Fig. 1. Primary graft patency of 90 infrapopliteal bypass grafts, according to Kaplan–Meier method. The dotted line on both sides of the curve represents the 95% lower and upper confidence intervals. The curve becomes a dash line when the standard error (SE) exceeds 10% (indicating lack of reliability of the estimate). At 60 months, the mean patency rate is estimated at 64.0 ± 15.2%. The numbers at the bottom of the graphic correspond to the number of grafts at risk at the beginning of each time interval (observation period).

Three patients were amputated with a patent distal bypass graft for persistent rest pain in two and extensive heel gangrene in one patient. The cumulative limb salvage rate was 88% at 4 years (Fig. 2). No independent risk factor predictive for amputation could be identified. Eighty-two percent of the patients operated on for limb salvage regained an autonomic walking capability. Of the nine patients who were

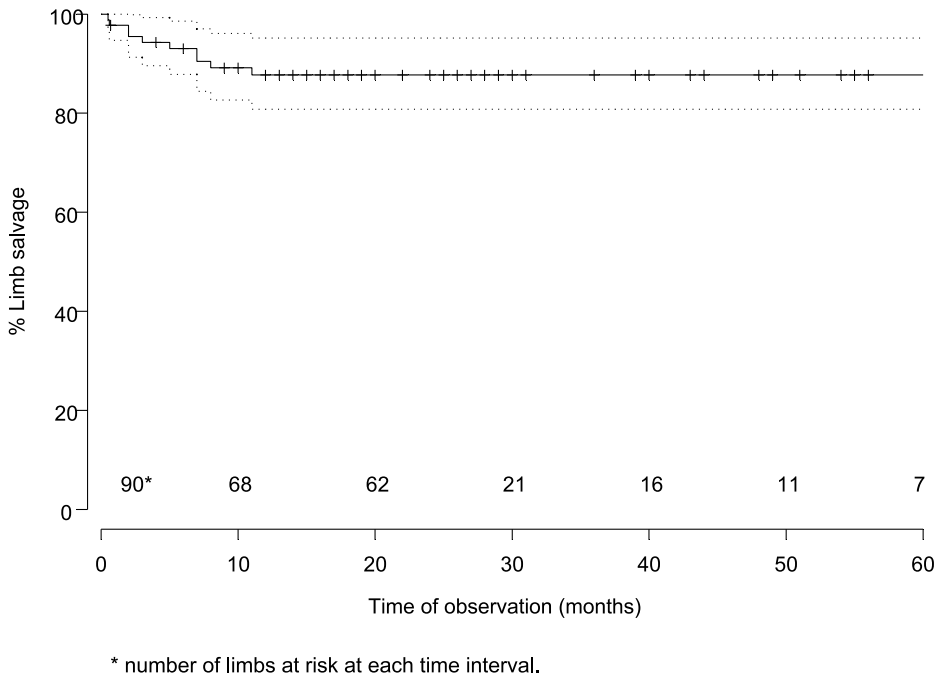

Fig. 2. Actuarial limb salvage estimate. The dotted line at both sides of the curve, delimits the 95% confidence interval.

amputated (five below-knee and four above-knee), only three (33%) of them were able to walk with their prostheses (two below-knee and one above-knee amputee).

There were 24 late deaths. The main cause of death was cardiac ($n = 15$). Other causes were stroke ($n = 3$), cancer ($n = 5$), and unknown ($n = 1$). The 4-year survival rate was 54% (Fig. 3). Independent risk factors predictive for late death are renal insufficiency ($p = 0.04$), hypertension ($p = 0.02$), and ischemic heart disease ($p = 0.01$). Patients with renal dysfunction were at highest risk of death (RR = 6.03, confidence interval 1.01–35.9), followed by patients with coronary artery disease (RR = 4.13, confidence interval 1.33–12.8). The subgroup of patients on hemodialysis ($n = 10$) had the worst outcome. Their mean survival was 20 months. Primary patency was 40% at 2 years, with a limb salvage rate of 70% at the same time.

Discussion

In the present series, although only half of the patients were alive at 4 years, 88% of those who were operated on had avoided major limb amputation of the operated leg. Three variables affect the late mortality (chronic renal insufficiency, coronary artery disease, and hypertension), and one variable was predictive for graft thrombosis (chronic renal insufficiency). Although the vast majority of surgeons agree that autogenous material should be used whenever possible, controversy continues around the details of technique, e.g. *in situ* vs. reversed, use of fistulae, bifurcated grafts, siting of the proximal and distal anastomosis, use of arm vein[4,7,11–15] (Fig. 4). For example, several authors have confirmed the adequacy of the popliteal artery as an inflow source, and it reduces the length of conduit required. In general, the results obtained with arm veins, composite or spliced veins and lesser saphenous vein are inferior to GSV.[12,16-18] The success rate obtained with arterial allografts is only half that of GSV[19] and the results of vein cuffs and collars are often disappointing.[20] The role of angioplasty remains controversial.[21,22]

In keeping with many other series, chronic renal insufficiency was a significant negative predictive factor for graft patency.[23–26] However, in selected patients, bypass may still be a better option than primary amputation.[8,23] The results of pedal bypass surgery (revascularisation of inframalleolar plantar or of the dorsalis pedis artery) are comparable to those obtained for crural artery revascularisation (Tables 3 and 4).[5,7,27–30] However, early or late graft failure remains a matter of concern.[31] In this series, we also observed a 5% postoperative graft failure rate. The aetiology is multifactorial, including surgical technical

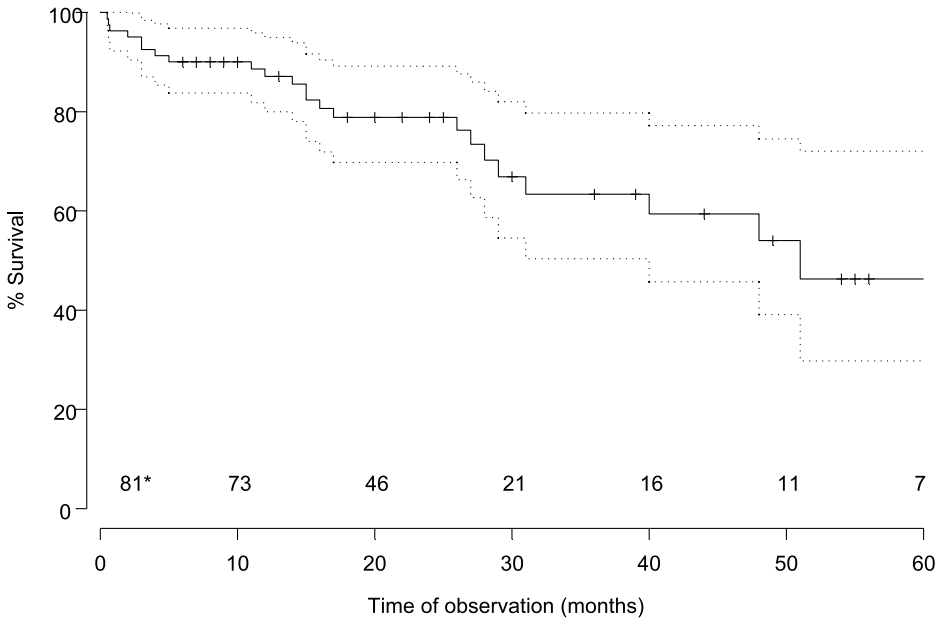

Fig. 3. Actuarial patient survival curve. At 60 months the estimated survival rate is 46.3 ± 10.4%.

Fig. 4. Bilateral popliteo–pedal venous bypass grafts (to the plantar artery at the right and the dorsalis pedis artery at the left).

errors and poor patient selection. Graft surveillance[32,33] appears logical but as it lacks a level I evidence base, remains controversial. It is noteworthy that four patients in this series required major amputation (half of all the amputations) despite a patent bypass. Deep ischaemic ulcers exposing bones, joints or tendons, or locating in weight-bearing areas, require coverage with free flaps.[34,35] (Fig. 5).

In conclusion, this retrospective single centre study suggests that this time consuming limb-saving procedure is worth its effort, since it offers an 88% limb salvage rate at 5 years. The natural history of critical limb ischemia is worse, with half of the limbs evolving to amputation if not revascularised. A weak point of this retrospective study is its heterogeneity (a heterogeneous patient cohort and different anastomotic sites). It is the authors' conviction that crural artery revascularisation with an autologous vein bypass graft is the best option to be offered to the patient with limb

Table 3. Published series of tibial artery revascularisation.

Author	Ref. no.	Year	No. limb	Operative mortality (%)	Primary patency at 5 year (%)	Secondary patency at 5 year (%)	Limb salvage at 5 year (%)	5-year survival (%)
Szilagyi	26	1963–1977	133	3.7	37	N.A.	N.A.	44
Reed*	4	1978–2000	249	2.0	62	73	81	45
Shah	7	1975–1995	1423	3.7	72	78	85	59
Shah*	6	1981–1993	106	2.8	75	83	93	47
Schneider	5	1984–1991	203	2.0	61	79	82	50
Conte	3	1993–1997	370	2.0	67	72	84	70
This series	–	1990–2000	90	3.3	64	68	88	46

N.A., not available.
*Popliteo–tibial bypass grafts.

Table 4. Published series of pedal artery revascularisation.

Author	Ref. no.	Year	No. limb	Operative mortality (%)	Primary patency at 5 year (%)	Secondary patency at 5 year (%)	Limb salvage at 5 year (%)	5-year survival (%)
Klamer	28	1983–1988	68	7.6	80	N.A.	95.	50
Schneider	5	1984–1991	53	9.0	58	82	90	52
Shah	7	1975–1995	152	3.7	60	68	94	58
Connors	30	1988–1998	157	N.A.	70	80	78	N.A.
Berceli	2	1990–1995	432	0.5	62	67	87	50
Bergamini	27	1985–1993	175	3.6	70	77	74	51
Pomposelli	29	2003	1032	0.9	56.8	62.7	78.2	48.6

N.A., not available.

Fig. 5. A popliteo–pedal bypass graft with a reversed GSV, associated with a concomitant free tissue transfer (the main artery of the flap is sutured on the dorsalis pedis artery, two centimetres distal to the graft anastomosis) (*see small arrows*).

threat and infrapopliteal arterial occlusive disease. The benefit of crural artery revascularisation is less evident for dialysed patients, who can be considered as poor candidates for this procedure.

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