Part VII

Surgical treatments

The Bridge Graft

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The autogenous saphenous vein, when present and of suitable length, caliber and quality, remains the premier arterial substitute for infrainguinal and infrapopliteal bypass surgery. It is extremely compliant and comparable in size to the lower extremity arteries thus facilitating anastomosis. Its viable endothelium explains the remarkable ability of saphenous vein grafts to remain patent also in low flow situations.

Unfortunately in 20 – 40% of the patients who need lower extremity bypass, the autologous saphenous vein will be diseased, too small, too short or previously excised. Furthermore even in those patients for whom a vein is available and a successful infrainguinal bypass can be performed, 25 – 50% will occlude within 5 years and an alternative bypass must be found (1).

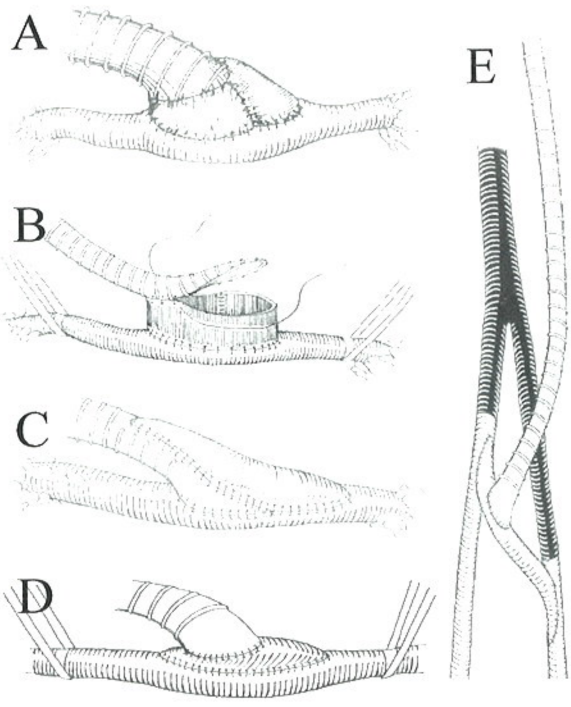

FIGURE 1

Different methods to improve the distal anastomosis. A: The St Mary's boot, B: The Taylor patch, C: The Miller cuff, D: The Linton patch, E: The bridge graft

There are numerous advantages to the use of prosthetic grafts for lower extremity revascularization. The graft material is readily available in a variety of length and diameters. The operative procedure is significantly expedited and anesthesia time is shortened, as much as an autogenous bypass graft does not have to be harvested. This may be an important consideration in patients with serious associated medical conditions facing potential limb loss. Finally the saphenous vein may be spared for later use as a coronary artery bypass graft (2). Nevertheless in contrast to autologous vein grafts the long term results of ePTFE prosthesis are disappointing in crural reconstructions. It is generally accepted that surface thrombogenicity and a mismatch of anastomotic compliance both contribute to the poorer performance of graft material. By reducing the impact of anastomotic size and compliance mismatch through modifications like the Linton (3) or Taylor patch (4), the St Mary's boot (5) and the similar Miller collar (6), results of PTFE grafts could be improved.

Material and method

At our institution, the Department of Cardiovascular Surgery, Lainz Hospital, we went one step further and developed a surgical technique, which addresses both anastomotic mismatch and poor run-off (7) (Figure 1). Between 1994 and 2001 we have performed a total number of 666 crural reconstructions, of which 52 (7,8%) patients underwent a bridge graft for femoro-crural reconstruction (Figure 2). The lack of an adequate vein with sufficient length was the indication for using the ePTFE. This graft is biologically inert, provokes little sourrounding reaction and in addition it has a strong electronegative potential and hydrophobic properties, which are antithrombogenic effective. The length of the vein bridge varied between 5 and 20 centimeters. The venous valves were made incompetent in order to allow blood flow in both directions. There is a wide variety how to connect two crural arteries (Table I). The PTFE graft is inserted very close or even within an extended proximal anastomosis (about 25-30 mm long) of the bridge in order to minimize flow disturbances. An intraoperative angiography at completion of the bypass procedure should be mandatory as well as electroma-

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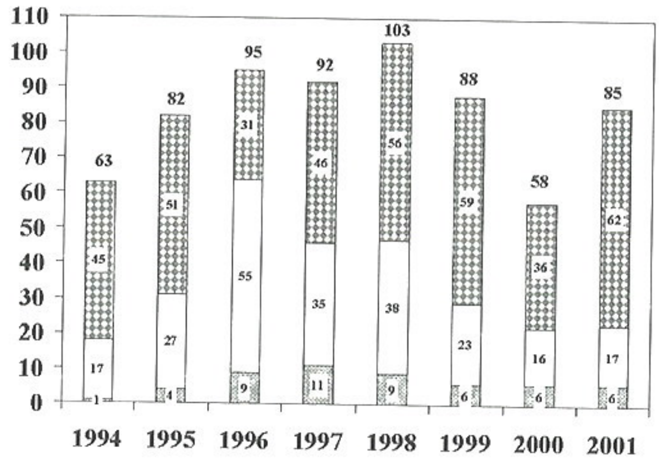

FIGURE 2

Different crural reconstructions at the Dept of Cardiovascular Surgery, Lainz Hospital, Vienna, between 1994 and 2001 (checkered: conventional crural reconstructions, cross dashed: sequential crural bypasses, dotted: Bridge grafts)

gnetic or ultrasound based flow measurements in order to quantify the hemodynamic performance in both crural run-off vessels. When no suitable segment of the greater saphenous vein for the bridge was available, sufficient autologous vein material could be obtained from the lesser saphenous vein.

Exclusion criteria have been:

1. a preceeding vascular or endovascular procedure at the aorto-iliac level;
2. bridges, which originated from an isolated popliteal segment;
3. reconstructions as a third re-operation at the crural level.

All patients were operated upon for critical limb ischemia or necrosis. 26 (50%) were in stage II and 26 (50%) in stage III according to Rutherford's classification, 29 were male and 23 of female gender. The mean age of this patient cohort was 69,7 (SE ± 8,81) years. Concomitant risk factors have been ID diabetes (67,3%), hypertension (51,9%), hyperlipidemia (30,8%) and smoking (19%). For anticoagulation 10.000 U of standard heparin were administered intraoperatively and postoperative coumadin after removal of suction catheters and the performance of a control DSA angiography. Follow-up investigations consisted of Doppler sonography and duplex screening after 3, 6 and 12 months and twice a year thereafter. The Kaplan-Meier analysis was used to determine actuarial graft patency. Angiographic examples of various bridge grafts are shown in Figure 3 and 4.

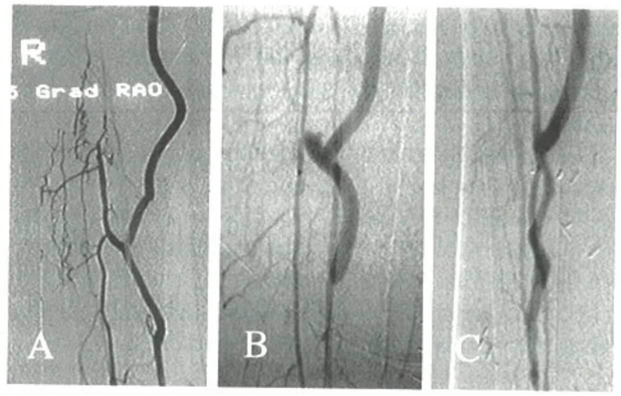

FIGURE 3

Three bridge grafts:
A and B: from the peroneal to the posterior tibial artery
C: from the posterior tibial artery to the peroneal artery

TABLE I

Posterior tibial artery	→	Anterior tibial artery	16
Posterior tibial artery	→	Dorsal pedal artery	13
Posterior tib. artery (retromall.)	→	Dorsal pedal artery	3
Peroneal artery	→	Posterior tibial artery	11
Peroneal artery	→	Dorsal pedal artery	5
Tibiofibular trunk	→	Peroneal artery	4

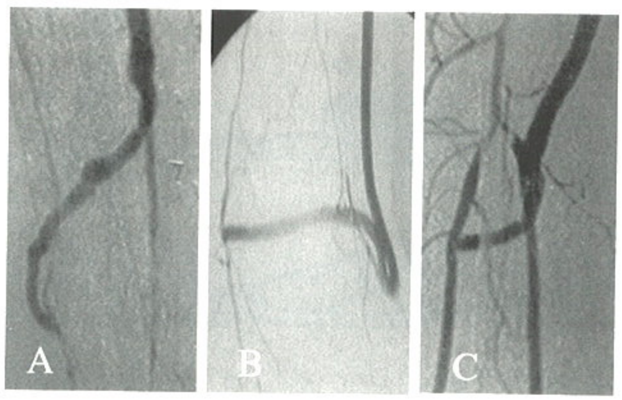

FIGURE 4

Three bridge grafts:
A: from the posterior tibial artery via the membrane to the anterior tibial artery
B: a distal bridge from the dorsal pedal to the posterior tibial artery
C: a proximal bridge combining the posterior tibial and the peroneal artery.

Results

Median follow up was 37 months. Kaplan-Meier analysis show primary patency rates of 42%, 27% and 20% at 1, 3 and 5 years, respectively. The assisted primary patency rates were 56%, 40% and 40% at the same time intervals (Figure 5), while the corresponding limb salvage rate was 70%, 60% and 40%. In a subgroup of 19 patients, where the bridge graft reconstruction represented the 1st crural procedure, the primary patency rate was 58% at 1 year and 30% after 5 years. The figures for the primary assisted patency of this group of first operations were for one year 68% and for 5 years 60,5% (SE ± 0,13) (Figure 6). When patency rates of these patients were compared with the remaining patients who had one or more redo operations, no statistical significance was revealed, which could be expected due to uneven distribution of patient numbers (assisted primary patency $p = 0.28$; limb salvage $p = 0.41$). However, the long rank test for primary patency was $p = 0.07$ and, therefore, close to the 5% significance level. Three patients experienced an early occlusion (5,8%) within 48 hours of which two needed an acute amputation. A forefoot amputation was necessary in eight patients (15,4%). Surgical complications were post-operative bleeding in one patient, wound healing disorders in six patients and a CVA in one patient. The 30-day mortality was 5,8%.

Discussion

The long term results of crural reconstructions based on the use of prosthetic grafts are disappointing in regard to patency and limb salvage (8-13). Since the luminal surface of alloplastic conduits contains no endothelial cells and an in vitro endothelialization (14) of the ePTFE graft would take too long and therefore jeopardize the leg, they are all inherently thrombogenic. The connection of a 6 mm graft to a 2 mm crural artery creates also a low flow condition, which also enhances the possibility of graft occlusion. Last but not least the often minuscule crural arteries sometimes pose a technical limitation. To overcome the compliance and size mismatch between the synthetic graft and the crural arteries, several concepts for sleeved distal ePTFE anastomosis have been propagated as Linton and Taylor patch, St Mary's boot and Miller collar. These techniques were accepted as helpful tools and showed some promising results. In order to minimize the pro-thrombotic effect of low blood flow, surgeons investigated the possibility of increasing flow through the creation of an AV fistula (15-17). Apart from adding surgical complexity, such fistulas may even jeopardize the perfusion of the extremity. According to the law of Poiseuille the blood flow to the target tissue "at risk" is necessarily diminished. As opposed to the lowering of the arterial perfusion pressure as the result of an "escape" into the

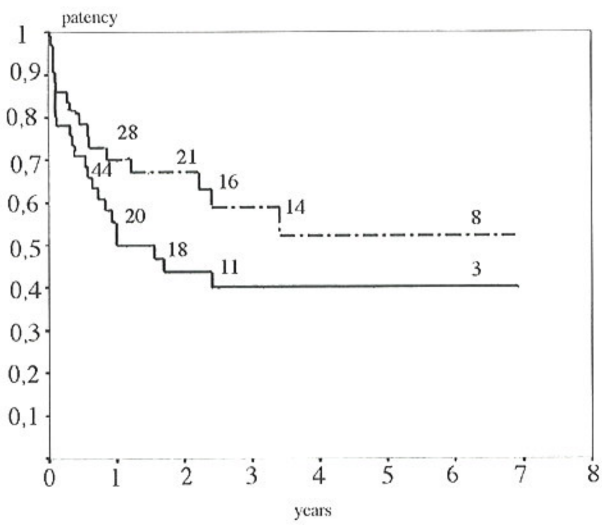

FIGURE 5

Kaplan-Meier Life table analysis: primary assisted patency rate and limb salvage rate (dotted line) of 52 reconstructions.

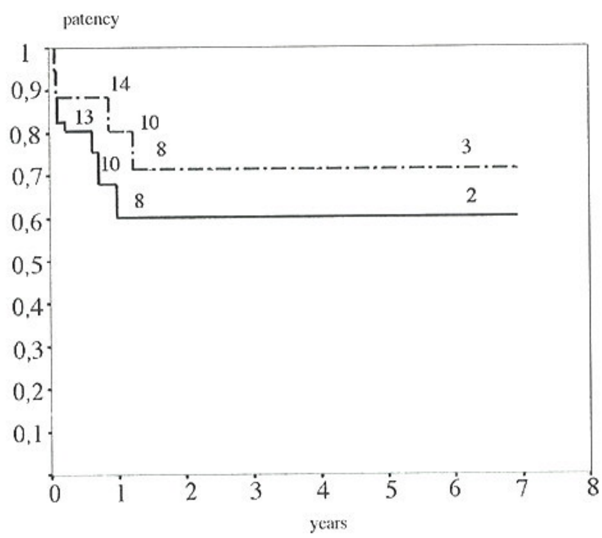

FIGURE 6

Kaplan-Meier Life Table Analysis of 19 primary bridge grafts regarding primary assisted patency and limb salvage (dotted line).

venous low-pressure system, an increased blood flow through the prosthetic graft would be ideally achieved through an increased arterial run-off. As a consequence of our observations in sequential crural bypass grafts (18) we got to the conclusion that a venous bridge graft could achieve such an increased arterial run-off to the ischemic and jeopardized tissue. During years of experience with sequential crural vein grafts, we made some interesting observations. We noted repeatedly that graft occlusion was only partial. If the distal venous graft segment between the two crural anastomoses occluded, the sequential graft turned into a simple crural reconstruction. If the segment proximal to the first crural anastomosis got occluded, the intercrural vein often remained patent due to collateral flow thus preserving the peripheral vasculature, a main prerequisite for a successful reoperation. Similarly, a bridge graft reconstruction allows collateral flow from one crural segment to the other, if the ePTFE inflow graft occludes. By extending the anastomosis between the bridge graft and the first crural artery to a length of about 30 mm, it effectively creates a patch for the ePTFE insertion that is comparable to a Linton patch, Taylor patch, St Mary's boot or Miller collar. The distinct difference to these well-established and helpful techniques lies in the integration of a second crural arterial segment into the bypass reconstruction. This helps to markedly improve the peripheral perfusion and reduces tissue loss. A technical advantage lies in the fact that the distal anastomosis of the relatively stiff and over-sized ePTFE graft is done to the proximal vein segment rather than the smaller and more friable crural artery. Furthermore and by analogy with sequential grafts, the venous bridge tends to stay patent if the central inflow conduit occludes. Therefore it is for the outcome of the bridge graft procedure of great importance, to destroy the venous valves of the bridge in order to allow flow from the vasculature of the higher to that of the lower collateral blood pressure. The beneficial effect of the so-called "doubling" of flow in the ePTFE graft is reflected in the impressive clinical performance of bridge grafts. Our 5-year assisted primary patency rate of 40% and limb salvage rate of 50% differ favorably from results reported by other groups (19-20). If we compare the outcome of different methods in crural reconstruction, due to the homogenecity of primary procedures this subgroup should be used as the reference to competing surgical methods, because in this cohort we obtained a primary assisted patency rate of 68% at 1 and 60,5% at 3 years (Figure 7).

The reason for the high mortality rate of our patients may have several reasons. We operated mainly very old patients and in 63,5% of patients redo surgery was being performed. Moreover, they all suffered from end stage occlusive peripheral vascular disease. This group of patients frequently has severe myocardial, pulmonary, renal or (and) cerebral comorbidity. The main disadvantage of this technique is the fact that it is only applicable in those patients who have more than one crural artery available for grafting. In our experience of crural reconstructions we noticed in about 50% of our cases the presence of at least 2 distal crural segments. The operation time is not substantially longer, because in conventional crural reconstructions with PTFE, when the bridging of two crural arteries is not possible, we prefer in most cases a complementary Linton patch. The time, necessary for the creation of a Taylor patch, Miller cuff or St Mary's boot probably does not differ significantly from the time necessary for a venous bridge. We conclude that crural bridge-graft reconstructions offers an effective new tool for the challenging field of distal arterial reconstruction. Apart from their promising clinical performance, they may help vascular surgery to regain the initiative in a discipline which underwent sometimes traumatic changes and painfully experienced infringements by interventional radiologists or angiologists during the past decade.

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