Limb Salvage Using Bypass to the Perigeniculate Arteries

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KEYWORDS
Critical Limb Schemia; Revascularization; Perigenicular arteries

Abstract  Objective: To describe bypass to perigeniculate vessels for limb salvage.
Design: Retrospective cohort study.
Material and methods: Between 1995 and 2009, 47 bypass procedures to perigeniculate collateral arteries were performed in 46 patients (15 women, 31 men; median age, 68 years). All patients presented with critical ischaemia (tissue loss in 87.5%, rest pain in 12.5%). Mean ankle brachial index was 0.27 ± 0.17. The site of distal anastomosis was the descending genicular artery (DGA) in 23 bypasses (1 bilateral) and the medial sural artery (MSA) in 24. Proximal anastomosis was to the external iliac artery in 2 cases, common femoral artery in 23 cases, superficial femoral artery in 8 cases, deep femoral artery in 8 cases, above-knee popliteal artery in 2 cases, and previous graft in 4 cases.

Results: There were four deaths during the immediate postoperative period. Mean follow-up duration was 27 months. Ten patients required major amputation. Mean ankle brachial index post-operatively was 0.60 ± 0.21. At 3 years, primary patency was 74.7 ± 7%, secondary patency was 83.4 ± 8%, and the limb salvage and survival rates were 73.5 ± 7% and 77.4 ± 7%, respectively.

Conclusion: Bypass to perigeniculate arteries is a viable treatment option for critical limb ischaemia in selected patients.

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Bypass to perigeniculate collateral arteries is previously described as an option for limb salvage in selected patients.1 Although initially reported more than 10 years ago, its use has been restricted to a few groups of vascular surgeons1–5 and its usefulness for limb salvage is
underestimated. The presence of large genicular arteries that can provide a suitable site for distal anastomosis is commonly overlooked if the team is not accustomed to this type of procedure.

We present an update of our experience in the use of such arteries as an option for distal anastomosis for infrainguinal revascularisation in selected situations.

### Material and Methods

We retrospectively reviewed 47 bypasses performed to perigeniculate collateral arteries in 46 patients (15 women, 31 men; median age, 68 years) from 1995 to 2009. Approximately 1500 open infrainguinal reconstructions were performed during this period at the institutions involved in this research. Major risk factors and co-morbidities are described in Table 1. All patients presented with critical ischaemia (tissue loss in 87.5% and rest pain in 12.5%) and TASC II D femoral popliteal lesions. This procedure was indicated instead of a conventional bypass because of a lack of the usual distal runoff in 25 cases, lack of a suitable long vein in 17 cases and presence of skin lesions over the target tibial branches in five cases. Mean preoperative ankle brachial index (ABI) was 0.27 ± 0.17.

In the present series, the distal site of anastomosis was the descending genicular artery (DGA) in 23 bypasses (1 bilateral) and the medial sural artery (MSA) in 24. Proximal anastomosis was to the external iliac artery in two cases, common femoral artery in 23 cases, first section of the superficial femoral artery in seven cases, second section of the superficial femoral artery in one case, first section of the deep femoral artery in three cases, second section of the deep femoral artery in two cases, third section of the deep femoral artery in three cases, above-knee popliteal artery in two cases and previous graft in four cases. The second and third sections of the deep femoral artery were chosen to avoid areas of scarring from previous interventions; this surgical approach provides a sound donor artery, represented by the profunda segment. As a corollary of this surgical manoeuvre, the length of the required vein is reduced, which is critical in patients lacking a suitable long vein.

The operation was primary in 25 cases and secondary to previous revascularisation in 22 cases (four proximal procedures, four femoro popliteal (one above and three below the knee), 10 femoro crural, two popliteal crural bypasses and two previous angioplasties). A saphenous vein was used in 28 operations, an arm vein in 18 and, in one case, a combination of expanded polytetrafluoroethylene (ePTFE) and a vein.

Conventional arteriography was performed in 44 patients and angioCT as the only preoperative imaging examination in two patients (Figs. 1–3). Perigeniculate arteries could be demonstrated connected with the tibial and/or peroneal arteries in 22 patients, while no patent tibial artery was visualised in 24 patients.

#### Surgical technique

The DGA is a branch of the superficial femoral artery, while the medial sural is a branch of the popliteal artery at the level of the knee joint. They can both be dissected by the regular approach to the main arteries, which was routinely performed in the early stages of development of this technique.

As more expertise was gained with the procedure, the targeted genicular branch was located by direct approach over its anatomic location, and eventually guided by duplex imaging, portable Doppler or angioCT. Under magnification, an end-to-side anastomosis was formed between the graft and the genicular artery using a 7/0 or 8/0 polypropylene

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### Table 1  Risk factors and survival, limb salvage, and patency.

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CAD: Coronary artery disease/CHF: Chronic heart failure.
running suture. We employed a non-reverse and valvulotomy policy as standard for all vein segments used.

Long-term aspirin was given, but no other antiplatelet drugs, anticoagulants or haemorrhheologic agents were specifically prescribed.

During the first 3 months after hospital discharge, visits to the outpatient clinic were planned on an individual basis for management of wound care. Subsequent visits occurred at intervals of 3 months during the first year of follow-up and every 6 months thereafter. Graft patency was clinically assessed and ABI measurement compared with the respective preoperative values. Clinical symptoms of recurrent ischaemia or a decrease in ABI index were absolute indications for duplex imaging and eventual intervention if a stenosis was detected. Regular duplex surveillance was performed with a 6-month interval between scans according to the protocol followed at each institution.

Statistical analysis

Patency and patient survival were calculated using the Kaplan–Meier method, employing the Statistical Package for the Social Sciences (SPSS) Statistics program (SPSS 17.0.1, SPSS Inc., Chicago, IL, USA). Statistical significance was defined as $p < 0.05$. The log-rank test was used to compare survival curves.

Results

Clinical results

There were four deaths before hospital discharge and another five during follow-up, resulting in an estimated 3-year survival rate of $77.4 \pm 7\%$. At 3 years, primary
patency was 74.7 ± 7%. Four patients were identified as having an at-risk patent graft, and the surgery was reperformed with success, with a primary-assisted patency rate of 83.4 ± 6%. Three of these patients were diagnosed by duplex with a segmental stenosis of the body of the vein graft and were successfully submitted to endovascular balloon angioplasty, and the other patient had a donor deep femoral stenosis not amenable to balloon angioplasty that was corrected by open surgery and patch.

No occluded graft had successful reoperation, which is why secondary patency is the same as primary-assisted patency. In some cases of occlusion when images were done, mostly only the graft was occluded and main arteries preserved. Nevertheless, most of these patients underwent subsequent amputation as the operation was the last resort for limb salvage. For this reason, in most cases no further images were done. Ten patients required major amputation, with an estimated 3-year limb salvage rate of 73.5 ± 7% (Fig. 4).

Postoperative ABI calculated at the mean follow-up time was 0.60 ± 0.21. The distribution of procedures over the study period was not uniform: 12 bypasses were performed from 1995 to 1999, eight from 2000 to 2004 and 27 from 2005 to 2009, resulting in a mean follow-up period of 27 months. Sixteen patients had more than 3 years of follow-up.

No risk factor was statistically significant in terms of patient survival, but patency was statistically significant for foot salvage. Patients without coronary artery disease or chronic heart failure had better patency (Table 1).

Three patients with patent grafts underwent major amputation: two at the transtibial level (nineth and 17th postoperative months) because of unsalvageable foot (infected diabetic ulcer) and one knee disarticulation in the first month of follow-up due to a large and non-healing ulcer. In all patients who had a patent graft and did not undergo major amputation, their ulcers healed and/or rest pain was treated.

Patency is strongly related to limb salvage, as shown in Fig. 5. All occlusions that occurred in the first month resulted in major amputation.

Discussion

Increasingly challenging cases demanding revascularisation for treatment of critical limb ischaemia are usual in current vascular practice, with cases of extensive disease, previous failed endo- or open vascular attempts, lack of the usual crural arterial runoff or autogenous substitutes being common scenarios. In this situation, the perigeniculate arteries present an option for distal bypass runoff.

The rationale for this operation is increased flow through collateral vessels, which are mainly nurtured by the perigeniculate arteries. Even when no pulsatile flow may be detected at the foot, perfusion pressure may be sufficiently high to enable healing of a limb threatened by an ischaemic lesion. This concept is the same as that for revascularisation of an isolated popliteal artery segment. Even so, option for genicular arteries as outflow is exceptional, used only when other conventional bypasses are not possible, as the last resort.

Various criteria must be fulfilled to achieve the physiological principles of this type of bypass: the genicular artery should be disease free in its entire length, it must be of
a diameter comparable to that of distal leg arteries, and it must be connected to other collaterals or tibial arteries. The choice of a suitable genicular usually requires angiographic assessment. In our experience, CTA is as efficient as angiography for the genicular selection, as shown on Figs. 1–3.

Establishing direct tibial or pedal flow is the accepted method for ischaemic wound healing; nevertheless, the choice of a more proximal vessel offers an elegant solution that may lessen the need for an autogenous substitute and that provides arterial revascularisation to arteries of good calibre that are usually spared of atherosclerotic disease. We consider that our frequent use of upper limb veins (38%) suggests that autogenous material is often scarce and indicates the usefulness of a technique that may shorten bridging needs.

Perigeniculate revascularisation has the potential to lower the level of amputation when the foot is not salvageable and a major amputation is required. Patent grafts provide pulsatile flow at a transtibial amputation level. Although the small series of patients in the present study cannot provide objective data to support this concept, it is reasonable to believe that increased flow at the surgical site would enhance tissue-healing capability. Of the patients in the present study who had a major amputation performed (with a patent graft), amputation was done at the transtibial level.

Patency is related to limb salvage. In the presence of thrombosed grafts, most patients returned to the preoperative ischaemic state and underwent major amputation. Over the years that the technique has been performed, genicular artery bypasses have represented approximately only 3% of our infrainguinal bypasses; however, this type of bypass can be considered a valid option for limb salvage in selected patients, such as those in the present study.

In conclusion, bypass to perigeniculate arteries is an effective procedure for ischaemic relief and limb salvage and should be incorporated into the vascular surgical armamentarium, particularly for patients who are not suitable for conventional or endovascular revascularisation.

Conflict of Interest
None.

Funding
None.

References
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