Preoperative Prediction of Graft Patency for Infrapopliteal Arterial Bypass using Pulse-generated Runoff


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Objective: to assess: (i) pulse-generated runoff (PGR) as a tool for preoperative prediction of graft patency; (ii) the effect of PGR use on graft patency.

Design: retrospective analysis of continuous patient data.

Materials: all patients undergoing bypass to the infrapopliteal vessels in the Oxford Regional Vascular Unit between 1989 and 1993.

Methods: preoperative assessment using ankle-brachial indices, intra-arterial digital subtraction angiography and PGR. Six-monthly and then yearly clinical and duplex sonography follow-up to assess graft patency. Univariate analysis of graft patency to assess discriminatory ability of PGR for graft patency.

Results: a biphasic signal in the artery of insertion was associated with significantly better graft patency rate at 1 month and at maximum follow-up than was a monophasic signal. A monophasic signal was associated with a 12-month patency of 25% and a mortality of 37.7%.

Use of PGR did not affect graft patency significantly.

Conclusion: PGR is a useful, non-invasive, means of preoperative patient assessment to determine the potential for maintained graft patency.

Key Words: Infra-popliteal; Bypass; Patency; Non-invasive; Assessment.

Introduction

A more aggressive approach to severe limb ischemia in patients with occlusive arterial disease at the popliteal trifurcation has led to a gradual increase in the number of femorodistal (infrapopliteal) grafts in this institution. Sometimes, however, the results are disappointing, and this has prompted a review of our results with such surgery. One major variable in determining long-term arterial graft patency is the runoff from the distal anastomosis. Unfortunately, conventional preoperative angiography frequently fails to demonstrate the potential runoff arteries adequately, and attempts have been made to develop other assessment techniques. Pulse generated runoff (PGR) assessment involves insonation of the crural vessels and the pedal arch for the presence and nature (monophasic or biphasic) of a signal while a calf cuff is rapidly inflated and deflated over 300 mmHg. PGR measurement provides a preoperative assessment of the distal arteries, which correlates well with intraoperative peripheral resistance measurements. It enables preoperative selection of the best vessel for graft insertion, but might also allow identification of those patients in whom long-term graft patency is unlikely. We have performed 88 femorodistal (infrapopliteal) bypass grafts since 1989 and all patients have been followed up to assess patency. We have analysed our data to determine whether PGR is a useful predictor of graft patency and whether the introduction of this technique has affected our patency results.

Patients and Methods

A consecutive series of 88 patients undergoing bypass to infrapopliteal arteries between 1989 and 1993 were reviewed. Their median age was 75 (39–91 years) and 55 (63%) were male. Case notes, follow-up clinic and graft surveillance records were studied. There were no exclusions from the study.
**Indications for surgery**

The indication for surgery was rest pain alone in 24 (27%) cases, tissue necrosis alone in eight (9%) cases and both rest pain and tissue necrosis in the remaining 56 (64%) cases. In all cases such reconstructive surgery was performed only if the patient would otherwise have required major limb amputation.

**Risk factors**

Eighteen (20%) patients were current smokers and 43 (49%) were ex-smokers. Hypertension requiring treatment was present in 52 (59%) cases. Thirty-three (37%) patients were diabetic and six (7%) were insulin-dependent. Hypercholesterolaemia was identified in 11 (12.5%) patients. Five patients suffered from angina and 11 patients had previously sustained a myocardial infarction.

**Previous surgery**

Thirty-nine patients had undergone previous vascular intervention in the same limb, including 22 who had balloon angioplasty, 15 who had bypass surgery, nine who had phenol sympathectomy and six thrombectomy or thrombolysis.

**Preoperative investigation**

The median dorsalis pedis ankle–brachial pressure index (ABI) was 0.29 (range 0–1.0). Median posterior tibial ABI was 0.30 (range 0–1.0). All patients underwent preoperative digital subtraction angiography. Pulse generated runoff (PGR) assessment was gradually introduced from 1990. Fifty-six patients had PGR studies, and in 41 of these a patent foot arch was demonstrated using the patency test of Roedersheimer.

**Operative techniques**

The distal anastomotic site was chosen on the basis of angiography, PGR and operative findings including “on-table” angiography. An intact pedal arch was not a prerequisite for bypass grafting. Fifty-eight percent of grafts were in situ and 15% were “reversed” saphenous vein, 9% were PTFE (± vein cuff) and the remainder were arm-vein or composite grafts. Eighty-one percent of grafts originated in the common femoral artery or proximal superficial femoral artery, while the remainder arose variously from the iliac, profunda or popliteal arteries. Seventy-five percent of grafts were inserted into crural vessels and 25% into pedal vessels. On-table completion angiography was performed in all cases.

**Follow-up**

Ankle–brachial indices were measured during clinical assessments 1, 3, 6, 12, 24 and 36 months after surgery, with coincident duplex sonography of the graft in those patients included in the graft surveillance programme (n=36). Median follow-up period was 11.7 months (1–44 months).

**Statistical methods**

Univariate analysis of risk factors for graft patency was performed. Actuarial patency curves were produced and significance taken at the 5% level. The Chi-squared test was used to determine the significance of intergroup differences.

**Results**

**Overall graft patency**

Cumulative primary graft patency at 30 days, 6 months, 12 months, 24 months and 36 months was 76, 64, 58, 58 and 57%, respectively; cumulative secondary graft patency at the same time intervals was 80, 72, 62, 58 and 58%, respectively (Fig. 1). Thirty-six (41%) patients have undergone limb amputation during the time period of the study.

**Patient survival**

The 30-day mortality was 10%. Mortality had reached 26.1% by 36 months.
Preoperative Prediction of Graft Patency

Fig. 1. Cumulative primary and secondary patency of all femorodistal arterial grafts. (–) Primary and (▲) secondary patency.

Assessment of distal anastomosis site

There was a substantial discrepancy between angiography and PGR where the latter demonstrated a good (i.e. biphasic) signal. There were 50 arteries with biphasic signal, but only 27 of these were visible on angiography. Angiography was generally in agreement, however, in patients with no signal recorded by PGR. The cumulative secondary patency of grafts was calculated for patients grouped according to whether the preoperative PGR demonstrated a monophasic or a biphasic signal in, or runoff to a patent foot arch from, the insertion vessel (Fig. 2). The presence of a patent foot arch on PGR did not make a significant contribution to long-term patency, but there was a significant difference between the monophasic and biphasic group at one month (monophasic patency = 58%, biphasic patency = 95%. Chi-squared = 9.186, p<0.025) and at maximum follow-up (monophasic patency = 25%, biphasic patency = 69%, Chi-squared = 14.777, p<0.01). When only a monophasic signal was present, graft patency at 12 months was 25% and mortality 37.5%. There was no significant difference in graft patency between patients who had PGR assessment and those who had not.

Graft patency was also analysed for patient groups based on combined angiography and PGR results (Fig. 3). Failure to demonstrate the vessel of insertion on angiography had no significant effect on patency: the quality of the PGR signal was a much stronger predictor of patency.

Fig. 2. Cumulative secondary graft patency according to availability of PGR study, nature of PGR signal and presence of a patent foot arch. (□) Biphasic; (△) biphasic and patent arch; (○) monophasic; (■) no PGR; (▲) overall PGR.
Fig. 3. Cumulative graft patency according to angiographic and PGR findings.

Discussion

Patients undergoing distal arterial bypass surgery in the lower limb are a selected population on the basis of symptoms, medical fitness, limb salvage potential and the results of vascular assessment. These selection criteria may vary between surgeons and perhaps account for some differences in results. Our patency figures compare well with other published U.K. studies of femorodistal bypass which have excluded those to the plantar arch. Prior to the introduction of PGR, the only means of preoperative evaluation of distal arterial runoff was by angiography. Preoperative angiography fails to opacify many of the vessels subsequently shown to be patent at operation or by PGR. Unless a universal policy of exploration of the distal vessels before amputation had been carried out, many such patients would not have been considered for a distal bypass graft. It might be argued that the introduction of PGR has encouraged us to perform reconstructive surgery on patients with poorer distal arteries, less likely to be opacified by angiography and destined to have a poorer outcome. The cumulative patency of patients who had PGR did not differ from those who did not, however, and the demonstration of vessels by angiography made no difference to the subsequent patency, suggesting that we are not accruing cases with a poorer prognosis by using PGR.

Scott et al. showed that bypass graft patency was better at 1 year in those patients with a complete foot arch on PGR than in those with an occluded arch. We failed to show any difference in graft patency on this basis, but we did find a better patency both at 1 month and at maximum follow-up in patients with a biphasic signal on PGR compared with those in whom a monophasic signal was found. There was no correlation between the nature of the signal and foot arch patency. In fact, there are two arterial arches in the foot and the pedal arch patency of Roedersheimer et al. assesses only the “primary” arch (dorsalis pedis a./deep plantar a./lateral plantar a.). O’Mara et al. (1981) demonstrated that femorodistal bypass graft patency correlated with patency of either the primary or secondary pedal arch (secondary arch = medial tarsal/medial plantar a. or lateral tarsal/lateral plantar a. or lateral plantar/arcuate a.). Graft patency in their study was similar at 6 months whether the primary arch alone, or the secondary arch alone, provided runoff. It might be argued that the introduction of PGR has encouraged us to perform reconstructive surgery on patients with poorer distal arteries, less likely to be opacified by angiography and destined to have a poorer outcome. The cumulative patency of patients who had PGR did not differ from those who did not, however, and the demonstration of vessels by angiography made no difference to the subsequent patency, suggesting that we are not accruing cases with a poorer prognosis by using PGR.

Scott et al. showed that PGR scoring (biphasic signal = 2, monophasic signal = 1, no signal = 0 in each of the three crural vessels) correlated with peripheral resistance and, to a lesser extent, with angiographically demonstrated crural vessel patency. Peripheral resistance measured after papaverine injection has an important influence on graft patency at 1 and 4 months, and so it is not surprising that PGR proved to be a predictor of patency in our study.

One might expect the use of PGR to improve graft patency rates, but in this study it was always used in conjunction with preoperative and on-table angiography and was never the sole criterion in deciding whether or not to perform femorodistal bypass. The importance of PGR lies in the fact that it is a preoperative investigation, unlike measures of peripheral resistance, and so can be used to influence decisions on whether or not to attempt bypass.

The perioperative mortality rate in our series was 10%, high compared with some other reports but
similar to that reported by Sayers et al.\textsuperscript{5} It reflects a fairly aggressive policy of revascularisation and should be compared with the high mortality of amputation, also reported to be about 10%.\textsuperscript{4,11} Cheshire et al.\textsuperscript{4} have shown that, even if amputation is required in a few cases following failed femorodistal bypass graft, a policy of femorodistal bypass grafting wherever technically possible is less expensive overall than primary amputation. Perioperative mortality rises in elderly patients, however, when a long vascular reconstruction is followed a few days later by amputation. Although aggressive use of distal bypass grafts may provide long-term savings overall, in a proportion of patients it will lead to unnecessarily high mortality. To date we have used PGR to decide the site of distal anastomosis, but have not used it to determine likelihood of long-term success. If we can identify those patients in whom grafting is unlikely to succeed and who will come to amputation whatever we do, then it will only be sensible to avoid arterial reconstruction in this group. One year after the operation, three out of four femorodistal bypass grafts into monophasic vessels have failed and a third of these patients have died; perhaps such operations should be avoided.

Throughout the study period our policy has always been to perform distal arterial bypass only when the limb would otherwise be lost. Our results therefore relate only to patients with severe limb ischaemia. We know from studies of more proximal grafts that results of arterial bypass are poorer when performed for more severe ischaemia, largely due to the poorer quality of runoff vessels. There is a case for considering infrapopliteal arterial bypass in patients with rest pain or static ulceration who are not about to lose their limb. A larger proportion of such patients are likely to have a biphasic signal on PGR and the patency at 1 year for patients with a biphasic signal in the vessel of insertion is approximately 80%.

On the basis of our findings we would argue for more discrimination in the use of femorodistal infrapopliteal arterial bypass. Preoperative assessment by PGR should play a much greater part in the decision to reconstruct or amputate, given the poor outcome when only monophasic signals are detected in the proposed implantation vessel. On the other hand, when the signal is biphasic, patency results are comparable to those of more proximal arterial bypass; we should be extending the use of such grafts to patients who have not yet reached end-stage ischaemia.

References


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