CASE REPORT

Case of lower limb revascularisation using composite sequential bypass graft with a 'diamond' intermediate anastomosis

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SUMMARY

In patients with critical infrarural disease, autologous saphenous vein grafting offers the best reported conduit patency and limb salvage rates but is only feasible in approximately 30% of patients due to the lack of available or suitable vein. In the absence of a suitable length of available vein, various composite grafting techniques have been explored with the aim to improve graft longevity, maximise native vein use and improve overall clinical outcomes, including limb salvage rates. We report a case of a 66-year-old man with critical limb ischaemia and a history of venous disease, where a complex composite sequential bypass graft combining both native vein and synthetic graft, incorporated into a novel intermediate anastomotic technique in a 'diamond' configuration, offered promising results in limb salvage. This case highlights the key steps and advantages in this novel technique.

BACKGROUND

Best published evidence supports superior outcomes after lower limb revascularisation using autologous saphenous vein grafting over synthetic material, in terms of conduit patency and limb salvage in patients with critical infrarural disease.^{1,2} However, autologous saphenous vein grafting is only feasible in approximately 30% of patients due to the lack of available or suitable vein.^{3,4} In the absence of a suitable length of available vein, various composite grafting techniques have been explored with the aim to improve graft longevity, maximise native vein use and improve overall clinical outcomes, including limb salvage rates. We report a case of complex composite sequential bypass grafting combining both native vein and synthetic graft, incorporated into a novel intermediate anastomotic technique in a 'diamond' configuration.

CASE PRESENTATION

A 66-year-old man was admitted to our vascular service through the emergency department with increasing rest pain and a recurrence of right lower limb arterial ulceration with cellulitis. His medical history included chronic obstructive pulmonary disease, pulmonary embolus (currently on anticoagulation), prostate cancer (controlled) and a 50 pack-year smoking history. His recent vascular history included a 1-year history of short-distance (<30 m) intermittent claudication affecting the right calf

with arterial ulceration. A recent magnetic resonance angiogram (MRA) demonstrated a complete occlusion of the ipsilateral femoral-popliteal arterial segment. However, the patient had declined revascularisation options at that time and opted for continuing conservative management with best medical therapy, a smoking cessation programme and exercise therapy. However, progression to rest pain prompted his re-presentation to our service.

On examination, he was systemically well with normal vital signs and no signs of systemic sepsis. There was evidence of chronic venous insufficiency bilaterally with ulceration over the right gaiter area, in addition to small distal ulcerations over the toes, consistent with a mixed picture of dual arterial and venous disease. He was treated with intravenous antibiotics, and a repeat MRA was performed showing complete occlusion of the right femoral-popliteal segment on the affected side. The below-knee run-off vessels were also heavily diseased with evidence of reformation from collateral supply, with the posterior tibial artery being the dominant pedal vessel (figure 1). After vascular multidisciplinary team discussion, and in light of the new presentation of critical ischaemia (forefoot rest pain with tissue loss), with limited options for angiointervention management (likely to be futile), it was decided to proceed to surgical revascularisation in the form of a complex femoral-distal bypass. However, due to the limited supply of suitable native vein (due to history of varicose veins and venous hypertension) and the need to perform a distal anastomosis, it was decided to perform the bypass as a composite sequential graft combining the limited amount of available suitable native vein with a synthetic graft, joined by an intermediate anastomosis to the above-knee popliteal artery in a novel diamond configuration, first described by our unit.

TREATMENT

Intraoperatively, proximal access was gained via a right standard longitudinal groin incision and vessels controlled (figure 2) in a standard fashion. There was excellent inflow into the common femoral artery (CFA), with good backflow from the profunda femoris artery, but no backflow from the superficial femoral artery as expected. An end-to-side anastomosis was performed using 8 mm expanded polytetrafluoroethylene graft (ePTFE)

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Figure 1 Preoperative magnetic resonance angiography of the lower limb showing (A) adequate inflow, (B) complete occlusion of the right superficial femoral and popliteal arteries (arrow) and replacement with collaterals, and (C) two-vessel run-off on the right (anterior and posterior tibial arteries).

to the right CFA proximally (figure 3) and the graft tunnelled anatomically in the subsartorial canal exiting at the above-knee popliteal segment. Long saphenous vein was harvested in parallel and a suitable segment of the above-knee vein identified for use as the distal segment of the bypass (ie, suitable length with minimal venous hypertensive changes) (figure 4).

The above-knee popliteal artery was dissected via the standard medial approach and a longitudinal popliteal arteriotomy performed (figure 5), approximately twice the length required for a standard anastomosis. The vessel was endarterectomised to improve inflow to the vessel from the graft. An intermediate diamond-shaped anastomosis was created by fashioning the distal end of the tunnelled synthetic graft, incorporating a triangular slit on its dorsal hood and anastomosing it to the proximal half of the popliteal arteriotomy (figure 6). Then, the proximal portion of the reversed vein graft was anastomosed as

a 'hood'-patch plasty to the distal half of the arteriotomy, but simultaneously incorporating the modified distal ePTFE hood into the same complex anastomosis (figure 7). This triumvirate anastomosis of the synthetic graft, reversed vein and above-knee popliteal artery formed the completed intermediate anastomosis in the above-knee segment (figure 8). The distal portion of the vein graft was then tunnelled anatomically (via the popliteal fossa) and anastomosed to the posterior tibial artery at its distal third (figures 9–11), with a total clamp time of 76 min. Layered closure of the wounds was performed and the skin closed with skin clips. At the end of the surgery, the patient had a palpable posterior tibial pulse.

Figure 2 Right groin dissection with the common femoral artery controlled.

OUTCOME AND FOLLOW-UP

The patient had an uncomplicated postoperative course and was discharged on postoperative day 10. At 1-month and 3-month clinic reviews, he no longer complained of either rest pain or claudication and had complete healing of his ulcers with a clinically palpable posterior tibial pulse.

DISCUSSION

Peripheral arterial disease (PAD) is common, with an age-adjusted prevalence of 12%.⁵ Approximately 11% of patients with PAD will progress to critical ischaemia.⁶ Revascularisation in these patients is necessary for both symptom control and limb salvage. A Cochrane review has concluded that autologous vein grafting gives the best patency outcomes after revascularisation.⁷ By using ipsilateral autologous vein, graft patency rates of up to 70% in 5 years have been reported.^{8,9} However, saphenous vein is often unavailable for a variety of reasons, including previous harvest (eg, coronary artery bypass), previous lower limb revascularisation, or due to poor-quality vein from varicosities, phlebitis and changes associated with chronic venous hypertension. Rarely, venous hypoplasia renders the vein unavailable. Inadequate or

Figure 4 Harvested long saphenous vein with tributaries controlled.

unavailable vein affects up to 30% of patients requiring lower limb bypass.^{3,4,10} Other alternate options include using synthetic graft or vein harvested from elsewhere (eg, short saphenous, arm vein), but these offer poor patency rates when the distal anastomosis is below the knee. Veith *et al*¹¹ have suggested as an alternative to adopt a more distal site for graft inflow if possible to minimise the actual length of vein graft required. Prosthetic grafting is an alternative option, but is associated with lower graft patency and limb salvage rates.¹ Various adjuncts to prosthetic grafting to improve their patency and longevity have been described, such as distal arteriovenous fistula and distal venous patching and cuffs (eg, Miller cuff, Taylor patch, St Mary's boot), with variable results.^{9,12} Umbilical vein as an alternative graft is associated with very poor patency rates (4-year patency rate of 25%).¹³

Composite grafts, using a combination of available native vein at the below-knee segment with synthetic grafting proximally, have the advantage of providing superior graft longevity, when the venous component comprises the below-knee distal anastomosis, in addition to maximising vein use with prosthetic supplementation only.^{2,9,14} However this adjunctive technique comes at a disadvantage of requiring an additional anastomosis to join the vein and synthetic graft, with longer operative times and with

Figure 3 End-to-side proximal anastomosis of the expanded polytetrafluoroethylene (ePTFE) graft to the right common femoral artery.

Figure 5 Longitudinal popliteal arteriotomy at the medial popliteal dissection. ePTFE, expanded polytetrafluoroethylene.

Figure 6 Proximal end of the diamond anastomosis with the expanded polytetrafluoroethylene graft in place.

the propensity for neointimal hyperplasia and restenosis at this additional anastomosis.^{2 15}

Various configurations of composite grafting have been described with variable patency rates. A simple bevelled end-to-end anastomosis of the vein to the prosthetic graft has failed to demonstrate superior patency results over prosthetic grafts alone,¹⁶ possibly due to compliance mismatch and flow differences between the two component grafts.^{16–18} The ‘piggy-back’ extension of the vein graft taken off the distal prosthetic graft hood at an intermediate anastomosis junction is associated with a 2-year patency of 35%–64%, possibly with the same problems with compliance mismatch between the two graft components with a higher risk of graft occlusion.^{14 19 20}

Surgical techniques have been described in an attempt to overcome the challenge of compliance mismatch arising when synthetic graft is anastomosed directly onto the artery. The premise behind reducing the mismatch is to combine a more compliant graft (ie, vein) that is more matched to the compliance of arterial tissue in the anastomosis of synthetic with arterial vessel. These techniques include various configurations of venous cuffs (eg, Miller cuff, St Mary’s boot), where a segment of compliant vein is interposed between the synthetic

Figure 8 Completed diamond anastomosis.

graft and the artery, or using venous patches (eg, Taylor patch), where a separate vein patch is incorporated into the synthetic graft and arterial anastomosis as a longer ‘hood-plasty’ patch. Whichever technique is used, they each attempt to improve the compliance at the distal prosthetic graft-to-artery anastomosis. However, the use of a vein cuff creates a potential reservoir at the site of vein anastomosis with increased turbulence and shear force stress created due to the angle of configuration of the synthetic graft to the vein patch (almost right angles to the vessel wall), which is associated with the potential for thrombosis, neointimal hyperplasia and reduced graft longevity, despite improvements in graft compliance.^{16 21 22} The Taylor patch attempts to overcome this problem, as the angle of anastomosis of the graft to the artery is more ‘anatomical’ and streamlined.

Mahmood *et al* have described a composite synthetic and vein graft with spatulated ends, anastomosed with a side-to-side configuration, incorporated into an intermediate-level artery as a single anastomosis.¹⁰ This configuration showed promising results offering better compliance matching and with a reported 2-year patency rate of 73%.¹⁰ However this side-to-side anastomosis creates a deep reservoir with the potential for poor graft angulation at the intermediate

Figure 7 Harvested autologous vein graft anastomoses to the lower end of the popliteal arteriotomy to complete the diamond anastomosis.

Figure 9 Autologous vein graft tunneled to the calf dissection to be anastomosed to the posterior tibial artery.

Figure 10 Medial calf dissection showing the posterior tibial artery controlled.

site, thereby increasing turbulence and potentially affecting graft patency. By creating this intermediate anastomosis, the problem of direct graft-to-vein suturing and restenosis is overcome, in addition to including an additional run-off channel via the intermediate vessel and its branches, which is associated with improved graft longevity compared with poor vessel run-off. However, one disadvantage of this technique is the potential that it creates a reservoir at the intermediate anastomosis by virtue of the side-to-side anastomotic configuration, with increased turbulence and thus risk of restenosis.

Our novel diamond intermediate anastomosis described in this case incorporates the best elements of a side-to-side composite anastomosis with the advantages of an intermediate anastomosis, but with a more favourable anatomical angulation (similar to the advantages of the Taylor patch angulation), with potential for less turbulence that is associated with other anastomotic configurations that potentially generate a venous reservoir and a more acute graft angulation. We combine our anastomosis in a novel diamond configuration of synthetic graft to vein graft at an intermediate arterial anastomosis with the hypothesis that there will be improved compliance (due to the vein and arterial component), better graft run-off

Figure 11 Distal end of the autologous vein graft anastomosed to the posterior tibial artery.

Figure 12 Graphical representation of diamond anastomosis at the popliteal arteriotomy showing the proximal polytetrafluoroethylene (PTFE) graft and distal vein anastomoses.

(by incorporating an intermediate arterial anastomosis), and reduced shear stress and venous reservoir turbulence due to the angulation that the diamond-shaped anastomosis allows, and ultimately the possibility of improved graft patency and limb salvage rates.¹⁶ Overall, this tripartite of ePTFE, vein and artery potentially offers improved compliance at the anastomosis as the vein comprises 50% of the anastomotic circumference (figure 12). The advantages of the diamond anastomosis include the following: decrease in inflow and outflow angulations reducing turbulence at the anastomotic site, allows outflow from the synthetic graft and inflow to the vein from the native artery maximising patency, and a longer arteriotomy reducing turbulence and stenosis.¹⁶ Rogers *et al* reported early results from this novel technique.¹⁶ The pilot series showed promising results, with all six patients having resolution of symptoms and successful limb salvage at 6-month follow-up. Longer follow-up data are awaited.

Composite sequential anastomosis using synthetic and autologous graft offers an effective alternative method of revascularisation in cases where autologous vein is limited. This case highlights the key steps and promising results in limb salvage in the novel technique of composite sequential bypass grafting with the unique diamond intermediate anastomosis.

Learning points

- ▶ Composite sequential anastomosis using synthetic and autologous graft offers an effective alternative method of revascularisation in cases where autologous vein is limited.
- ▶ A novel technique of composite sequential bypass grafting is described with a unique diamond intermediate tripartite anastomosis of expanded polytetrafluoroethylene graft, vein and artery.
- ▶ This novel technique demonstrates promising results on limb salvage, with the advantages of reducing turbulence at the anastomotic site and maximising patency.

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