Infra-Inguinal Bypass Surgery

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Abstract

Infrainguinal bypass remains a mainstay in dealing with lower extremity ischemia in claudication, rest pain, and tissue loss, many times after failed percutaneous attempts. Autogenous reconstruction remains favored compared to prosthetic bypass secondary to issues with increased risk of infection and diminished patency. Lifelong surveillance of all infrainguinal bypass grafts is critical for success and limb salvage.

Introduction

The decision to go forth with infrainguinal bypass in the twenty-first century is often once made after endovascular options have been attempted or exhausted. Indications – claudication versus critical limb ischemia – along with patient comorbidities will play a central role in which revascularization option is recommended. There is a paucity of data comparing percutaneous versus open revascularization. Randomized trials that do exist often have a very heterogenous mix of patients with differing anatomic details and varied measured outcomes, making it difficult to draw conclusions. For patients with favorable anatomy and significant operative risk and for the treatment of claudication in general, percutaneous therapy has assumed a primary initial role. When medical therapy or percutaneous treatment has proven inadequate, open surgical revascularization

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remains the gold standard. The roles of open surgery and percutaneous revascularization are continually being reevaluated in the management of claudication and critical limb ischemia. Nonetheless, with the rising popularity and success of femoral and tibial percutaneous interventions, the number of infrainguinal bypass procedures may be decreasing or subsequently being delayed. Oftentimes it is the case that patients are best treated with a combination of percutaneous and open surgical procedures in a single – hybrid – procedure making the two treatment modalities complementary rather than competitive.

Operative Techniques

The success of infrainguinal bypass is predicated on arterial inflow, outflow, and conduit available. Aortoiliac angioplasty and stenting are increasingly utilized to provide adequate inflow. It can be done prior to or concurrently with infrainguinal bypass. Aortobifemoral, femoral-femoral, and axillofemoral bypass remain important options as well to provide sufficient arterial flow proximal to a more distal infrainguinal bypass. At times, the necessity of improving the inflow to support an infrainguinal bypass is determined intraoperatively, either by direct visual assessment of the arterial flow at the desired donor site or by comparison of a transduced pressure tracing from the donor site with that of a systemic pressure tracing, typically obtained from a radial arterial line.

Target vessel selection is of equal importance to the outcome when considering infrainguinal bypass. In general, the distal target is the least diseased artery that is the dominant runoff vessel to the foot. If tissue loss is present, restoration of pulsatile flow to the foot is often necessary to obtain full and sustainable healing of ulcerations.

Infrainguinal bypass can be performed under general anesthesia or regional or epidural in select patients. Epidural and regional anesthesia can be especially helpful in preventing pneumonia in the patient with chronic tobacco abuse. The ubiquitous use of clopidogrel for coronary artery and cerebrovascular disease, however, often precludes use of these anesthetic techniques. Cases involving multiple sites of dissection such as harvest of arm vein, lesser saphenous vein, or others benefit from a two-team approach to lessen operative and physiologic insult. The patient is sterilely prepped from the umbilicus to the foot. If an autogenous bypass is being performed, it is the author's practice to assess the conduit first and then expose the site of the proximal anastomosis followed by dissection of the distal target.

For patients with superficial femoral artery disease, the initial dissection is most commonly at the level of the common femoral artery. The artery is exposed through either a longitudinal or oblique incision directed over the femoral pulse. If there are no plans for an extensive profunda dissection or endarterectomy of the profunda, the author favors an oblique exposure, which often affords fewer wound complications. Lymphatic tissue overlying and medial to the femoral vessels is best ligated or clipped effectively to help prevent lymphocele or fistula. In most instances, the extent of dissection spans from the inguinal ligament to the common femoral bifurcation where the superficial femoral and profunda femoris arteries are individually isolated with vessel loops.

If a profundaplasty with endarterectomy is necessary, the dissection is extended distally along a sufficient portion of the profunda femoris artery until a relatively disease-free segment is reached, thereby allowing for a suitable endpoint for endarterectomy, clamping, and sewing (Fig. 1). The inguinal ligament can be partially divided to facilitate exposure to the distal external iliac artery in cases where a more extensive endarterectomy is needed or more proximal control. Once endarterectomy is complete, a vein, bovine pericardium, or prosthetic patch is used onto which the proximal anastomosis can be constructed. It is critical to utilize gentle tissue handling and careful technique in order to ensure adequate incision healing particularly in those patients with diabetes, prior groin radiation, obesity, and multiple prior groin access sites and incisions. If the groin is functionally impenetrable, alternative arterial inflow may need to be considered.

If all or part of the superficial femoral artery (SFA) is relatively disease-free, the proximal

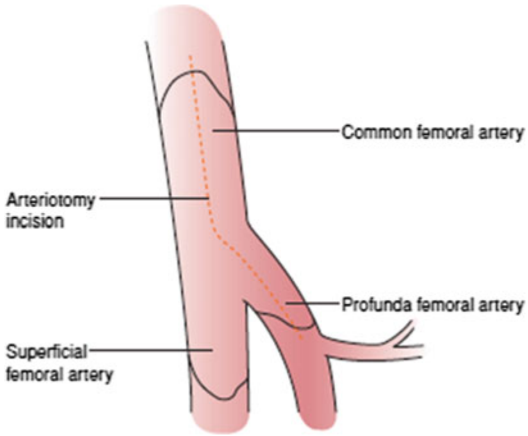

Fig. 1 Anatomy of common femoral bifurcation and orientation of arteriotomy for profunda endarterectomy

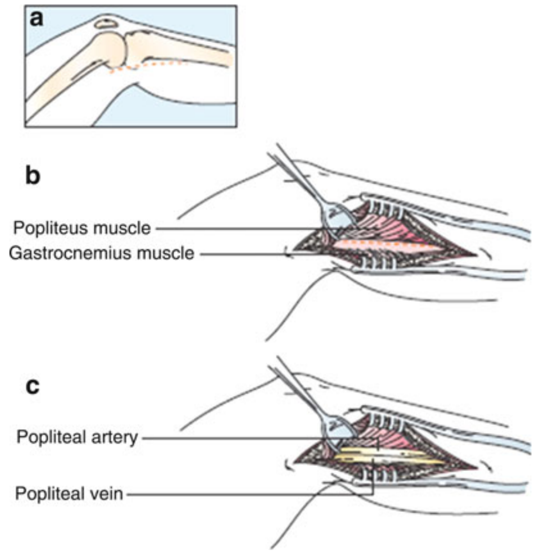

Fig. 2 Above- and below-knee popliteal artery exposures

anastomosis can be moved more distal and a "distal origin graft" (Reed et al. 2002) constructed. This scenario is particularly effective in diabetics who routinely have more popliteal- and tibial-level disease compared to smokers who tend to have more iliofemoral disease, as well as in those patients with sparse conduit who may need the proximal SFA to be stented either before or at the time of infrainguinal bypass.

The above-knee popliteal artery is exposed through a distal medial thigh incision with posterolateral retraction of the sartorius muscle. A rolled collection of sterile towels placed as a bump below the knee will facilitate separation of the above-knee tissues and allow easier exposure than if the bump is placed directly under the leg in the above-knee position. The artery lies just posterior to the femur with its accompanying vein and nerve. External palpation of the vessel will help guide where a soft suitable spot is for an anastomosis. The below-knee popliteal artery exposure is through a medial incision in the proximal calf with a bump placed under the leg in the above-knee position (Fig. 2). If the saphenous vein is to be used, care must be taken to protect it during retraction. For the below-knee exposure, the incision is placed directly over the great saphenous vein in order to avoid devascularized skin flaps. Again, care is taken to protect the saphenous vein as the incision is extended to the popliteal artery. The distal popliteal artery is dissected free from the adjacent tibial nerve and popliteal vein. If the target is the tibioperoneal trunk, then dissection continues in the anterior surface of the distal popliteal artery, taking down the origin of the soleus muscle. Lateral exposure of the below-knee popliteal artery is possible by resecting the proximal portion of the fibula, taking care to protect the superficial peroneal nerve from damage.

Exposure of the posterior tibial and peroneal arteries can be obtained by continuing the tibioperoneal trunk exposure mentioned above; however, as the target vessel becomes near to the mid-calf, a more directed exposure is recommended by a medial incision going through the musculotendinous insertions of the soleus muscle on the tibia. The peroneal artery can be exposed by taking this dissection plane more lateral. Distal exposure of the posterior tibial artery is relatively straightforward as the vessel is much closer to the skin surface. The distal peroneal artery can be exposed laterally by exposing the distal fibula. Careful resection of a small portion of the distal fibula bone will reveal the artery immediately posterior to the bone.

The anterior tibial artery is typically approached from the anterolateral aspect of the calf and is found deep within the anterior compartment with the adjacent deep peroneal nerve and anterior tibial veins. It is best identified by developing the intermuscular plane between the anterior tibialis muscle medially and the extensor digitorum longus laterally. The dorsalis pedis artery is easily exposed through an anterior incision on the dorsum of the foot just lateral to the extensor hallucis longus tendon. The artery lies just deep to the extensor retinaculum.

Autogenous Infrainguinal Bypass

In general, infrainguinal bypass surgery is best performed with autogenous vein conduit, preferably the ipsilateral greater saphenous vein if available (Veith et al. 1986). This preference is particularly true for grafts extending below the knee, where prosthetic conduits of Dacron or polytetrafluoroethylene have significantly poorer patency rates. Given the orientation of the vein valves, the vein can be reversed such that the distal end of the vein is sewn to the proximal inflow artery and the larger proximal end of the vein is sewn to the distal outflow artery. The vein is harvested through a long incision overlying the course of the vein or by more tedious but less invasive sequential skip incisions with intervening cutaneous skin bridges. All side branches are ligated, and after harvest, the vein is cannulated and gently dilated with a solution containing heparin and papaverine to assess its suitability. Veins with chronic fibrosis or that fail to dilate to a diameter of 3 mm or greater will most likely have poor long-term function.

An alternative and less invasive approach to open great saphenous vein harvest involves the use of endoscopic technology. In the case of harvesting of the greater saphenous vein, a small skin incision is made over the great saphenous vein near the knee joint, and guided by a videoscope inserted distally and advanced proximally, the side branches of the vein are serially identified and either cauterized or clip ligated. The vein is then divided distally and proximally with a stab incision near the saphenofemoral junction and removed, leaving the overlying skin undisturbed. Advocates of this method cite a significant reduction in wound complication rates and reduced rates of hospital stay (Rosenthal 1995). Although it has not been widely adopted by vascular surgeons, the technique does have particular theoretical appeal in cases, for example, when contralateral saphenous vein is to be utilized or the healing potential of the donor leg is compromised.

For prosthetic grafts, a tunnel is usually fashioned through the subsartorial plane between the groin incision and the above-knee popliteal space in the interests of protecting the graft from subsequent infection. For vein conduits, it remains the surgeon’s preference as to whether the graft is tunneled deeply or in a superficial location in the subcutaneous space. The more superficial configuration greatly facilitates ongoing clinical examination and ultrasonographic surveillance as well as later surgical revision, but carries a risk of graft exposure should there be wound healing problems. Occlusion from trauma to grafts placed superficially has been of theoretic, but not practical, concern. It is our practice to perform the proximal anastomosis prior to the distal anastomosis. First, this allows confirmation of adequate inflow before the bypass is performed. Second, performance of the proximal anastomosis first allows the graft to be tunneled and tailored to an appropriate length under arterial pressure. This is of critical importance to prevent kinking along the length of the graft. Some surgeons also prefer to mark the distended graft to ensure against mechanical twisting of the graft during the tunneling process. Prior to occluding the target vessel, the patient is systemically anticoagulated with 5,000–10,000 units of heparin. Additional heparin is given throughout the procedure to maintain the activated clotting time near the target range of 250–300 s.

After allowing sufficient time for the heparin to circulate, atraumatic vascular clamps are placed proximally and distally and the artery is incised. The vein is then spatulated and a beveled anastomosis carried out. Typically, a 5-0 monofilament suture of polypropylene is used for the femoral anastomosis, a 6-0 used at the popliteal level, and a very fine 7-0 suture used at the tibial or pedal level. If the target tibial vessel is deep within the calf and visibility is challenging, a technique of “parachuting” the heel of the distal anastomosis is often employed. After completing the proximal anastomosis, the graft is carefully tunneled under arterial pressure. Occasionally, such extensive calcification of the target vessel is encountered that the risk of a significant injury from clamping, even with the minimally traumatic clamps in use today, is prohibitively high. In such cases, proximal inflow and distal artery backbleeding can be controlled by occlusion balloons placed intraluminally. For distal anastomoses at the knee or more distal level, another alternative technique is the use of a proximally placed sterile pneumatic tourniquet. This technique is particularly advantageous when sewing to diminutive distal tibial or pedal targets, where the impact of a crush injury or plaque dislodgment on graft function could be considerable. Removing the need for clamps by using the tourniquet has two further advantages. First, it improves the operative visibility. Second, and more importantly, given that less longitudinal and circumferential dissection is needed, the degree of vessel spasm and venous bleeding that frequently accompanies vessel exposure at this level is kept to a minimum. Flow through the graft and the outflow artery is assessed following completion of the bypass with a continuous wave Doppler. Completion arterial duplex or contrast arteriogram is essential to detect any areas of kinking or areas of stenosis, which can be corrected immediately.

In Situ Bypass Grafting

There has been ongoing enthusiasm in some circles for in situ vein bypass grafting, whereby except for its proximal and distal extent, the greater saphenous vein is left undisturbed in its native bed. This technique was first described in 1962, but was later popularized by Leather et al. in the late 1970s (Leather et al. 1979). Recent reports of in situ saphenous vein grafting have indicated 5-year graft patency rates of up to 80 % and limb salvage rates of 84–95 % 51, 52, 78, 82–84 (Belkin et al. 1996). The in situ approach minimizes trauma to the vein during excision and handling and in theory enhances preservation of the vasa vasorum and endothelium. It further lowers the considerable risk of wound healing complications seen with traditional vein harvesting, increases vein utilization, and facilitates the creation of more technically precise anastomoses because the proximal and distal vein diameters are more closely matched to those of the inflow and outflow target vessels. The extent of the proximal vein mobilization is dictated by the location of the saphenofemoral junction relative to the proposed site of the proximal anastomosis. It may at times be necessary to perform an endarterectomy of the superficial femoral artery if the length of proximal vein is insufficient. Lysis of the valve cusps is obligatory given the nonreversed configuration and is facilitated by newer, less traumatic valvulotomes that function safely through the blinded segments of undissected graft. Critics of this technique argue that the advantages listed previously have not translated into improved graft function or patency. They further argue that the time required and dissection involved in finding and ligating substantial side branches that can develop into physiologically important arteriovenous fistulas that "steal" distal flow obviate the stated benefits of this approach. Newer techniques using angioscopy and endoluminal coiling of larger side branches may help to minimize these concerns.

Nonreversed/Transposed Great Saphenous Vein Grafting

Recognizing the many practical advantages inherent to the in situ technique, some surgeons have modified the approach to infrainguinal bypass grafting with venous conduit to incorporate several of the same principles (Belkin et al. 1996). In particular, if the harvested vein is tapered to any significant extent, it is used in a nonreversed fashion. By optimizing the size matching between the artery and vein at both the proximal and distal anastomosis sites as discussed previously, one can often accept for use smaller veins than would be suitable for reversed vein grafting. The nonreversed configuration also allows preservation of the saphenous vein hood, which both extends the available conduit length and is especially beneficial when the femoral artery is thick walled and diseased.

The vein is harvested and dilated in a similar fashion to reversed vein grafts, and the cusps of the proximal valve of the greater saphenous vein are excised under direct vision with fine Potts scissors. There are currently two main types of valvulotomes available. The modified Mills valvulotome is a short, metal, hockey stick-shaped cutter that can be introduced through the distal end of the vein or through the side branches. After the proximal anastomosis is performed, and with the perfused conduit on gentle stretch, the valves are carefully lysed in a sequential fashion by pulling the valvulotome inferiorly. An alternative, recently designed self-centering valvulotome allows lysis of all valves in a single pass and is thought by some to be less traumatic. Once acceptable pulsatile flow is ensured, the distal anastomosis is performed in the standard fashion. It is important to note that similar patency rates have consistently been demonstrated regardless of which technique is applied (Moody et al. 1992; Wengerter et al. 1991), and so surgeon preference and comfort level is an acceptable reason for choosing one method over another.

Prosthetic Bypass

It is recommended that infrainguinal bypass surgery be performed with saphenous vein or an autologous substitute whenever feasible given the clearly demonstrated enhanced patency rates (Belkin et al. 1996; Whittemore et al. 1989). Some institutions more frequently rely on prosthetic grafts. When the distal target is the above-knee popliteal artery and the tibial outflow is relatively well preserved, this is an acceptable approach, as patency rates in this situation approach those of vein grafts (Quinones-Baldrich et al. 1992). A variety of surgical adjunctive procedures, from patching the distal anastomotic target vessel to the creation of a distal arteriovenous fistula or various autogenous vein cuffs interposed between the distal prosthetic and the target artery (Fig. 3), have all been attempted as a means of improving the patency rates of grafts extending below the knee (Miller et al. 1984). More recently, flared grafts designed to minimize turbulence and shear stress between the prosthetic and native vessel have gained some popularity. Polyester (Dacron) and polytetrafluoroethylene grafts are the two main types of prosthetic available, and as in other anatomic positions, available data show generally equal results with either choice. The entire procedure is carried out through two small proximal and distal incisions between which the graft is tunneled anatomically near the native superficial femoral artery. The selection of a 6- or 8-mm graft is dictated by the size of the native vessels.

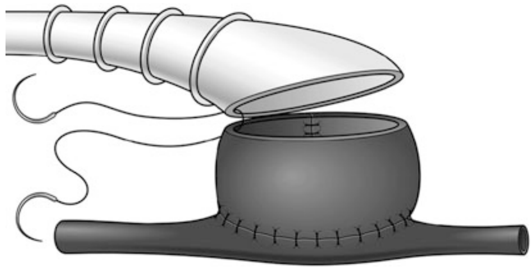

Fig. 3 Creation of a Miller cuff for prosthetic infrainguinal bypass grafts

Lack of Autologous Conduit

When the ipsilateral great saphenous vein is no longer available due to vein stripping or ablation or harvesting for coronary artery bypass, the contralateral great saphenous vein is the optimal conduit. Valid concerns exist in using contralateral vein due to the high incidence of peripheral arterial disease in the extremity as well as high incidence of coronary bypass and need for the great saphenous vein. This has been reviewed and found that fear of using the contralateral great saphenous due to future concerns is unfounded and that little short- or long-term impact is appreciated (Chew et al. 2002).

When lower extremity vein is not available, arm vein is a possibility and should be evaluated with duplex ultrasound. Basilic and cephalic veins are generally harvested proximal to the antecubital fossa due to significant scarring that often exists in the forearms from prior intravenous lines and phlebotomy. Harvesting of the arm veins can be technically challenging due to multiple side branches requiring ligation and the proximity to multiple nerves. Due to the short length of the arm veins, venovenostomies are performed with wide, spatulated end-end anastomoses to create a conduit long enough to reach the distal arterial target (Fig. 4). Great care must be taken with tunneling as composite arm vein conduits are prone to twisting and kinking due to their thin-walled nature. Decisions must be made with regard to reversal or nonreversal of the sections of arm vein when piecing them together as the thin walls of the arm veins may make valve lysis treacherous for a nonreversed conduit.

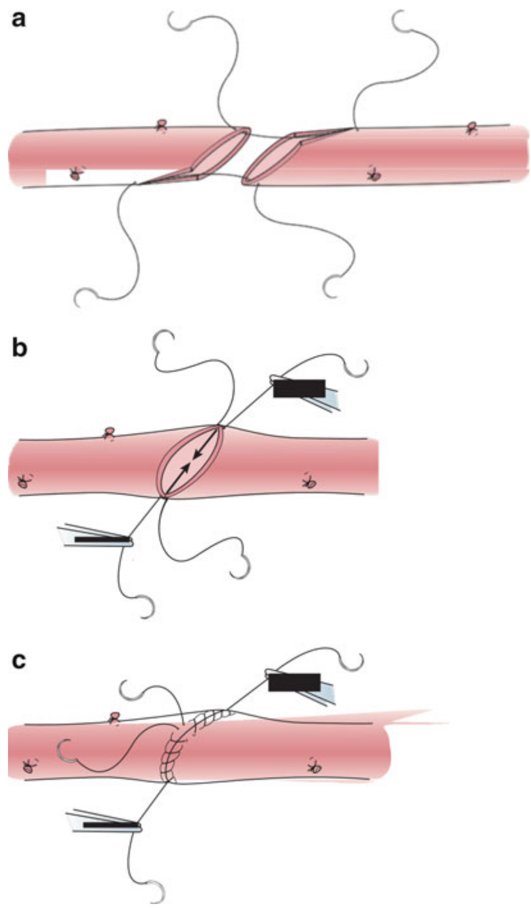

Fig. 4 Creation of venovenostomy for composite vein grafts

Postoperative Management

Patients who undergo peripheral bypass in the twenty-first century have often failed endovascular intervention attempts and are now presenting with critical limb ischemia. Many will have small ulcerations on the foot, which can be managed conservatively after bypass construction. Those with larger gangrenous lesions of the forefoot or toes will require debridement of all devitalized tissue at the completion of the revascularization procedure. Persistence of devitalized tissue after revascularization can result in limb loss particularly in diabetics and those patients with end-stage renal disease.

Swelling of the lower extremity owing to lymphedema from great saphenous harvest and surgical incisions is typical after bypass. Left unchecked, the swelling can dehisce even the most well-closed incisions. The author is fond of using a 6-in. double ace wrap from the foot to the thigh at all times in the early post-op period to combat wound complications. Bed rest for the first 24 h after a distal bypass can help as well in combatting significant swelling. Once out of bed, aggressive physical therapy and rehabilitation is the norm with many of these debilitated patients requiring short-term rehabilitation stay after discharge from the hospital. Antiplatelet therapy as well as statin use is continued indefinitely in bypass patients.

Complications

Many of the complications noted after lower extremity bypass surgery stem from underlying cardiac disease, including myocardial infarction, dysrhythmias, and congestive heart failure. Bleeding, hematoma, cellulitis, wound dehiscence, and more are all potential issues postoperatively that the surgeon must be on the lookout for.

Graft Surveillance

Bypass grafts, which fail in the first 30 days, are typically considered "early" technical failures. This can result from kinking, compression, poorquality vein, inadequate distal target, or incomplete valve lysis. Graft failure between 30 days and 2 years is more often due to intimal hyperplasia. This can occur at anastomoses or prior valve sites. Graft failures beyond this time are typically a result of progression of atherosclerotic disease within the inflow or outflow arteries. Because of these issues, graft surveillance is paramount in limb salvage (Veith et al. 1984). Duplex ultrasounds of the grafts will help identify significant stenosis that could threaten long-term patency of the bypass graft. Velocities less than 40 cm/s or greater than 300 cm/s or a threefold increase in velocity in one segment compared to another suggests an impending failure of the graft and needs to be treated either with angioplasty, surgical patch angioplasty, or short-segment revision of the bypass.

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