Tourniquets in Arterial Bypass Surgery

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Background: successful infra-popliteal bypass depends on precise, atraumatic technique in performing the distal anastomosis. The use of a tourniquet facilitates the distal anastomosis, reducing dissection, avoiding traumatizing clamping of the vessels and providing an “uncluttered” operating field. Despite these advantages the technique is under-used.

Objectives: to review the use of tourniquets in arterial reconstruction, with particular reference to safety issues and complications.

Design, methods and materials: a Medline search was performed (last search Feb. 2000), and keywords from relevant papers were used to perform subsequent searches. References were reviewed from each relevant paper.

Results: no randomised controlled trials were found. The review details reported use of tourniquets in arterial reconstruction, including techniques, outcomes and potential complications.

Conclusion: the use of a tourniquet is a safe and effective technique to facilitate arterial reconstruction.

Key Words: Femorodistal bypass; Tourniquet.

Introduction

Patency rates of infra-popliteal bypasses fall the further down the leg the distal anastomosis is placed. Refinements in surgical technique, improved case selection and aggressive use of autologous vein, or venous interposition grafts, have led to an improvement in the patency rates. However, tibial vessels are small, invariably diseased and associated with poor run-off. Success depends on precise, atraumatic technique in performing the distal anastomosis to avoid further narrowing of the native vessel or the formation of intimal flaps or tears, either of which may act as a nidus for thrombosis or induce neo-intimal hyperplasia.1 In turn, there is no doubt that good, clear exposure and complete control of blood flow are vital to meticulous technique.

Problems of Vascular Clamps and Occluders

Vascular clamps are effective in controlling bleeding during arterial reconstructions, but they can cause problems. Their presence within the operating field reduces visibility and interferes with access, conspiring to make the anastomosis technically difficult. Accurate application requires circumferential dissection of the vessels, which may cause intimal flaps, damage associated veins and disrupt small muscular branches which form part of the collateral circulation.2 Scarring due to dissection or damage of the vasa vasorum may render the peri-anastomotic vessel stiffer and unable to expand fully in response to the increased blood flow2,3 and may induce vessel wall ischaemia and cause plaque progression.4,5 Intimal and medial damage has been reported from clamp use.6–13 Atherosclerotic arteries have been shown to be particularly susceptible to injury irrespective of the intimal thickness at the site of clamp application.9,14 A fall in fibrinolytic function and impaired smooth muscle relaxation have been reported following clamp or sialastic sling application.15,16 Furthermore, clamps may not effectively occlude heavily calcified vessels, and firmer application can cause plaque and even vessel disruption as the rigid plaques cut through the wall.

Alternative techniques of extra-vascular control include the use of sialastic slings or intra-vascular “occluders”. Sialastic slings have been shown to be a...
less traumatic form of occlusion, causing little or no damage when applied to compliant arteries. However, with the increased force needed to control atherosclerotic vessels the damage approaches that seen with clamps. In addition, “sloops” cannot effectively control calcified arteries and judging the tension required to occlude the lumen is difficult without opening the vessel. Intra-arterial occluders can be balloon or bulb tipped. Balloon-tipped occluders may cause little damage at low pressures, but with higher pressures intimal and medial damage may occur with later intimal thickening. Bulb-tipped occluders are equal sized, making control difficult if the vessel tapers. Both types of occluder can be awkward to place in deep operative sites, get in the way during the anastomosis, and neither control side branch bleeding.

The significance of clamp trauma is uncertain. Intimal damage may form a focus for the development of thrombosis or dissection with early graft occlusion. Whilst peri-anastomotic scarring and intimal damage may contribute to late graft failure, its importance is difficult to assess. De Palma et al. have shown that clamps can cause loss of endothelium for up to 13 months and act as a nidus for platelet aggregation and atheroma formation, but the significance of these findings with respect to human atherosclerotic vessels is uncertain. Peri-anastomotic stenosis, at the site of previous clamp application, has been reported and proposed as a possible cause of graft failure. However, the incidence is unknown, with most longitudinal studies including such narrowings in the category of anastomotic hyperplasia or progressive disease. Donaldson et al. suggested that 9% of primary graft failures may relate to clamp damage.

Many of these problems can be reduced by using a tourniquet. A tourniquet provides good control, even of heavily calcified vessels, avoids the damage related to clamp application and, with exsanguination, virtually obliterates bleeding at the operation site. Furthermore, it provides an "uncluttered" operative field which aids surgery. Despite these advantages the technique remains poorly utilised.

The Tourniquet

The tourniquet has a long history, extending back at least to ancient Roman times where a constricting band was used to control haemorrhage. Their use in surgical procedures has been described as early as the 16th century, when Paré advocated their use in performing amputations. Pelet coined the term tourniquet from his innovation; the screw tourniquet. Exsanguination of the limb prior to application was found to reduce bleeding further and facilitate surgery by providing a “bloodless field”. Elevation of the limb is simple and effective, but more complete exsanguination can be achieved by bandaging the limb with an elastic material: an idea usually credited to Eschmarch, although earlier reports of the technique have been attributed to Nicoise. Eschmarch used a thin rubber tube, the width of a finger, in his technique. The modern “Eschmarch bandage” was in fact designed by von Langenbeck. In 1904 Harvey Cushing described the use of a pneumatic tourniquet with a pressure manometer, which was the forerunner of modern tourniquets. The pneumatic tourniquet has been used now for nearly a century as a safe, effective way of controlling bleeding and achieving a bloodless operating field.

Tourniquets in Arterial Reconstructions

The first use of a tourniquet in a vascular reconstruction was reported by Scheinin and Lindfors, who used a thigh tourniquet to facilitate repair of four popliteal aneurysms. Shortly after this, Bernhard et al. reported a series of 40 femoro-popliteal and tibial bypasses with a tourniquet. They noted the technique was safe and that it simplified surgery. Both these groups used a pneumatic tourniquet. In 1992 Shindo et al. recorded the use of an Eschmarch bandage to both exsanguinate the limb and form a tourniquet in 49 distal bypass operations. The value of tourniquets in vascular reconstruction has been supported by series from Collier and Myers, and more recently by Wagner et al., who reported 88 tibial or pedal bypasses with a tourniquet. We recently presented our data from 168 consecutive femoro-distal bypasses in which we used an Eschmarch bandage both to exsanguinate the leg and act as a tourniquet. Our series comprised 112 femoro-crural and 56 femoro-distal popliteal grafts, with 78% primary, 20% secondary and 2% tertiary reconstructions. There were almost equal numbers of vein grafts to prosthetic with venous interposition. Our early patency rates were comparable with the reported literature, and most importantly we found no complications attributable to the use of the tourniquet. More recently, Shindo et al. have reported the long-term results of their work with patency rates of 80.3% at 10 years. Others have reported the use of tourniquets in arterial surgery, formation of haemodialysis access and vascular trauma.

The majority of studies have used a pneumatic tourniquet, and some reports condemn the use of an
Eschmarch bandage as unsafe and uncontrolled. We and others have had no such problems. Furthermore, work by Biehl et al. has shown use of an Eschmarch bandage as a tourniquet to be safe and reproducible. With 10 operators, using 3 or 4 inch bandages and either three or four final wraps around the limb, they recorded mean pressures from 225 to 291 mmHg, with a maximum of 413 mmHg. These figures lie well within the accepted range for tourniquet pressures in the lower limb. In addition, it has the benefit of simplicity, cheapness and minimal disruption of the operation. More recently a “roll-on, roll-off” pneumatic tourniquet has been developed, but there are no reports of it being used in arterial surgery.

Concerns about Tourniquet Use

Bernhard suggests worries about occluding collateral vessels and the lack of studies documenting the effect of tourniquets in atherosclerotic limbs have hindered the general use of tourniquets. This reluctance is further reinforced in a recent review of arterial tourniquets which states “peripheral arterial disease is a contraindication” to tourniquet use. It goes on to say that the presence of calcified vessels is a further contraindication, because of incompressibility. Interestingly, the above reports have found significant complications related to tourniquet use in patients with peripheral arterial disease, and Wagner et al. started using a tourniquet because of a need to control calcified arteries.

The reluctance of some surgeons to use tourniquets probably relates to worries about possible side effects or complications. One of the main concerns is the duration of the tourniquet and pressure of application. Tourniquet times should be as short as possible. From the literature, 2 h is commonly given as an upper limit based on functional, histological, metabolic and clinical studies. In arterial reconstructions, the tourniquet is only applied once dissection and exposure has been achieved, thus minimising tourniquet time. Two hours allows plenty of time to complete even a venous interposition graft, and we have found that in many cases the tourniquet actually reduces the Anastomosis time. The question of tourniquet pressure is equally unclear. Some authorities use the blood pressure as a guide to tourniquet pressure, quoting ranges from 20 to 150 mmHg above systolic pressure. Advocates of fixed tourniquet pressure suggest pressures ranging from 500 to 1150 mmHg in the lower limb, without adverse effects. In principle, the quote by Sanders that “the correct pressure is the minimal required to produce a bloodless field” is right. However, it can be difficult to determine this value without repeated inflations of the tourniquet. A range of pressures from 300 to 500 mmHg seems to include the majority of reports and is probably a reasonably safe range. The use of an Eschmarch bandage by the current authors (and others) precludes the measurement of pressure. However, the study by Biehl et al. suggests that with consistent technique reproducible pressures between the range given above can be achieved by different operators. Work by Graham et al. has shown that a bloodless operating field can be achieved at sub-systolic pressures using wide tourniquet cuffs (cuff width to limb circumference ratio greater than 0.5). An Eschmarch bandage is particularly useful as a single bandage and can be tailored to produce a wide cuff for any leg size.

When using a tourniquet the effect of inflation and deflation should be considered. Exsanguination of the limb and inflation of the tourniquet will cause an increase in the circulating volume of around 400 ml. This may be important in vascular patients, who often have concomitant cardiac disease and poor cardiac reserve. Similarly, on deflation the fall in blood pressure may be more profound than that usually seen with reperfusion of an ischaemic limb. In addition, tourniquet release is associated with an increase in plasma potassium, lactate and pCO₂ levels, as well as a fall in pO₂ and pH. These phenomena are usually seen on reperfusion of an ischaemic limb following vascular reconstruction, but tourniquet use may cause more pronounced changes which may be significant in the presence of pre-existing cardiac or pulmonary impairment.

Complications of Tourniquet Use

The primary risk of tourniquet use is neuromuscular injury, usually in the area under the tourniquet. The milder form of neuromuscular injury, referred to as the post-tourniquet syndrome, is characterised by stiffness, pallor, oedema, weakness and subjective numbness, but no objective abnormality. The majority of these symptoms have resolved within a week, and consequently it is difficult to distinguish them from the routine post-operative symptoms following bypass surgery. Significant muscle injury is rare, although histological and electromyographical abnormalities have been reported for tourniquet times under 2 h. Electromyographic abnormalities have been found in up to 72% of cases following tourniquet use. However, clinical abnormalities are minimal and the significance of EMG changes is unclear, particularly in...
patients with PVD who demonstrate abnormalities in up to 78% of limbs prior to surgery.54 Severe nerve injury is well described and the incidence of clinically important nerve palsy, due to tourniquet use, is put at 1 in 13 000.54 The pathophysiology of these nerve injuries is unclear. Evidence tends to support a role for direct compression; however, impairment of the microcirculation may contribute.36 We avoid applying the tourniquet below the knee where it may compress the common peroneal nerve as it crosses the head of the fibula. Interestingly, nerve palsies have been reported with a venous tourniquet, where compression is far less.55 The majority of nerve injuries have a good prognosis, recovering within a few days to several months.41,56–58 We routinely use a tourniquet for infra-popliteal reconstructions and have found no clinically detectable nerve or muscle injuries in our patients. Bernhard et al. reported a case of necrosis of the gastrocnemius muscle, but related this to inadequate anticoagulation.7 Apart from this there are no reports of nerve or muscle injury using tourniquets in vascular cases. It may be that the anticoagulation, with or without aspirin, used during vascular surgery maintains the microcirculation and preserves nerve and muscle function. In addition, the existence of chronic tissue ischaemia may act to condition the tissues and the microcirculation to better withstand the complete ischaemia of tourniquet application.

Worries of occult venous injury, during dissection under tourniquet, and deep vein thrombosis may deter some surgeons from using a tourniquet. However, using a tourniquet reduces the extent of the dissection and hence the likelihood of venous injury. Furthermore, all dissection is performed prior to application of the tourniquet and any venous injury can be controlled. Orthopaedic studies have suggested a reduced incidence of deep vein thrombosis using a tourniquet, even in high risk cases.59 Wagner et al. abandoned routine post-bypass venous duplex because they found no DVTs.1 This low incidence is probably multifactorial. Exsanguination of the leg empties the venous system and prevents stasis, whilst the use of intra-operative anticoagulation will preclude thrombosis. Furthermore, there is evidence that tourniquet release is associated with increased fibrinolysis.60,61 Injury to arteries has been described with tourniquet occlusion. Two cases of superficial femoral artery thrombosis have been reported following the use of a thigh tourniquet, but in the absence of anticoagulation.52,53 Rupture of atherosclerotic plaques has also been noted.54 In lower limb vascular reconstruction the SFA is usually occluded, and hence placement of the tourniquet over this vessel has little adverse effect. In cases where the SFA is patent above the origin of the graft, Wagner et al. reported no evidence of stenosis or damage.1

Infection is considered a bar to tourniquet use.24 In our series 47% of cases had tissue loss including ulceration and gangrene, many with secondary infection. There was no increase in septic complications due to exsanguination or tourniquet use. This agrees with other work.1 The only definite contraindication to the use of a tourniquet is the presence of deep vein thrombosis, as exsanguination and/or tourniquet release may precipitate break off of thrombus and subsequent pulmonary embolism.36,37

No method of arterial control is without complications and risks. However, we and others have found an arterial tourniquet to be a safe and effective technique in vascular surgery. Many of the perceived problems do not occur, and it provides excellent control and superb bloodless operative fields for microvascular anastomosis. Although considered to be less safe, we found no complications arising from use of an Eschmarch bandage tourniquet, which has the added advantage of being quick and simple to apply, as well as cheap and reusable. It would be difficult to prove use of a tourniquet improves graft patency. Estimates suggest that a long-term randomised controlled study of over 3000 patients would be required to demonstrate a 5% advantage in graft patency at 95% confidence level with a power of 80%.3 However, the technique facilitates microvascular anastomosis, is quick, simple and, most importantly, safe. We use this technique for all infra-popliteal bypass grafts.

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