Retrograde Pedal Approach for Below-the-Ankle Revascularization in Patients With Critical Limb Ischemia

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**ABSTRACT:** Diabetic patients with critical limb ischemia (CLI) usually have significant multilevel arterial disease, very often with compromised outflow in pedal arteries. The combination of severe arterial occlusion with the increased blood flow requirement, necessary to achieve the healing of skin lesions or surgical incisions, makes this population particularly challenging to treat. Additionally, diabetic and CLI patients have a high rate of comorbidities, which increase surgical risks. Recent studies support the role of endovascular therapy in diabetic patients with CLI caused by below-the-knee (BTK) and below-the-ankle (BTA) arterial occlusive disease, as percutaneous angioplasty for BTK and BTA vascular disease has shown to be feasible and safe in this setting, with good results in terms of limb salvage and amputation-free survival rates. Nonetheless, the success rate remains suboptimal in a significant percentage of patients, related to a diffuse arterial disease with tibial and pedal arteries involvement. In addition to the traditional approach, pedal-plantar loop technique, transcollateral recanalization, and retrograde percutaneous access have been shown to be beneficial in increasing success rates, achieving a complete and successful revascularization, necessary for limb salvage and ulcer healing, and avoiding amputations. We hereby propose an overview of our experience with the retrograde pedal techniques to improve the success rate in the endovascular treatment of diabetic foot.

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**Key words:** endovascular therapy, retrograde pedal approach, critical limb ischemia, angioplasty.

Critical limb ischemia (CLI) is a major worldwide cause of morbidity, and treating the limb increases mortality because of factors relating to the procedure as well as risk factors. Critical limb ischemia is also a frequent complication of diabetes and occurs as the results of progressive and multilevel obstructive arterial disease.

Despite the benefits of pharmacologic therapy, arterial revascularization remains a mainstay in the management of CLI for restoration of arterial blood flow. The clinical objective of treating CLI is to avoid amputations, achieving limb salvage, and it is considered successful when the lesions are healed and the plantar stand is maintained, even when achieved by minor tarsal-metatarsal amputation. Due to good clinical results, endovascular treatment of CLI is gaining acceptance as a primary therapeutic strategy, with acceptable limb salvage and amputation-free survival rates.
However, the standard percutaneous approach can still be inadequate, because procedural failure can occur in up to 20% of patients, often relating to long total chronic occlusions (CTOs), wall calcifications, and a diffuse involvement of the pedal arteries, compromising distal run-off at the foot level, after tibial recanalization. In addition to the traditional approach, pedal-plantar loop technique, transcollateral recanalization, and retrograde percutaneous access have been shown to be beneficial in increasing success rates, achieving complete and successful revascularization, necessary for limb salvage and ulcer healing, and avoiding amputations. The purpose of this paper is to describe the retrograde approaches that could improve technical and clinical success in diabetic patients with CLI.

RETROGRADE TECHNICAL STRATEGIES

Based on the authors’ experience, antegrade recanalization should be the first strategy considered to recanalize tibial and pedal arteries, supported by endoluminal or subintimal approach of a CTO. In some cases, the antegrade approach of a CTO can be unsuccessful due to the inability to identify the ostium of an occluded tibial vessel, rupture or loss of the antegrade vessel pathway, inability to re-enter into the distal true lumen, or high risk of damaging the distal patent lumen, continuing the antegrade subintimal dissection. In these situations, the problem can be solved by switching to a retrograde approach.

The technical options for retrograde pedal approach are different, such as retrograde-antegrade recanalization (pedal-plantar loop technique or transcollateral recanalization), which combines retrograde and antegrade arterial recanalization using a single entry site, retrograde percutaneous distal access at different locations (pedal or plantar arteries), or advanced access (tarsal branches, transplantar arch or digital access).

PEDAL-PLANTAR LOOP TECHNIQUE

This approach has been described, consisting of the recanalization of both pedal and plantar arteries and their anatomical anastomosis in order to restore di-
rect arterial in-flow from dorsal and plantar circulation, achieving a complete below-the-knee (BTK) and below-the-ankle (BTA) revascularization.\textsuperscript{23,24} Specifically, this technique is based on the creation of a loop from the dorsal to the plantar circulation (or vice versa) by means of the guidewire and balloon tracking through the plantar arch of the foot. This technique may be of particular value in cases of diffuse disease involving the pedal vessels (desert foot), typical of diabetic and end-stage-renal-disease patients, where opening the distal distribution system (plantar arch) becomes essential for wound healing.\textsuperscript{5}

Pedal-plantar loop technique consists of one of the following approaches: (1) antegrade recanalization of the anterior tibial artery and pedal artery, including the plantar arch, followed by retrograde recanalization of the lateral plantar artery and then of the posterior tibial artery (Figures 1 to 3); or (2) antegrade recanalization of the posterior tibial artery and the lateral plantar artery, including the plantar arch, followed by retrograde recanalization of

![Figure 2. An endovascular approach included antegrade recanalization of the anterior tibial artery and pedal artery followed by retrograde recanalization of the plantar arch and lateral plantar artery (A, B). The retrograde progression of the guidewire showed an anatomical variation, by means of plantar flow through the peroneal artery (C, D). Angioplasty of the plantar arch (E).](image)

![Figure 3. Angiographic results show complete revascularization: recanalization of the anterior tibial and peroneal arteries (A) and recanalization of the pedal and plantar arteries, with dorsal and plantar flow to the foot (B).](image)
the pedal artery and then of the anterior tibial artery.

The technique can be adapted case by case, and a combination of other technical possibilities, such as antegrade subintimal recanalization of the tibial artery, followed by a re-entry on the pedal artery or a retrograde subintimal recanalization of the pedal and tibial arteries, followed by a re-entry at the origin of the tibial vessel, could help to reach both technical and clinical success.

This technical strategy has been thoroughly tested and proven useful for recanalization in patients with CLI due to below-the-knee and below-the-ankle atherosclerotic disease, providing a high rate of acute success as indicated by the ability to cross the lesions and inflate the balloon and adequate angiographic results without periprocedural complications.

Transcollateral Recanalization

In many cases of extreme vascular intervention, meaning treatment of multilevel arterial disease involving femoral, popliteal, tibial and foot vessels (Figure 4), either it is not possible to perform regular antegrade recanalization of the occluded tibial and pedal arteries, or antegrade revascularization fails. The only recourse in these cases can be to resort to unusual techniques, such as the transcollateral approach, to restore direct blood flow to the foot.

The transcollateral strategy has been described in the literature and was intended as an option to recanalize the tibial arteries. It can also be used to recanalize arteries of the foot using a natural anastomosis in the foot, such as the so-called “deep arch” of the foot, which connects the medial plantar artery with the lateral tarsal branch. It can also be used to recanalize dorsal or plantar circulation or to reach the pedal arch through the tarsal branch.

In the same way, there is a natural anastomosis between the peroneal artery and the “deep arch” of the foot, through a perforating deep branch. This can be

Figure 4. Diagnostic angiography shows anterior tibial and posterior tibial arterial occlusion, with patency of the peroneal artery (A, B) as well as patency of the plantar arteries and distal occlusion of the pedal artery (C, D).
Figure 5. An endovascular procedure involved an antegrade attempt to recanalize the posterior tibial artery that failed to re-enter in the plantar artery (A-C). After antegrade recanalization of the anterior tibial and pedal arteries, retrograde recanalization was performed across the natural anastomosis between the first dorsal and the first plantar digital branches, arriving in the medial plantar artery and in the common plantar artery (D-F). After re-entry with the retrograde guidewire and predilatation, an antegrade guidewire was deployed in the lateral plantar artery and balloon angioplasty was performed.

Figure 6. A final result shows complete revascularization: the three tibial vessels are patent (A, B) and there is direct blood flow for dorsal and plantar circulation and for the toes (C).
used to recanalize the anterior or posterior tibial arteries in retrograde fashion, via the peroneal artery, using the “deep arch” of the foot.27 The vessels are then treated by antegrade angioplasty.

In addition to the transcollateral approaches described, there are other collateral pathways or natural anastomoses between pedal arteries that allow performing retrograde-antegrade recanalization of the pedal and tibial vessels, and they represent an alternative option to recanalize the target pedal vessel (Figures 5 and 6).

This technique may represent a feasible endovascular option that can avoid more invasive, time-consuming, or riskier procedures but could be limited by spasms or dissection in the pedal collateral circulation.

Retrograde Percutaneous Revascularization

Retrograde percutaneous revascularization should be considered when the possible solutions described above fail or if there is high risk for damaging the distal patent vessels (Figure 7). The technique consists of a direct percutaneous retrograde puncture of a distal patent vessel, followed by a retrograde recanalization of the target vessel (Figure 8). When antegrade and retrograde approaches are combined, the procedure can continue with a standard antegrade angioplasty and hemostasis of the distal puncture site (Figure 9).18,28,29 A retrograde puncture can be performed in every segment of the pedal vessel, providing good technical and clinical results.5

Figure 7. For a patient who previously underwent Chopart amputation for osteomyelitis, diagnostic angiography shows proximal occlusion of the posterior tibial artery and distal occlusion of the anterior tibial artery (A, B). The thin plantar arteries are patent (C).
The key points to consider for retrograde puncture are as follows:

- **Vasospasm.** Especially for the distal vessels, the use of vasodilator (nitroglycerine, verapamil) is essential to avoid spasm. It can be administered intra-arterially, as close as possible to the puncture site, and subcutaneously around the puncture site.

**Figure 8.** An antegrade attempt to recanalize posterior tibial artery with artery rupture and acute bleeding (A, B). A retrograde percutaneous approach was also performed at the lateral plantar artery level as well as retrograde recanalization of the common plantar and posterior tibial arteries (C, D). Re-entry of the retrograde guidewire is shown in the antegrade catheter. Antegrade angioplasty and hemostasis in the plantar artery and antegrade recanalization of the anterior tibial artery were achieved (E, F).

**Figure 9.** Final results demonstrate complete revascularization, including patency of the anterior, posterior, and peroneal arteries, as well as direct blood flow for the amputated area through the dorsal and plantar circulation (A, B). Surgical reconstruction was performed with skin graft and metal sutures (C).
• **Puncture technique.** The puncture is performed with a 21-gauge needle, under fluoroscopic guidance with contrast medium injection and at the maximum magnification or under ultrasound guidance. The operator must keep in mind the concept of parallax technique and advance the needle while maintaining a perfect overlap with the target vessel.

• **Sheath.** In pedal arteries we prefer to avoid a standard sheath and instead use a sheathless approach or the Micropuncture Introducer Set (Cook Medical), containing a microsheath.

• **Retrograde crossing strategy.** Although both 0.014” and 0.018” guidewires can be used for retrograde crossing of the CTO, we usually prefer to start with a 0.018” wire, because it enhances the support. Low-profile support catheters are very useful for wire support, orientation, and exchange.

• **Reconnection with the antegrade approach.** After retrograde crossing of the occluded vessel, reaching the proximal patent arterial segment, the aim is to perform a rendezvous with the antegrade catheter. When the rendezvous is obtained, the retrograde wire is externalized at the groin level. After reversion of the approach, final hemostasis is obtained by advancing a balloon catheter beyond the puncture site and inflating it to nominal pressure after microsheath removal.

**ADVANCED ACCESS**

In select cases in which traditional percutaneous access sites are absent or not available for puncture (such as in the case of thin and diseased arteries), a retrograde access in the tarsal branches or retrograde percutaneous metatarsal artery access may be performed.

Usually, the first metatarsal artery is the best option for extreme retrograde percutaneous access, but a complete analysis of vascular anatomy of the foot, with multiple angiographic projections, is mandatory to identify the possible puncture site. The best site to perform the access is at the dorsum of the foot, through the first dorsal metatarsal artery, because plantar access is not a practical pathway due to the thickness of the skin. It is typically possible to reach the plantar arch via the dorsal branch of the first metatarsal, and across the arch it is possible to recanalize the dorsal or plantar circulation.

To avoid spasms that compromise the puncture and wiring of small vessels, pharmacological support is mandatory before performing percutaneous retrograde transmetatarsal artery access. In our experience we use verapamil (Isoptin 5mg/2mL) diluted to 10 mL of saline and inject 9 mL intra-arterially, as distally and close to the foot as possible. We also utilize local anesthesia in the dorsum of the foot, close to the target digital branch. We inject 1 mL of the diluted verapamil with lidocaine into the subcutaneous tissue as a support to avoid spasm.

The puncture is performed with a 21-gauge needle under fluoroscopic or ultrasound guidance. We usually use the micropuncture set, with microsheath, which is very useful for performing the access, and we deploy a 0.018” guidewire.

Retrograde percutaneous metatarsal artery access, followed by retrograde recanalization of pedal and tibial vessels, provides good technical and clinical results in patients in which surgical treatment is not feasible or
is contraindicated, antegrade recanalization fails, or pedal retrograde access is not possible due to chronic total occlusion of the dorsalis pedis or common plantar artery.  

**DISCUSSION**

Critical limb ischemia and diabetic foot disorders represent a frequent cause of amputation as a result of progressive obstructive atherosclerosis associated with tibial and pedal arterial disease. Endovascular intervention has garnered particular interest and is recommended for the treatment of patients with severely symptomatic peripheral artery disease. Nonetheless, BTK and BTA angioplasty can still be unsuccessful in up to 20% of patients, and this reflects an acute need for technical refinements for percutaneous revascularization of BTK and BTA vessels. The combination of antegrade and retrograde technical strategies help to improve the technical and clinical success rate.

Retrograde pedal approach should be considered after antegrade recanalization failures, in cases of the absence of the stumps at the ostium of the occluded vessels, in cases of subintimal recanalization followed by a no re-entry in the landing zone, or in cases of suboptimal landing zone.

**CONCLUSION**

Retrograde pedal approach techniques are safe and useful for retrograde recanalization of the pedal and tibial arteries in challenging cases of CLI, after failure of antegrade recanalization. When retrograde-antegrade recanalization fails, retrograde percutaneous access can be of help for limb preservation.

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