Editor's Choice

The Clinical Utility of Below-the-Ankle Angioplasty using “Transmetatarsal Artery Access” in Complex Cases of CLI

Luis Mariano Palena,1* MD, Enrico Brocco,2 MD, and Marco Manzi,1 MD

Objectives: To appraise clinical results of foot arteries recanalization using percutaneous retrograde transmetatarsal arteries access followed by retrograde recanalization of foot and tibial vessels. Background: Arterial revascularization by means of percutaneous transluminal angioplasty (PTA) is a mainstay in the management of patients with critical limb ischemia (CLI). Nonetheless, when employing standard approaches, success rate remain suboptimal. We report the clinical results of foot arteries recanalization through transmetatarsal artery access. Methods: From September 2011 to November 2012, 38 patients (28 men; mean age 73.2 ± 11.4 years) underwent metatarsal artery access after antegrade recanalization failure, followed by retrograde recanalization of the foot and tibial vessels. The primary end point was TcPO2 improvement. The secondary end point was limb salvage rate, amputation-free survival and radiation exposure. Results: Technical success (ability to deliver the balloon across the lesion and inflate it at nominal pressure) was achieved in 33 (86.84%) of cases, with <50% residual stenosis and no complications. Failures were because of spasm or no true lumen re-entry. During follow-up (mean 6.7 ± 2.3 months/range 1–14) clinical improvement was observed in the patients having technical success, with TcPO2 increasing, from 10.3 ± 7.6 to 50.7 ± 8.2 mm Hg, avoiding major amputations. Amputation-free survival rate calculated by Kaplan–Meier analysis was 81.5% at 12 months. Radiation exposition was major than in patients treated by antegrade way (45.5 ± 56.1 vs. 52.5 ± 11.5 min of fluoroscopy and 69.1 ± 83.2 vs. 94 ± 26.5 GYm² of X-ray dose; P < 0.001). Conclusion: Transmetatarsal artery access appears feasible and beneficial in cases with a failed antegrade recanalization and unsuitable for retrograde pedal/plantar access. © 2013 Wiley Periodicals, Inc.

Key words: critical limb ischemia; retrograde recanalization; limb salvage; infrapopliteal occlusions

INTRODUCTION

Chronic critical limb ischemia (CLI) is a major worldwide cause of morbidity and, especially when threatening the limb, mortality [1] and affect a large number of patients around the world, bringing about important health issues and severe disabilities. Major and minor amputations are usually associated with significant increases in mortality risk, and every effort should be pursued to minimize amputations and ensure limb salvage [2].

Arterial revascularization is the first-line treatment to relieve clinical symptoms related to CLI-like rest pain or improve wound healing [2,3]. Endovascular

1Interventional Radiologist Unit, Foot & Ankle Clinic, Policlinico Abano Terme, Abano Terme (PD), Italy
2Diabetic Foot Department, Foot & Ankle Clinic, Policlinico Abano Terme, Abano Terme (PD), Italy

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*Correspondence to: Luis Mariano Palena, Interventional Radiologist Unit, Foot & Ankle Clinic, Policlinico Abano Terme, Piazza C. Colombo 1, 35031 Abano Terme (PD), Italy.
E-mail: marianopalena@hotmail.com

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interventions have been increasingly used for the treatment of patients with severe infrapopliteal arterial disease and CLI, related to good clinical results [4–11].

However, standard percutaneous approach and techniques for the recanalization of below-the-knee (BTK) and foot arteries occlusions can still be inadequate, as procedural failure can occur in up to 20% of patients [4], related to long total chronic occlusions (CTO’s), wall calcifications, and a diffuse involvement of the foot arteries [12] compromising distal run-off at the foot level, after tibial recanalization. In addition to the traditional approach, retrograde access, transcollateral recanalization, and pedal–plantar loop techniques have been shown to be beneficial in increasing success rates [13–16]. Nonetheless, even these strategies may fail or proven unfeasible when the distal vessels are also diseased [15]. For this reason, technical improvements are necessary for percutaneous revascularization of BTK atherosclerotic disease. We hereby report the clinical results of the retrograde transmetatarsal artery access, a novel approach to recanalize challenging infrapopliteal and foot arteries total occlusions in the setting of CLI.

MATERIALS AND METHODS

Patient Population

From September 2011 to November 2012, 811 consecutive patients with CLI (Rutherford category 5/6, TcPO2 ≤30 mm Hg) underwent endovascular recanalization at our catheter laboratory.

In 38 (4.68%) patients (28 men; mean age 73.2 ± 11.4 years) who had failed antegrade recanalization and were unavailable for percutaneous retrograde access at the pedal or plantar arteries, required metatarsal artery access to recanalize the target vessels, identified by wound-related artery and angiosome concepts [17,18] to restore direct blood flow line to the compromised tissue. All patients signed the informed consent before the procedure and the retrospective study was conducted in accordance with the local ethics committee rules. Demographics, comorbidities, and clinical conditions are summarized in Table I.

Endovascular Procedures

Three days before of the procedure, the patients are pretreated with aspirin (75–160 mg) and ticlopidine (500 mg), or clopidogrel (300 mg). After local anesthesia, an antegrade access to a common femoral artery is obtained under ultrasound guidance (7.5-MHz linear probe), and a 5-F sheath is deployed. Five thousand units of unfractionated heparin are administered.

The target vessel for treatment is chosen according to the angiosome and wound-related artery concepts, according to the clinical indications and surgical targets (Fig. 1). The revascularization strategy is planned with the objective of providing a direct, in-line (i.e., noncollateral) blood supply to the foot (specifically, to the angiosome of any ischemic lesion), considering that the vascular anatomy of the leg and foot is composed of two circulatory pathways that are connected through the plantar arch. Specifically, the anterior tibial artery gives rise to the anterior and dorsal circulation of the foot, and the posterior tibial artery, to the posterior and plantar circulation of the foot. Both tibial arteries, together with the peroneal artery, supply to different regions of the foot and ankle. The heel, plantar region of the foot, and the medial part of the ankle are supplied by the posterior circulation; the anterior part of the ankle and the dorsum of the foot, by the anterior circulation; and the lateral border of the ankle and heel, by the peroneal artery. The toes are supplied by the metatarsal branches that originate from the plantar arch [17].

The first attempt to recanalize the target vessel is made via antegrade recanalization. Specifically, intraluminal revascularization is attempted as a first choice in calcified vessels, using 0.014”-in guidewire and support catheter or catheter balloon, when intraluminal revascularization fails, in not calcified or spot calcified vessels a subintimal technique is performed using 0.018”-in guidewire and support catheter or catheter balloon. When antegrade techniques fails (Fig. 2a and b), retrograde recanalization and SAFARI technique are considered, immediately and during the same procedure [20], but when the anterior and posterior tibial arteries and/or pedal/plantar arteries are occluded or unfeasible for puncture (thin and diseased arteries), then the metatarsal artery access route is considered.

The access is created according to the recent literature [3,19]. Especially, pharmacological support to

<table>
<thead>
<tr>
<th>TABLE I. Demographics and Clinical Conditions of Patients Approached by Transmetatarsal Artery Access</th>
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<tbody>
<tr>
<td>Patients</td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>Mean age (Yr)</td>
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<tr>
<td>Male gender</td>
</tr>
<tr>
<td>Diabetes</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>Dyslipidemia</td>
</tr>
<tr>
<td>Coronary artery disease</td>
</tr>
<tr>
<td>Chronic renal failure</td>
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<tr>
<td>Rutherford class 5</td>
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<tr>
<td>Rutherford class 6</td>
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<tr>
<td>TcPO2 (mm Hg)*</td>
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</tbody>
</table>

Continuous variables are reported as mean ± standard deviation.
Categorical variables are reported as n (%).
*Pre-treatment data.
avoid spasms that can compromise the puncture and wiring of small vessels is mandatory. For this, 5 mg/2 mL of verapamil (Isoptin; Abbott S.p.A, Campo- verde, Italy) is diluted to 10 mL with saline, and 9 mL of this solution is injected intra-arterially as distal as possible, close to the foot. Local anesthesia is

Fig. 1. Diagnostic angiography of diabetic patients affected by CLI, presenting ulcer in the heel and in fifth toe. (a and b) Occlusion of the P3 popliteal artery tract and occlusion of the posterior tibial artery (white arrows). Patency of the anterior tibial and peroneal arteries with stenosis of the tibioperoneal trunk. (c and d) Laterolateral and anteroposterior view of the foot. Occlusion of the pedal artery in a probably anatomic variation related to the presence of multiple tarsal branches without stump of pedal artery. Occlusion of the plantar arteries with stump of the medial plantar artery (c: white arrow). In the anteroposterior view (d) is possible to observe the blush at the level of the fifth toe (white arrow). Target vessel: Popliteal, posterior tibial, and lateral plantar arteries.

Fig. 2. Endovascular procedure. (a and b) Antegrade subintimal recanalization attempt of the posterior tibial artery finished in a fissure of the common plantar artery. (c–e) Retrograde transmetatarsal artery access followed by retrograde intraluminal recanalization of the plantar arch and lateral plantar artery (white arrows). (f and g) Retrograde recanalization of the common plantar and posterior tibial arteries followed by rendezvous, engaging with the retrograde guidewire the antegrade diagnostic catheter (g: white arrow). (h) PTA and hemostasis was performed by antegrade approach in the metatarsal artery, lateral plantar artery, and posterior tibial artery.
administered close to the target area, and 1 mL of the diluted verapamil together with lidocaine is injected into the subcutaneous tissue to avoid spasm.

In authors' experience, the best site to perform the access is at the dorsum of the foot through the first dorsal metatarsal artery, plantar access is not a practical way to gain access. By way of the dorsal branch of the first metatarsal artery, it is usually possible to reach the plantar arch, and across the arch, it is possible to recanalize the dorsalis pedis or lateral plantar artery (Fig. 2c–e).

The puncture is performed with a 21-gauge needle under fluoroscopic guidance with contrast medium injection and at the maximum magnification to identify the target vessel. We usually use the Micropuncture Introducer set (Cook Medical, Cook Group Incorporated, William Cook Europe A.p.S., Denmark), which is composed of one long 21-gauge needle, a dedicated torq-flex 0.018-in. guidewire, and a microsheath, which is useful for gaining access. After access creation, retrograde intraluminal recanalization of the metatarsal artery and plantar arch is performed followed by intraluminal or subintimal recanalization of the foot and tibial vessel followed by rendezvous technique, engaging the antegrade catheter left in the tibial artery, after the failed antegrade attempt (Fig. 2f and g). The procedure is completed by the antegrade access, passing the guidewire beyond the puncture site, retrieving the microsheath, and inflating a catheter balloon (1.5 mm in diameter), achieving hemostasis (Fig. 2h) at the metatarsal artery level.

For tibial and foot arteries dilation, the balloons are sized by visually estimating the distal reference vessel diameter, as well as the target lesion, delivered via the antegrade access and inflated for at least 1 min at nominal pressure.

The challenges associated to the access creation is the recanalization of the small vessels that could be compromised by the spasms, 0.014"-in guidewire could be useful to avoid these but do not provide the necessary support. Usually, using a 0.018-in guidewire (V18®; Boston Scientific Corp., Natick, MA) and support catheter (CXI; Cook) we obtain a good compromise between support, pushability, and spasm. We also use a microsheath, sheath-less technique is possible but it is not recommended, in our experience, related to the poor support in the small vessels with sheath-less technique; the possibility to inject contrast media through the microsheath and exchange catheters and guidewires without damaging the access site in the small vessels.

After the procedure, aspirin is continued indefinitely and ticlopidine or clopidogrel is continued for 3 months [19]. After discharge, clinical follow-up is routinely performed at 1 month and then at 3-month intervals.

**Statistical Analysis**

The primary end point was clinical improvement in functional status, intended as TcPO2 improvement and maintained during follow-up. The secondary end point was limb salvage rate, amputation-free survival rate, and radiation exposure. Continuous variables are reported as mean ± standard deviation. Categorical variables are reported as N (%).

Radiation exposure was assessed comparing the time of fluoroscopy (min) and the radiation dose (Gy) between the patients treated by mean of antegrade recanalization and the patients treated by mean of retrograde metatarsal artery access. The null hypothesis that a sample came from a normally distributed population was tested by Shapiro–Wilk test (P < 0.05) and the Mann–Whitney test was used to compare the values. Statistical significance was set at 0.05.

**RESULTS**

Retrograde transmetatarsal artery access was performed in 38 cases, at the level of the first dorsal metatarsal branch. Technical success (ability to deliver the catheter balloon across the lesions and inflate it to nominal pressure) was achieved in 33 cases (86.84%), with adequate angiographic results (<50% residual stenosis and noncomplications, Fig. 3). Technical failures were related to spasm (one case) or no true lumen re-entry after successful transmetatarsal artery access (four cases).

Clinical improvement was observed in the patients having technical successful tibial and foot arteries recanalization, with a significant increase of TcPO2 after 15 days, from 10.3 ± 7.6 (pre-treatment value) to 50.7 ± 8.2 mm Hg (post-treatment value) and was maintained during the follow-up (mean 6.7 ± 2.3 months/range 1–14).

In this population, at high risk of amputation related to the baseline clinical conditions, during the follow-up three patients underwent transmetatarsal amputation and three patients had phalange or toe amputations with good clinical results in terms of surgical incision healing. No major amputations were observed in the entire cohort (limb salvage rate 100%). Amputation-free survival rate calculated by Kaplan–Meier analysis was 81.5% at 12 months (Table II). The patients with technical failure obtained inferior clinical benefit because of femoropopliteal recanalization or did not...
have clinical improvement and underwent minor amputations.

Radiation exposition, compared to the patients treated by mean of antegrade revascularization, was major in patients treated by retrograde transmetatarsal artery access. The fluoroscopy time was 45.5 ± 56.1 vs. 52.5 ± 11.5 min and the radiation dose was 69.1 ± 83.2 vs. 94 ± 26.5 GYm² ($P < 0.001$) (Fig. 4).

**DISCUSSION**

CLI and diabetic foot disorders represent a frequent cause of amputation and these are a result of progressive obstructive atherosclerosis, associated with tibial and foot arteries disease.

Endovascular interventions has become of particular interest and is recommended for the treatment of patients with severely symptomatic peripheral artery disease [2–9]. Nonetheless, BTK and below-the-ankle (BTA) angioplasty can still be unsuccessful in up to 20% of patients [4,14,21] and these is thus an acute need for technical refinements for percutaneous revascularization of BTK atherosclerotic disease. Different approaches, such as retrograde and SAFARI or transcollateral techniques that have already been described [13–15,19,21–26]. Despite this, there still remains much space for improvement, especially when atherosclerotic disease diffusely involves the distal tracts of the tibial vessels and foot arteries, compromising the use of the retrograde or transcollateral techniques.

In order to further improve success rates of PTA for challenging BTK and BTA disease, a novel revascularization technique has been conceived [3,19]. In fact, when the tibial or pedal arteries are occluded and not available for puncture, retrograde percutaneous transmetatarsal artery access is a useful alternative to retrograde recanalization of foot and tibial vessels, after failure of antegrade approach. These maneuvers can improve both technical and clinical results for nonsurgical candidates in whom all other percutaneous techniques have failed or are unavailable [3].

Our results confirm that transmetatarsal artery access, a minimally invasive approach, is of particular value to treat BTK and BTA atherosclerotic occlusive disease, whenever a proximal occlusion stump is unavailable, when a dissection flap or a perforation in the proximal tract of the target vessel impairs guidewire advancement, after subintimal recanalization failure because of no re-entry in the true lumen, as well as

**TABLE II. Amputation-Free Survival Rate Estimated by Kaplan–Meier Analysis**

<table>
<thead>
<tr>
<th>Time period (Month)</th>
<th>At risk</th>
<th>Became unavailable (amputated)</th>
<th>Survival rate (%)</th>
<th>$S(\tau)$</th>
<th>SE</th>
<th>SE(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>38</td>
<td>0</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>1</td>
<td>34</td>
<td>4</td>
<td>0.882</td>
<td>0.882</td>
<td>0.028</td>
<td>2.828</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>2</td>
<td>0.925</td>
<td>0.815</td>
<td>0.077</td>
<td>7.778</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>0</td>
<td>1.000</td>
<td>0.815</td>
<td>0.091</td>
<td>9.192</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>0</td>
<td>1.000</td>
<td>0.815</td>
<td>0.141</td>
<td>14.142</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>0</td>
<td>1.000</td>
<td>0.815</td>
<td>0.190</td>
<td>19.092</td>
</tr>
</tbody>
</table>

![Image](https://example.com/image.png)

**Fig. 3.** Final results. (a and b) Patency of the popliteal artery and patency of the posterior tibial artery (white arrows). (c and d) Patency of the lateral plantar artery (black arrows) with evident blush in the heel ulcer and at the level of the fifth toe ulcer (white arrows).
when distal disease makes retrograde percutaneous puncture unfeasible or impossible.

This novel technique provides good clinical results with significant improvement of the TcPO2 value after 15 days. These results are similar to the data reported in literature for the BTA angioplasty using pedal–plantar loop technique [16].

The 100% of limb salvage rate and the 81.5% of amputation-free survival rate at 12 months, in our cohort allowed avoiding mayor amputations maintaining the limb functionality by preserving the maximum amount of the plantar stand.

This technique is also of particular value as a rescue procedure in cases where retrograde percutaneous access leads to dissection and acute occlusion allowing recovery of the complication by a more distally retrograde access followed by retrograde recanalization.

Despite the usefulness of this technique, it is not free from the risk of failure. In our small group of patients, almost 13.5% of the transmetatarsal artery access failed because of spasm or no re-entry in the true lumen. In our experience these kind of access are free of complications. These should be performed in extreme situations, in patients with Rutherford 5/6 class and high risk of amputation, with the objective to avoid amputation or distalize the amputation level.

The challenge for the interventionist with the retrograde access is the radiation exposure [27]. In our cohort we compared the time of fluoroscopy and the radiation dose between the patients treated by mean of antegrade revascularization and the patients treated by transmetatarsal artery access and the results shows a major fluoroscopy time and radiation dose in patients treated by transmetatarsal artery access. For this reason we recommended using all the X-ray protection devices available (also protective gloves and glasses).

The limits of our study are that not all patients completed 12 months follow-up and that we are limited to compare the fluoroscopy time and the X-ray dose information recorded during endovascular interventions as mean of dose-area product calculated by the dosimeter integrated in the angiography unit. A clinical trial evaluating the X-ray dose by a dosimeter badge to assess the precise X-ray dose for the patient and for the interventionist could be useful.

CONCLUSIONS

Our results confirm that transmetatarsal artery access is of particular value in challenging cases of CLI and foot wounds, providing good clinical results and amputation-free survival rate, but is reserved for extreme cases in which other revascularization strategies or options are unfeasible or contraindicated. X-ray dose exposition is major than antegrade recanalization techniques for patients and interventionists and it could be considered before using this technical strategy.

REFERENCES


