Diagn Interv Radiol 2013; 19:134–140

© Turkish Society of Radiology 2013

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

US-guided retrograde tibial artery puncture for recanalization of complex infrainguinal arterial occlusions

Serkan Gür, Levent Oğuzkurt, Kamil Gürel, Güven Tekbaş, Hakan Önder

PURPOSE
We aimed to describe the technical aspects and outcomes of the retrograde tibial approach and balloon predilation for recanalization of complex infrainguinal arterial occlusions and determine the efficacy of this approach in minimizing failure rates.

MATERIALS AND METHODS
Between September 2006 and April 2011, antegrade revascularization failed in 22 limbs with complex total occlusions within the infrainguinal arterial territory. For each of these antegrade failure cases in 22 patients, a retrograde tibial puncture had been attempted. Percutaneous recanalization and predilation were initially performed through tibial access, and final balloon dilatation or stent placement was performed from antegrade femoral access. The patients were followed up for functionality and wound healing.

RESULTS
Access from the tibial artery was successfully obtained for all patients (100%). Successful recanalization was obtained in 18 patients (82%). Retrograde access was performed from the anterior tibial/dorsalis pedis artery in 12 patients and posterior tibial artery in 10 patients. One major and one minor complications were documented.

CONCLUSION
Retrograde tibial recanalization technique in the infrainguinal complex arterial occlusion safely increases the success rates of percutaneous recanalization in the failed traditional approach and is a feasible endovascular option to avoid more invasive, time-consuming, and high-risk procedures.

From the Department of Radiology (S.G. ✉ *mserkangur@yahoo.com*), Şifa University School of Medicine, İzmir, Turkey; the Department of Radiology (L.O.), Başkent University Adana School of Medicine, Adana, Turkey; the Department of Radiology (K.G.), Abant İzzet Baysal University School of Medicine, Bolu, Turkey; the Department of Radiology (G.T., H.Ö.), Dicle University School of Medicine, Diyarbakır, Turkey.

Received 29 May 2012; revision requested 2 July 2012; revision received 5 July 2012; accepted 6 July 2012.

Published online 21 December 2012
DOI 10.4261/1305-3825.DIR.6122-12.1

Arterial revascularization through endovascular treatment is a common procedure for patients with infrainguinal arterial occlusive diseases. Percutaneous recanalization of the superficial femoral artery (SFA) is the most important alternative to surgery and appears equivalent to surgery in the management of patients with critical limb ischemia (CLI) (1). However, arterial occlusions can be difficult to treat by endovascular means especially in long segment occlusions; failure of the endovascular approach may result in amputation for patients with CLI. Approximately 20% of patients with complex crural occlusions cannot be treated using the conventional antegrade approach (2). After revascularization failure, 40% to 50% of these patients will lose their leg within six months, and up to 20% will die (3).

The unsuccessful endovascular treatment is not mainly due to the inability to cross the occlusion with the guidewire, but rather due to an unsuccessful re-entry of the guidewire into the true lumen distal to the occlusion. Dedicated re-entry devices, such as the Pioneer catheter (Medtronic Vascular, Santa Rosa, California, USA) or the Outback catheter (Cordis, Miami Lakes, Florida, USA), are successful in a majority of cases, with a reported success rate of 80% to 100% (4). However, the devices are unsuccessful in some patients, and a re-entry device specifically designed for infrapopliteal arteries does not yet exist. High cost, a steep learning curve, and complications related directly to a re-entry device are other drawbacks. The retrograde tibial artery approach seems to be a good alternative method to increase the technical failures that arise from the inability to gain entry into the distal lumen in such patients.

The purpose of this retrospective study was to describe the technical aspects and outcomes of the retrograde tibial approach for endovascular recanalization of infrainguinal arterial occlusions, which could not be recanalized from the traditional antegrade approach, and also to determine the efficacy of this approach in minimizing technical failure rates.

Materials and methods

Patients

A retrospective review was performed for 22 consecutive patients (19 males, three females) who underwent a failed endovascular recanalization attempt for chronic infrainguinal atherosclerotic occlusive arterial disease. The mean age of the patients was 60±13 years (range, 35–78 years). All patients were from a single institute dating from September 2006 to April 2011. Patients underwent endovascular treatment for moderate to severe intermittent claudication or CLI. Diagnosis of the underlying arterial ischemia in each patient was determined from patient history records and physical exams using color Doppler ultrasonograpy (US) in the outpatient clinic. All patients underwent magnetic resonance angiography prior to angiography for confirmation of the diagnosis and for endovascular intervention planning. Rutherford category of disease severity and atherosclerotic risk factors were obtained for each patient. Ankle brachial index was not obtained routinely. Patients who were 18 years and older with chronic atherosclerotic occlusive diseases of at least one infrainguinal artery (femoral, popliteal, or tibial) and an unsuccessful attempt for recanalization of target infrainguinal artery or arteries were included in the study. All patients suffered from unsuccessful antegrade recanalization attempts and were suitable for a retrograde tibial attempt for which there was angiographic evidence of distal reconstitution of the anterior tibial artery (ATA) or posterior tibial artery (PTA). Patients who had acute limb ischemia and those who had the peroneal artery as the only patent crural artery were excluded from the study, as puncture of the peroneal artery was difficult with US guidance. All retrograde tibial artery punctures were performed under US guidance during the same session of the failed infrainguinal recanalization. Patients who had significant ipsilateral or contralateral iliac artery occlusive disease were also treated during the same session.

The potential benefits and risks of the endovascular treatment were explained to each patient, and written informed consent was obtained. Each patient was also informed for a possible second artery puncture from the tibial arteries at the ankle level if the attempt from the inguinal region failed. All of the procedures were performed in compliance with the ethical standards of the World Medical Association Declaration of Helsinki.

Procedure

Endovascular procedures were performed in an interventional radiology suite under intravenous sedoanalgesia with dormicum and fentanyl using a flat panel digital subtraction angiography unit (Innova 3100, GE Healthcare, Milwaukee, Wisconsin, USA; or Multistar, Siemens, Erlangen, Germany). After preparation of the field with sterile techniques, access to the infrainguinal recanalization site was obtained through US-guided puncture of the contralateral or ipsilateral common femoral artery. If the proximal 10 cm of the SFA was involved, our initial means for endovascular treatment of an SFA occlusion was the contralateral retrograde femoral approach. If the proximal SFA was intact, we chose the ipsilateral antegrade femoral artery approach. A 5 F or 6 F, short or long vascular sheath (Cordis) was placed into the proper artery. The SFA occlusion was crossed subintimally with a hydrophilic guidewire (Terumo, Miami, Florida, USA; or Roadrunner, Cook Medical, Bloomington, Indina, USA), whereas a tibial artery occlusion was crossed intraluminally, if possible, with a straight-tip 0.035-inch hydrophilic guidewire (Terumo) or a 0.018-inch straight-tip V-18 control wire (Boston Scientific, Natick, Massachusetts, USA). A heparin dose of 5000 IU was administered intra-arterially after placement of a vascular sheath. Diagnostic angiograms were obtained from the iliac or SFA to the tibial arteries at the ankle level. Recanalization was then attempted for the SFA, popliteal, or the tibial arteries.

If antegrade recanalization of the target infrainguinal artery failed, the ATA or PTA was prepared in a sterile manner, and local anesthesia was administered. The tibial artery was punctured at the ankle level with a 21 G micropuncture needle (Cook Medical) under US guidance using a 13-MHz linear array transducer (Acuson Antares, Siemens). A 0.018-inch control wire (Boston Scientific) was advanced proximally (Figs. 1 and 2). An introducer sheath was not placed in the tibial artery unless it was deemed necessary by the operator. This was performed to avoid occlusion of blood flow and trauma to the low profile artery. If the wire could not be advanced through the occlusion, the 0.018-inch guidewire was exchanged for a 0.035-inch hydrophilic guidewire with a micropuncture dilator system, and a 4 F angled glide catheter (Terumo) was used to negotiate through the target artery occlusion. After successful negotiation of the occlusion, a 0.018-inch guidewire was used for balloon dilatation. The occlusion was predilated with a small profile 3 mm balloon (Symmetry, Boston Scientific, Galway, Ireland) (Fig. 2a–c). Then, a guidewire was advanced from the antegrade approach through the predilated lumen. If the predilated lumen could not be negotiated through, a larger balloon catheter (5 or 6 mm, Symmetry) was used from the retrograde approach for further dilatation of the occlusion. At this point, the procedure was complete if recanalization was successful with less than 30% residual stenosis. If repeat balloon dilatations and/or stent placements were required, the procedure was continued from the antegrade access site. This was performed to avoid additional trauma to the small-diameter tibial artery during the exchange of balloon catheters. The guidewire was either removed right after successful negotiation of the occlusion from the antegrade access site or at the end of the procedure. Manual compression with a finger was held for 3 to 5 min to achieve hemostasis. In circumstances where hemostasis was difficult to obtain, a small profile balloon with a diameter of 2 to 3 mm was inflated just anterior to the tibial artery puncture site. Heparin was neither reversed nor continued after the procedure. If there was vasospasm after balloon angioplasty, nitroglycerin (100 µg doses, repeated when necessary) was administered through the proximal sheath. After the interventions, medical therapy consisted of acetylsalicylic acid (100 mg/day) alone. In one patient, the wire from the tibial artery could not cross the occlusion. Both antegrade and retrograde approaches were performed to create two subintimal channels by balloon angioplasty (5).

The puncture site was always imaged with angiography at the end of the procedure. Clinical follow-up at the access site was performed with color Doppler US both one hour and one month after the procedure. Longer follow-up was not attempted for the tibial artery puncture site. The follow-up for the revascularization process was performed with clinical examinations and color Doppler US at one, six, and 12 months and then annually.

Definitions of criteria

Access to the tibial artery was defined as a successful puncture with advancement of a guidewire. Recanalization (procedural) success was defined as successful passage of the guidewire through the occlusion with the help of the retrograde approach and consecutive balloon angioplasty. Angiographic success was defined as successful vessel calibration and blood flow after endovascular therapy at the occluded target artery with a residual stenosis <30%. Restenosis and occlusion of the tibial access artery were evaluated with angiography at the end of the procedure and a col-

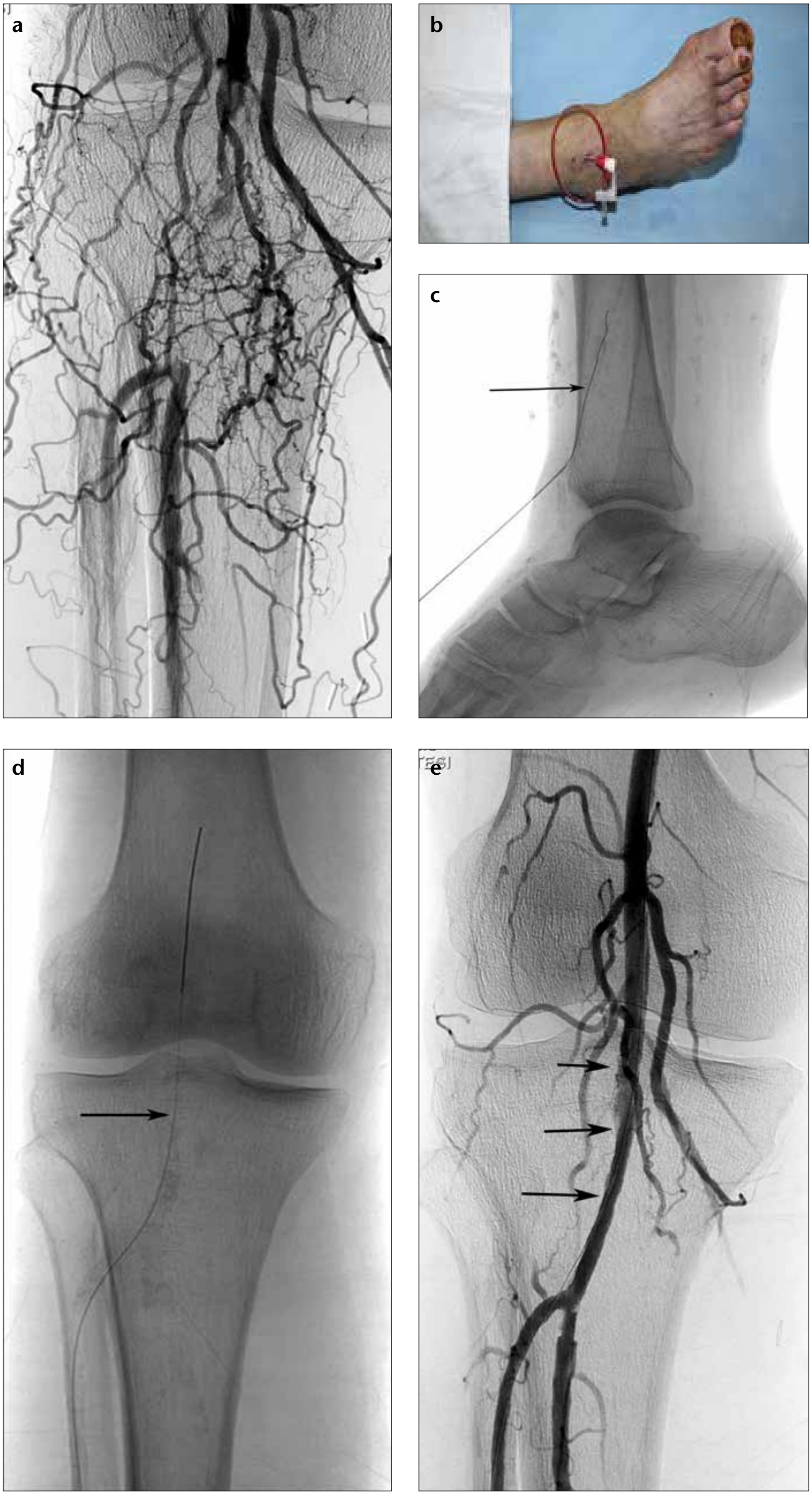

Figure 1. a–e. Angiographic image of a 68-year-old man with severe ischemia of the right forefoot and occlusion of the distal popliteal artery **(a)**. Retrograde dorsal pedal access and 4 F sheet in dorsalis pedis artery are seen **(b)**. Retrograde access into the anterior tibial artery and passage of a 0.018-inch guidewire and subintimal recanalization of the popliteal artery are noted (*arrows*) **(c, d)**. After retrograde subintimal recanalization and balloon angioplasty of the distal popliteal artery, normal vessel caliber and blood flow were achieved (*arrows*) **(e)**.

or Doppler US examination after the procedure. Restenosis was defined as a diameter reduction of more than 50% of the access tibial artery on follow-up. Complications from the tibial access site and target vessel revascularization were reported separately in accordance with the guidelines set by the Society of Interventional Radiology (6).

Results

The demographics and clinical characteristics of patients are summarized in Table 1. The most commonly associated comorbidities were diabetes mellitus (64%), smoking (55%), coronary artery disease (23%), hypertension (34%), and hyperlipidemia (50%). The clinical presentations of ischemic leg lesions were moderate to severe intermittent claudication (Rutherford category 3, eight patients), rest pain (Rutherford category 4, seven patients), and ulcers (Rutherford category 5, seven patients).

Almost all lesions were chronic total occlusions; the overall mean lesion length was 14.2±7.1 cm (range, 5–35 cm) (Table 1). The PTA was punctured in 11 patients (Fig. 2), the dorsalis pedis artery in five patients (Fig. 1), and the ATA in six patients. Access was gained in all 22 patients (100%). One patient required placement of a 4 F vascular sheath at the access site because of blood emission (Fig. 1b). In the other 21 patients, crossing of the occlusion and balloon predilation from the tibial artery access point was performed using 0.018-inch or, rarely, with 0.035-inch guidewires. Procedural (recanalization) success on the target vessel revascularization was achieved in 20 of 22 patients (91%). In the two unsuccessful cases, the mechanism of failure was as follows: first, the guidewire perforated the tibial vessel at the level of the occlusion, and it was not possible to find the true lumen. Perforation of the artery was managed with a low-pressure, long-duration balloon dilatation from the retrograde approach without any adverse outcome. Second, the guidewire could not be directed through the distal cap of the occlusion. In both of these cases, the tibial access guide was removed and hemostasis was achieved using manual pressure. No subsequent clinical evidence of limb perfusion deterioration was observed. Angiographic success was achieved in 18 of 22 patients (82%). In two patients, retrograde recanalization of the tibial and popliteal arteries was successful. However, in one patient, re-occlusion of one tibial artery occurred even after repeated balloon dilatations. In the other patient, significant elastic recoil resulted in more than 50% restenosis in the popliteal artery. A tibial artery stent was not available in the first patient, and stent implantation was not considered for the second patient.

In the course of the endovascular procedures performed in 22 patients, a total of 43 lesions were treated (Table 1). Four (18%) patients required an adjunctive self-expanding nitinol stent placement for SFA and external iliac artery occlusions. In one patient, recanalization of the SFA was achieved using the SAFARI technique (simultaneous dual-channel balloon dilation) (5).

Complications

After the procedures, angiography and duplex US confirmed no distal access site complication in any patients except one. This patient developed acute thrombosis of the accessed PTA at the one hour follow-up after retrograde recanalization. It was observed that there was a delay of heparin administration in this patient. Heparin was not administered immediately after antegrade or retrograde puncture of the artery, but instead after predilatation of the occluded target artery. The ATA was patent, and the thrombosis involved a short segment of the posterior tibial artery. Intravenous heparinization was started immediately and changed to subcutaneous low-molecular-weight heparin for two weeks. At the end of one week, the artery was patent without residual narrowing. Another patient had a minor complication of blood leakage through the occluded artery after guidewire manipulation. This complication was successfully treated with a low-pressure, long-duration balloon dilation. Hematoma at the access site did not occur in any patient with tibial artery access.

The longest follow-up for the tibial artery access site was one month. The mean follow-up for infrainguinal target artery revascularization was 8±8 months, which ranged from 1 to 36 months. The patient outcomes are summarized in Table 2. One patient (4.5%) died of heart failure two months after the procedure, and two patients (9%) were lost to follow-up. One patient with intermittent claudication required two additional interventional procedures during the follow-up period. None of the patients had major or minor amputations during the follow-up period.

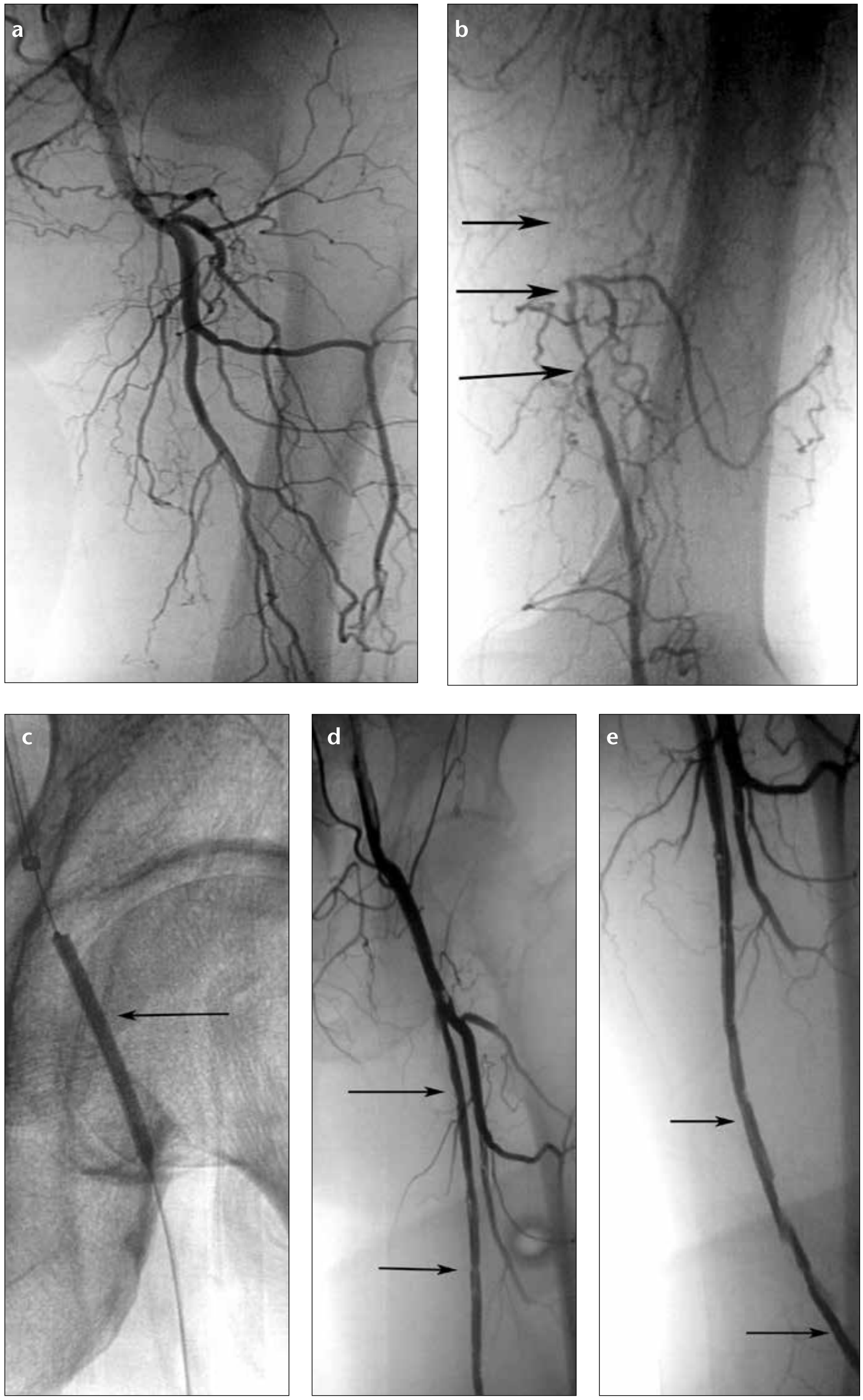

Figure 2. a–e. A 67-year-old man with severe claudication of the left foot. Femoral angiography images show completely occluded left superficial femoral artery (SFA) **(a)** and recanalized popliteal artery (*arrows*) **(b)**. Retrograde access into the posterior tibial artery, intraluminal passage of a 0.018-inch guidewire, and retrograde low-profile (3 mm) balloon predilation of SFA are seen (*arrow*) **(c)**. Successful retrograde recanalization and balloon angioplasty of the SFA are also seen (*arrows*) **(d, e)**.

Discussion

Despite advances in endovascular treatment of infrainguinal arteries, procedural failure rates ranging from 20% to 40% have been noted in at-

Table 1. Patient demographics, clinical condition, and treated lesions

Patient characteristics	Results
Number of patients	22
Gender, n (%)	
Male	19 (94)
Female	3 (6)
Age (years), mean±SD (range)	60±13 (35–78)
Medical comorbidities, n (%)	
Smoking	12 (55)
Chronic renal failure	5 (23)
Diabetes mellitus	14 (64)
Hypertension	8 (34)
Coronary artery disease	5 (23)
Hyperlipidemia	11 (50)
Clinical category of treated limb, n (%)	
Severe claudication (Rutherford 3)	8 (36)
Critical limb ischemia	
Rutherford class 4	7 (32)
Rutherford class 5	7 (32)
Number of treated lesions	43
Combined occlusions, n (%)	
Total number of combined occlusion	14
EIA+CFA+SFA occlusion	1 (4.5)
SFA+PA+TPT occlusion	1 (4.5)
SFA+PA+ATA occlusion	2 (9)
SFA+PA+PTA occlusion	1 (4.5)
SFA+PA occlusion	3 (14)
SFA+PTA occlusion	1 (4.5)
PA+PTA occlusion	2 (9)
PA+ATA occlusion	3 (14)
Isolated occlusions, n (%)	
Total number of isolated occlusion	8
SFA occlusion	2 (9)
PA occlusion	1 (4.5)

ATA, anterior tibial artery; CFA, common femoral artery; EIA, external iliac artery; PA, popliteal artery; SFA, superficial femoral artery; TPT, tibioperoneal truncus.

tempted recanalization of infrainguinal occlusions, either via crossover or ipsilateral antegrade femoral approaches (7–9). Endovascular therapy with retrograde tibial (anterior tibial or posterior tibial) artery access has an important role in increasing procedural success when antegrade re-entry into the target artery is unsuccessful. After crossing the occlusion from below, a modified technique was used in which a retrograde low-profile balloon predilatation via tibial access was used without a vascular sheath. We considered this technique as a method that could protect the tibial artery from potential trauma to the low-profile tibial artery from a high-profile vascular sheath insertion. At the beginning of infrainguinal revascularization, we preferred to use US-guided retrograde popliteal artery puncture for SFA revascularization when the antegrade approach had been technically unsuccessful. This method was quite safe and effective, but had some drawbacks. The method could not be used for tibial artery revascularization, as the patient would have been required to turn to a prone position, which would not have been comfortable. It takes time to turn a patient from the supine to prone position; this action could break sterility. Therefore, we used the US-guided retrograde tibial artery approach beginning at the ankle level.

Retrograde tibial artery recanalization of infrainguinal complex occlusions have been rarely reported in the literature; therefore, only a very small number of cases or individual reports without long follow-up are available (2, 10–14). Some small series and case series have reported a success rate of 100% for retrograde tibial artery recanalization (2, 12). Therefore, our 100% success of access to tibial artery is considered uneventful. However, recanalization success of the long occlusion was 91% (20/22), and the overall angiographic success rate was 82%. The lower rate of angiographic success was mostly due to tibial artery occlusions where we did not have a stent on hand or preferred not to use a stent for the crural arteries.

The retrograde recanalization technique was attempted during coronary interventions with a high success rate. It was assumed that the distal portion of an occluded vessel is less fibrotic or contains less calcified tissue and allows for easier passage of a guidewire into the occlusion (15, 16). The rationale behind the retrograde recanalization was that the guidewire could easily pass into the true lumen when advanced from the retrograde access artery. The ideal puncture site reported for the PTA access was 1 to 2 cm proximal to the level of the medial malleolus; the ideal puncture site for the dorsalis pedis artery access was 1 to 3 cm distal to the level of the malleoli. These locations easily allowed for the use of manual compression to establish hemostasis following the removal of the wire or the vascular sheath (17). Extreme care is required if there is only a single patent crural artery that provides the dominant inflow to the foot, so that the only outflow artery is not damaged. An occluded and/or severely diseased pedal artery, a high risk of dissection and/or perforation of the pedal

Table 2. Outcomes

	n (%)
Overall outcome	
Technical failure	4 (18)
Death	1 (4.5)
Lost to follow-up	2 (9)
Outcome of critical limb ischemia group	
Healed	9 (41)
Improved	1 (4.5)
Outcome of intermittent claudication group	
Healed	5 (23)
Tissue loss or amputation	0 (0)

artery, and a vessel suitable for bypassing distal graft are the main limitations of retrograde tibial access (18).

Some studies used subintimal recanalization rather than an intraluminal recanalization technique for both retrograde or antegrade approaches (5, 9, 19). With the subintimal recanalization technique, two wires may lie along two separate subintimal planes. Two balloons are introduced, one from above and one from below, followed by simultaneous balloon inflation over each wire with the goal of preventing the plane from separating the two subintimal spaces. Until now, it has never been shown that intentional subintimal recanalization of infrainguinal occlusions is more successful in terms of primary success, patency rate, or limb salvage. However, in some circumstances, such as severely calcified, long and chronic occlusions, the subintimal space might be the only way to pass an occlusion. Subintimal recanalization is our preferred technique for long-segment chronic SFA occlusions. We used subintimal recanalization in all SFA occlusions and preferred intraluminal recanalization for tibial artery occlusions in the current study. It is important to know that in the subintimal recanalization technique, re-entry into the true lumen after wire dissection may occur distal to the level of vessel lumen patency, which could damage collateral branches or vascular segments. These branches and segments are potential targets for bypass surgery.

In 15%–25% of patients, re-entry into the true lumen after subintimal wire dissection cannot be achieved (20). To overcome the challenge of re-entry into the true lumen, re-entry devices have been developed. Technical success and procedural complications of these devices have rarely been reported, and long-term patency remains unknown (21, 22). Furthermore, these re-entry devices are expensive; for example, the Pioneer catheter requires an intravascular US machine (4). Therefore, the cost and availability of an intravascular US machine are the determining factors in the choice of device. The learning curve for the use of re-entry devices is fairly reasonable.

Endovascular revascularization of chronic total occlusions of peripheral arteries has become the standard approach for shorter lesions and is increasingly applied to longer, more complex arterial occlusive lesions. As the complexity of the arterial occlusions increases, the demand for technical skills and devices needed to successfully cross and treat the occlusion also increases. The site and length of the occlusion, the degree of calcification, and the presence of the associated occlusive disease are important factors in deciding on whether to revascularize or bypass the occlusion. Bypass surgery for infrainguinal arterial occlusions is considered the gold standard of treatment and has produced favorable results, with five-year limb salvage rates greater than 80% (23, 24). There are several main disadvantages to surgical treatment. First, a suitable saphenous vein graft may not be present due to prior bypass grafting of coronary or femoral vessels. Second, an increasing number of patients are at a high surgical risk because of severe medical comorbidities. Finally, systemic or local complications may be higher than with endovascular therapy (24).

We preferred to use US guidance for all infrainguinal access, as opposed to other studies in which fluoroscopy guidance was commonly used. Fluoroscopy typically requires complex positioning of the X-ray tube and image intensifier but can be used to direct the puncture for a heavily calcified tibial artery. We considered US guidance for tibial artery access, as it is a technically easy and feasible method. US could be better than fluoroscopy or road map angiography in patients for whom immobilization cannot be provided. However, US-guided puncture of a small caliber artery may require additional expertise and has a steep learning curve. Using a small-profile, high-frequency US transducer would be better suited for this purpose.

In this study, we preferred a sheathless approach in all patients except one. One patient who did not have a vascular sheath developed tibial access site thrombosis. A technique that does not use a vascular sheath at the access site was adopted by Montero-Baker et al. (2) to minimize the profile of the device used in the tibial access. They experienced tibial access vessel occlusion with subsequent pedal bypass after unsuccessful retrograde tibial recanalization with a vascular sheath. However, placement of a sheath has the advantage of producing less vessel trauma in the case of repeated introduction of a balloon catheter for stepwise arterial dilations. In the current study, we performed a modified method used by Fusaro et al. (12). We used retrograde balloon predilation and introduced a guidewire from the antegrade access site. We then performed the final dilatations or stent placements from this access in most cases. The inflated balloon has a larger diameter than an unused balloon, potentially increasing the trauma to the tibial artery during retrieval and re-introduction into the artery (2, 15). We did not use the snare-kit to advance the guidewire into the proximal access, as these may take time and may make the procedure more complex. Yeh et al. (15) used a tibial access sheath without the retrograde balloon. They did not use a snare-kit to extract the retrograde guidewire. Instead, they maneuvered the guidewire into the tip of the guiding catheter at the antegrade access until the guidewire tip appeared outside of the proximal sheath as described by Spinosa et al. (9).

Complications using the retrograde tibial approach were not reported in the literature. In our series, we documented only one major and one minor complication. Access site complications can potentially be minimized by an approach that does not use a vascular sheath and therefore does not increase the puncture hole size and short transcrural instrumentation time (2). It is important to know that these complications reinforces the need for extreme caution in offering this technique to claudicants with a single pedal/tibial target that provides the dominant inflow to the foot.

The limitations of this study include its retrospective design, short-term patient follow-up, and the lack of baseline and follow-up of the ankle brachial indexs. However, we are particularly focused on the clinical improvement and the outcomes of access sites. The presence of follow-up arterial imaging of the accessed tibial vessels by color Doppler US is an advantage when compared to other studies. Furthermore, though patient population was also small, the current study was one of the largest studies of US-guided retrograde tibial recanalization.

In conclusion, the retrograde tibial approach can significantly decrease the procedural failure rate of endovascular treatment with little added morbidity in a patient population with CLI or intermittent claudication. This complimentary technique would result in longer survival and better quality of life for patients with CLI than amputees (25). Any technique that can correct the failed cases of antegrade recanalization would decrease the need for amputation. The retrograde tibial approach can correct the majority of antegrade access failures. New materials for the retrograde tibial approach to make the technique easier and to increase the success rate for complex infrainguinal occlusions are desirable.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Bradbury AW, Adam DJ, Bell J, et al. BASIL trial Participants. Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL) trial: an intention-to-treat analysis of amputation-free and overall survival in patients randomized to a bypass surgery-first or a balloon angioplasty-first revascularization strategy. J Vasc Surg 2010; 51:5–17. [CrossRef]
2. Montero-Baker M, Schmidt A, Braunlich S, et al. Retrograde approach for complex popliteal and tibioperoneal occlusions. J Endovasc Ther 2008; 15:594–604. [CrossRef]
3. Norgren L, Hiatt WR, Dormandy JA, et al. TASC II Working Group. Intersociety consensus for the management of peripheral arterial disease. Int Angiol 2007; 26:81–157.
4. Smith M, Pappy R, Hennebry TA. Re-entry devices in the treatment of peripheral chronic occlusions. Tex Heart Inst J 2011; 38:392–397.
5. Spinosa DJ, Harthun NL, Bissonette EA, et al. Subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) for subintimal recanalization to treat chronic critical limb ischemia. J Vasc Interv Radiol 2005; 16:37–44. [CrossRef]
6. Sacks D, McClenny TE, Cardella JF, Lewis CA. Society of Interventional Radiology clinical practice guidelines. J Vasc Interv Radiol 2003; 14:199–202. [CrossRef]
7. Adam DJ, Beard JD, Cleveland T, et al. BASIL trial participants. Bypass versus angioplasty in severe ischaemia of the leg (BASIL): multicentre, randomised controlled trial. Lancet 2005; 366:1925–1934. [CrossRef]
8. Söder HK, Manninen HI, Jaakkola P, et al. Prospective trial of infrapopliteal artery balloon angioplasty for critical limb ischemia: angiographic and clinical results. J Vasc Interv Radiol 2000; 11:1021–1031. [CrossRef]
9. Spinosa DJ, Leung DA, Harthun NL, et al. Simultaneous antegrade and retrograde access for subintimal recanalization of peripheral arterial occlusion. J Vasc Interv Radiol 2003; 14:1449–1454. [CrossRef]
10. Botti CF Jr, Ansel GM, Silver MJ, Barker BJ, South S. Percutaneous retrograde tibial access in limb salvage. J Endovasc Ther 2003; 10:614–618. [CrossRef]
11. Downer J, Uberoi R. Percutaneous retrograde tibial access in the endovascular treatment of acute limb ischaemia: a case report. Eur J Vasc Endovasc Surg 2007; 34:350–352. [CrossRef]
12. Fusaro M, Dalla Paola L, Biondi-Zoccai GG. Retrograde posterior tibial artery access for below-the-knee percutaneous revascularization by means of sheathless approach and double wire technique. Minerva Cardioangiol 2006; 54:773–777.
13. Hansen A, Krawzcynski H, Lacher F. Retrograde transpedale recanalisation of tibial artery occlusion. Vasa 2009; 38:249–253. [CrossRef]
14. Kawarada O, Yokoi Y, Sekii H, Higashiue S. Retrograde crossing through the pedal arch for totally occluded tibial artery. J Interv Cardiol 2008; 21:342–346. [CrossRef]
15. Yeh KH, Tsai YJ, Huang HL, Chou HH, Chang HJ, Ko YL. Dual vascular access for critical limb ischemia: immediate and follow-up results. Catheter Cardiovasc Interv 2011; 77:296–302. [CrossRef]
16. Saito S. Different strategies of retrograde approach in coronary angioplasty for chronic total occlusion. Catheter Cardiovasc Interv 2008; 71:8–19. [CrossRef]
17. Rogers RK, Dattilo PB, Garcia JA, Tsai T, Casserly IP. Retrograde approach to recanalization of complex tibial disease. Catheter Cardiovasc Interv 2011; 77:915–925. [CrossRef]
18. Fusaro M, Agostoni P, Biondi-Zoccai G. "Trans-collateral" angioplasty for a challenging chronic total occlusion of the tibial vessels: a novel approach to percutaneous revascularization in critical lower limb ischemia. Catheter Cardiovasc Interv 2008; 71:268–272. [CrossRef]
19. Gandini R, Pipitone V, Stefanini M, et al. The "Safari" technique to perform difficult subintimal infragenicular vessels. Cardiovasc Intervent Radiol 2007; 30:469–473. [CrossRef]
20. Met R, Van Lienden KP, Koelemay MJ, Bipat S, Legemate DA, Reekers JA. Subintimal angioplasty for peripheral arterial occlusive disease: a systematic review. Cardiovasc Intervent Radiol 2008; 31:687–697. [CrossRef]
21. Jacobs DL, Cox DE, Motaganahalli R. Crossing chronic total occlusions of the iliac and femoral-popliteal vessels and the use of true lumen reentry devices. Perspect Vasc Surg Endovasc Ther 2006;18:31–37. [CrossRef]
22. Hausegger KA, Georgieva B, Portugaller H, Tauss J, Stark G. The outback catheter: a new device for true lumen re-entry after dissection during recanalization of arterial occlusions. Cardiovasc Intervent Radiol 2004; 27:26–30. [CrossRef]
23. Faries PL, Logerfo FW, Arora S, et al. A comparative study of alternative conduits for lower extremity revascularization: all-autogenous conduit versus prosthetic grafts. J Vasc Surg 2000; 32:1080-1090. [CrossRef]
24. Black JH 3rd, LaMuraglia GM, Kwolek CJ, Brewster DC, Watkins MT, Cambria RP. Contemporary results of angioplasty-based infrainguinal percutaneous interventions. J Vasc Surg 2005; 42:932–939. [CrossRef]
25. Chetter IC, Spark JI, Scott DJ, Kent PJ, Berridge DC, Kester RC. Prospective analysis of quality of life in patients following infrainguinal reconstruction for chronic critical ischemia. Br J Surg 1998; 85:951–955. [CrossRef]