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INTERVENTIONAL RADIOLOGY
ORIGINAL ARTICLE

Combined percutaneous direct puncture of occluded artery – antegrade intervention for recanalization of below the knee arteries

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PURPOSE
We aimed to assess the technical success of the combined percutaneous direct puncture of occluded artery – antegrade intervention technique, as well as the clinical effectiveness of treatment, on the basis of changes in the Rutherford classification.

METHODS
Between June 2015 and July 2018, 441 patients underwent endovascular recanalization due to lower limb peripheral arterial disease at our center. Of these, 18 patients (4%; 15 males, 3 females; mean age, 63.2 years) had failed antegrade recanalization and percutaneous retrograde access because of long segment occlusion, arterial rupture or dissection. Combined percutaneous direct puncture of occluded artery and antegrade approach was applied to these patients. Clinical follow-up examinations were performed at 1 month, 3 months, 6 months, and annually thereafter.

RESULTS
The mean follow-up period was 22.8±10.9 months. The mean procedure time was 93.6±28.2 min. Technical success was achieved in 14 patients (78%). Complete restoration of arterial flow in the punctured vessel could not be achieved in 4 patients (22%). Minor complications occurred in 4 of 18 procedures (22%). Amputation-free survival and limb salvage rates (83.3% and 100%, respectively) were the same for 12 and 24 months.

CONCLUSION
Technical success in lower limb peripheral arterial disease may be improved with the use of a combined percutaneous direct puncture of occluded artery – antegrade intervention, particularly for patients in whom other techniques are not a viable option.

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Critical limb ischemia (CLI) is a serious condition described as a progressive atherosclerotic disease of the lower extremity arteries (1, 2). Uncontrolled CLI is usually related with high rates of limb loss and mortality (3). It has been reported that in the first year after diagnosis of CLI, 25% of patients will die and 30% will have a major amputation (1). Therefore, timely revascularization treatments play an essential role in restoration of the extremity arteries (4). Although surgery has been the traditional treatment option for limb salvage in CLI, angioplasty is now considered an effective treatment approach for the CLI due to the development of endovascular techniques and medical devices (5, 6). Lower extremity endovascular procedures are usually performed using contralateral retrograde or ipsilateral antegrade common femoral artery access (7). A brachial approach is rarely used for below-the-knee (BTK) interventions. However, the conventional antegrade approach fails in up to 20% of cases because of inability to pass the occlusion (8). In these cases, different techniques can be used to pass the occluded vessels. The antegrade pedal approach is another technique used when traditional antegrade recanalization has failed and other arteries are occluded (9). When antegrade recanalization is unsuccessful, retrograde access to BTK arteries is technically an effective alternative in many patients (7, 10, 11). The retrograde transmetatarsal approach can be used as an alternative when pedal and plantar arteries are not accessible for puncture due to chronic occlusion (12). In some patients, the procedure may fail due to spasm or no true lumen entry (12). Previous studies have stated that it

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is necessary to have patent arteries below the knee in order to apply these techniques. If patent arteries are available, it is usually easy to canulate using fluoroscopic or ultrasound guidance. However, even using these techniques, it may not be possible to pass through the occluded arteries in some cases. In this study, an alternative technique (combined percutaneous direct puncture of occluded artery – antegrade intervention) is described for the revascularization of totally occluded BTK arteries. This technique can be an effective alternative approach in many patients when other techniques cannot be applied.

Methods

Patient selection

Between June 2015 and July 2018, 441 patients underwent endovascular recanalization due to lower limb peripheral arterial disease at our center. Of these, 18 patients (4%; 15 males, 3 females; mean age, 63.2 years) had failed antegrade recanalization and percutaneous retrograde access because of long segment occlusion, arterial rupture or dissection. In these cases, the combined percutaneous direct puncture of occluded artery-antegrade intervention technique was used for recanalization of the occluded BTK arteries. This technique was applied to 8 patients (44%) with posterior tibial artery occlusion and 10 patients (56%) with anterior tibial artery occlusion. Patient data regarding demographics, indications, and comorbidities are shown in Table 1. This retrospective study was approved by the Institutional Review Board and written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Main points

- Timely revascularization treatments play an important role in the restoration of extremity arteries in patients with critical limb ischemia (CLI).
- With the development of new endovascular techniques and medical devices, angioplasty is considered an effective treatment approach for CLI.
- Combined percutaneous direct puncture of occluded artery – antegrade intervention is an alternative revascularization technique when other techniques are not a viable option.

Endovascular treatment

Prior to the angiography procedure, duplex ultrasonography (US) scanning was performed in all patients. The endovascular interventional procedures were performed in a dedicated angiographic room equipped with a C-Arm (Axiom Artis C-arm imaging system, Siemens) and a duplex US scanner (Acuson Antares, Siemens). The patients in this study were classified according to the Rutherford classifications (13) with history, clinic notes, physical examination, and laboratory tests. All patients were taking aspirin (100 mg/d) and clopidogrel (75 mg) before treatment. Local anesthesia was applied and access to the common femoral artery was obtained under US guidance (7.5 MHz linear probe), and a 5 F or 6 F sheath was introduced. Access to the femoral artery in 14 patients (78%) was on the ipsilateral antegrade puncture and in 4 patients (22%) with contralateral retrograde puncture. Following deployment of the sheath, 5000 units of unfractionated heparin was administered. Diagnostic angiography was performed before the endovascular treatment to document infrapopliteal occlusive disease. First, with the use of of multiple wiring techniques, it was attempted to obtain antegrade recanalization. A retrograde access via the direct puncture of the occluded artery was considered after failed attempts to antegrade access. When this approach was used, the application of subcutaneous tissue local anaesthesia was made in close proximity to the direct puncture site. The occluded artery was easily identified with the ultrasound probe around the ankle in either a longitudinal or transverse position to the vessel (Fig. 1). With the use of a micropuncture introducer set (Cook Medical), direct puncture was applied to the occluded artery with a retrograde approach under US guidance (7.5 MHz linear probe). Three dorsalis pedis arteries and one lateral plantar artery were filled more distally below the puncture site. No contrast filling in the other vessels under the puncture site was observed in 14 patients. After puncture of the occluded artery, the 0.014-inch or 0.018-inch guidewires (V control, Boston Scientific) were passed through the needle into the vessel under fluoroscopic guidance. After removal of the needle, access to the popliteal artery was achieved with a balloon or support catheter passed over the wire. Using multiple wiring techniques, access to the popliteal artery was obtained with the guidewire to the subintimal or true lumen, and balloon dilatation (2 mm or 2.5 mm) was applied to the proximal segment of the occluded artery. Then using an antegrade approach, the guidewire was inserted to the target vessel with the aid of a balloon or support catheter, and when the target artery was traversed, balloon dilatation was performed along the length of the occluded artery. The antegrade approach was used to complete the procedure (Figs. 2, 3). For 12 hours postprocedure, intravenous heparin was administered at 1000 U/h, aspirin was continued indefinitely and clopidogrel was continued for 6 months. Clinical follow-up and Doppler US for re-occlusion were performed routinely at 1 month, 3 months, 6 months, and 1 year after discharge.

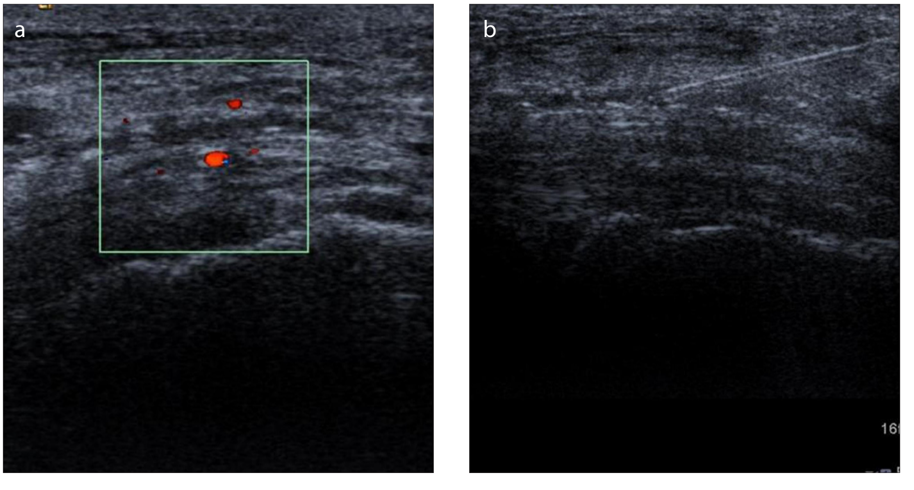

Figure 1. a, b. Totally occluded artery in color Doppler examination **(a)**, percutaneous puncture with needle into a totally occluded artery **(b)**.

Figure 2. a–h. Diagnostic arteriography shows peripheral arterial disease and occluded anterior **(a)** and posterior tibial arteries **(b)**. Diagnostic arteriography at the foot level **(c)** indicated that posterior tibial artery and lateral plantar artery were totaly occluded. The dorsalis pedis artery was filling via collateral arteries **(c)**. After unsuccessful intervention with the antegrade approach, the occluded posterior tibial artery was directly punctured with a micropunture set via the retrograde approach *(arrow)* **(d)**, providing access with a guidewire and support catheter into the popliteal artery **(e, f)**. The guidewire was inserted in the target vessel with the aid of a balloon or support cathteter via the antegrade approach **(g)**, Once the target artery was crossed from the antegrade approach, balloon dilatation was performed along the length of the occluded artery and the procedure was then completed from an antegrade approach **(h)**.

Study end-points

The primary purpose of this study was to evaluate the procedure in terms of technical success in obtaining the ability to puncture the occluded artery, pass the wire across the popliteal artery with a retrograde approach, pass the wire across the pedal arteries with an antegrade approach and obtain blood flow to the pedal arteries. The second aim of this study was to evaluate the clinical efficacy of the procedure, on the basis of changes in the Rutherford classification and limb salvage.

Statistical analysis

Statistical analysis was performed in IBM SPSS statistics version 23 (IBM Corp.). Descriptive statistics were presented using mean and standard deviation for normally distributed variables and median (and range) for non-nor-

Figure 3. a–f. Diagnostic arteriography images **(a, b)** show occluded anterior tibial artery. After unsuccessful intervention with the antegrade approach, the occluded anterior tibial artery was directly punctured with a micropunture set via the retrograde approach *(arrow)* (**c**), providing access with a guidewire and support catheter into the popliteal artery. Balloon dilatation was applied at the proximal segment of the anterior tibial artery (**d**). Anterior tibial artery was crossed from the antegrade approach, balloon dilatation was performed along the length of the occluded artery and the procedure was then completed from an antegrade approach (**e, f**).

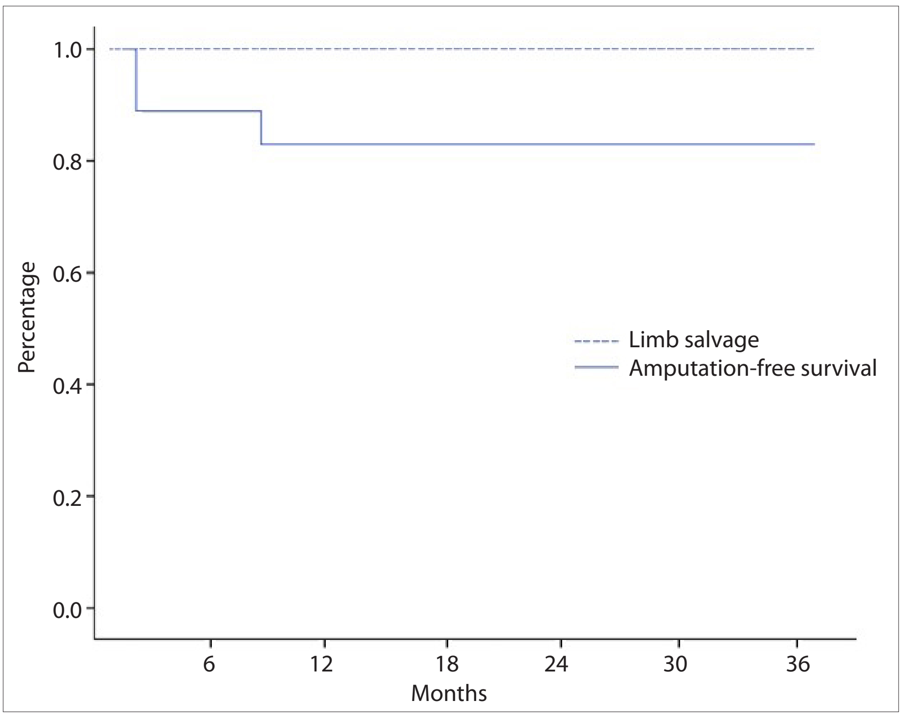

Figure 4. Limb salvage and amputation-free survival rates estimated by Kaplan-Meier analysis.

mally distributed variables. The Wilcoxon signed rank test was used for comparison of two non-normally distributed dependent groups. Statistical significance was accepted when the two-sided *P* value was less than 0.05. In addition, the time to limb salvage and amputation-free survival rates were studied by applying Kaplan-Meier analysis.

Results

Direct puncture of occluded BTK arteries was performed in 18 patients. Technical success was achieved in 14 patients (78%). Complete restoration of arterial flow in the punctured vessel could not be achieved in 4 patients (22%). In 2 of these cases, although the guidewire was passed to the popliteal artery with a retrograde approach, it could not be advanced distally from the entry site with an antegrade approach. Two other patients with patent peroneal artery did not respond to the angioplasty despite passing the anterior and posterior tibial artery. Conservative treatment such as exercise rehabilitation and antiplatelet therapy was applied in unsuccessful cases and no major amputation or death was observed in these patients. Minor complications occurred in 4 of 18 procedures (22%) and included hematomas not requiring treatment. No major complications were determined in any patient. In addition to the BTK artery procedures, 6 patients underwent superficial femoral artery (SFA) and popliteal artery intervention. Stent placement for SFA occlusion was applied in 2 patients, balloon angioplasty for SFA and popliteal artery occlusion in 1 patient, stent placement due to SFA occlusion and balloon angioplasty due to popliteal artery occlusion in 1, and balloon angioplasty for popliteal artery occlusion in 2 patients. The mean follow-up period was 22.8±10.9 months. Amputation-free survival and limb salvage rates (83.3% and 100%, respectively) were the same for 12 and 24 months (Fig. 4). Mean procedure time was 93.6±28.2 min. Hemostasis at the femoral access and pedal access was achieved with manual compression in all patients. Of 18 patients, 3 (17%) underwent an ipsilateral minor amputation after revascularization, because of previous gangrene in the fingers. At baseline, 8 patients (44%) had no patent BTK artery, 7 patients (39%) had one, and 3 patients (17%) had two patent BTK arteries. Postprocedure, 3 (17 %) had one, 6 had two (33%) and 9 (50%) had three patent BTK arteries. The details of the procedures are shown in Table 2. In 14 patients, all retrogradely accessed vessels were intact and showed no stenosis or occlusion at the point of access on completion

Table 1. Demographic characteristics of patients

	n/N (%)
Age (years), mean±SD	63.2±14.8
Sex (Male/Female)	15/3
Comorbidities	
Hypertension	12/18 (67)
Coronary artery disease	12/18 (67)
Diabetes mellitus	13/18 (72)
Preexisting renal insufficiency (creatinine level >2 g/dL)	3/18 (17)
Chronic renal insufficiency (requiring dialysis)	2/18 (11)
Hyperlipidemia	13/18 (72)
Smoking	
Prior	5/18 (28)
Current	8/18 (44)
Rutherford classification	
Category 3	7/18 (39)
Category 4	8/18 (44)
Category 5	3/18 (17)
Prevent III score	
Low risk	6/18 (33)
Medium risk	11/18 (61)
High risk	1/18 (6)
Lesion side	
Right	6 /18 (33)
Left	12/18 (67)
Number of non-occluded vessels (before procedure)	
0	8/18 (44)
1	7/18 (39)
2	3/18 (17)
Number of non-occluded vessels (after procedure)	
0	0/18 (0)
1	3/18 (17)
2	6/18 (33)
3	9/18 (50)

SD, standard deviation.

angiography. Recurrent occlusion was evidenced in 3 patients at 4, 13, and 27 months from the initial procedure and all were successfully treated with repeat angioplasty. One patient died due to cardiopulmonary disease 15 months after the procedure. The mean Rutherford score was 3.7±0.7 preprocedure, and 0.8±0.7 postprocedure. A statistically significant decrease was determined from the preprocedure Rutherford score to postprocedure score (Wilcoxon signed rank test, $P < 0.001$) (Table 3).

Discussion

Many different techniques can be used for endovascular recanalization procedures in CLI patients. The vasculature of the patient should be carefully examined when selecting the technique to be used (12–18). Procedural success depends on the ability to pass the occlusion or enter the true lumen after subintimal tracking (19, 20). Antegrade or retrograde techniques can be used to open the BTK arteries. The most preferred method of passing the occlusion is the ipsilateral antegrade approach but failure rates have been reported in 10%–40% (21–23). The pedal-plantar loop technique, transcollateral angioplasty, subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) technique and antegrade pedal approach are the other techniques for recanalization of occluded arteries (12–18). All of these techniques require a patent lumen of the artery for the puncture site. As the passage of the guidewire through the occluded artery is the most critical stage of the angioplasty procedure, antegrade approach is generally the first choice to pass the occluded segment. Limitations of the antegrade approach include proximal arterial disease (common-external iliac artery for the crossover approach and common-superficial femoral artery disease for the crossover – ipsilateral approach) and morbid obesity (24). In the antegrade approach, it can be very difficult to re-enter the patent artery lumen if the guidewire passes through the subintimal space due to the hard fibrotic cap (25). In this group of patients, it can be easier to cross the chronic total occlusion using the retrograde approach due to the convex distal cap (26). In cases where it is not possible to apply the antegrade approach, or it fails, the retrograde approach should be considered. The technical success of pedal access has been reported as 60%–100% in previous studies (7, 27, 28). Montero-Baker et al. (27) in 2008 reported procedural success rate of 86% with the use of retrograde access in 51 limbs. One major (a pedal access site occlusion) and 4 minor complications (arterial perforation in 3 cases and a pedal hematoma) were documented in that study. In 2012, Palena et al. (12) used the retrograde

Table 2. The details of the procedure

Patient	Occluded BTK vessels	Non-occluded vessels	Angioplastied arteries	Direct puncture vessels	Non-occluded vessels after procedure	Technically successful	Follow-up, months
1	AT, PT, PE	-	AT, PT	AT	AT, PT	Yes	34
2	AT, PT, PE	-	AT, PT, PE	PT	AT, PT, PE	Yes	34
3	AT, PT	PE	AT, PT	PT	AT, PT, PE	Yes	29
4	AT, PT	PE	AT, PT	AT	AT, PT, PE	Yes	39
5	AT, PT	PE	PT	PT	PT, PE	Yes	33
6	AT, PT	PE	AT, PT	PT	AT, PT, PE	Yes	29
7	AT, PT, PE	-	AT, PT	AT	AT	Yes	22
8	AT, PT, PE	-	AT, PT	PT	AT	No	11
9	AT, PT	PE	AT, PT	AT	PE	No	16
10	AT, PT	PE	AT, PT	PT	AT, PT, PE	Yes	17
11	AT, PE	PT	AT, PE	AT	AT, PT, PE	Yes	18
12	AT, PT, PE	-	AT, PT	PT	AT, PT	Yes	20
13	AT	PT, PE	AT	AT	AT, PT, PE	Yes	12
14	AT, PT, PE	-	AT, PT, PE	AT	PT, PE	No	14
15	AT, PT, PE	-	AT, PT, PE	AT	AT, PT, PE	Yes	8
16	AT	PT, PE	AT	AT	AT, PT, PE	Yes	32
17	AT, PT, PE	-	AT, PT	PT	AT, PT	Yes	39
18	AT	PT, PE	AT	AT	PT, PE	No	5

BTK, below the knee; AT, anterior tibial artery; PT, posterior tibial artery; PE, peroneal artery.

Table 3. Comparison between Rutherford clinical classification before procedure and during follow-up

	Mean±SD	Median (range)
Rutherford (preprocedure)	3.7±0.7	4 (3–5)
Rutherford (postprocedure)	0.8±0.7	1 (0–2)
*P**	<0.001	

SD, standard deviation.
*Wilcoxon signed rank test.

transmetatarsal or transplantar arch access with technical success achieved in 24 of 28 patients (86%). Amputation-free survival was 71% at 6 months and limb salvage rate was 100%. There were no complications in that study (12). In a 2014 study of 28 patients by Venkatachalam et al. (4), the success rate of the antegrade approach in passing the occlusion was 61%, while it was 93% with the antegrade-retrograde approach. In the same study, the rates of major amputation and wound healing were 9% and 100%, respectively, during a median follow-up of approximately 4 months (4). In another study conducted in 2014 by Ruzsa et al. (29), retrograde direct revascularization was achieved in 40 of 51 patients (78.4%), with limb salvage rate at 2 and 12 months of 93% and 82.3%, respectively. One major (tibial artery perforation) and three minor vascular complications (one tibial artery occlusion and two spasm) were encountered in the distal puncture site after the procedure. In 2016, El-Sayed et al. (7) reported that retrograde pedal access was successful in 95% of 21 patients and retrograde revascularization was achieved in 67%. In that study, 1-year limb salvage rate was 88%±8%, with amputation-free survival of 61%±12%. There were no complications related to the pedal access site. Also in 2016, Goltz et al. (30) reported that retrograde crossing the occlusion was successful in 12 of 16 patients (75.0%). The limb salvage rate was 72.9%, and the overall survival was 100% at 12 months. Minor complications occurred in 2 of 16 patients (12.5%). Major amputations after revascularization occurred in 2 of 16 patients (12.5%). In the current study, technical success was achieved in 14 of 18 (78%) patients. Although this rate may seem low compared to other studies, it should be taken into consideration that antegrade and conventional retrograde access could not be achieved in these patients.

CLI can cause major limb loss if left untreated. Although claudication is the typical symptomatic expression of CLI, asymptomatic disease may occur in 50% of these patients. The results of some studies have shown that patients with CLI have atypical leg symptoms (31, 32). Especially patients with infrapopliteal artery occlusion with diabetes may remain asymptomatic for years because they do not usually experience claudication or resting pain due to neuropathy. In these patients, tissue lesions or gangrene may occur even after a minor leg injury due to peripheral artery disease, and this may lead to limitations in the quality of life or amputation (33). Severe claudication and chronic CLI often refer to multilevel disease, and interventional procedures are generally considered for patients who experience severe, disabling and activity-limiting symptoms despite noninvasive treatment (34). Failure to respond to exercise and/or medication will lead to the next level of decision-making to consider the revascularization of the limb. Early diagnosis of patients at risk of CLI is very important to develop preventive intervention strategies to recognize possible risks and prevent complications (1). Treatment of proximal lesions is not sufficient to salvage a critical ischemic limb when the distal arteries are seriously affected. For clinical success, blood flow must be maintained in one or more tibial arteries. As the number of patent arteries correlate with a higher likehood of functional limb salvage, it is generally preferred to restore the patency of both tibial arteries (35). Decision on whether or not to apply revascularization to peripheral arterial disease patients is based on a number of factors, such as patient-specific characteristics, anatomic location, the severity of symptoms, the need for re-revascularization in the future, and patient and doctor preferences. There are many publications describing the adoption of tibioperoneal intervention for severe claudication (7, 36–39). In the current study, although the average Rutherford score was 3.7±0.7 before the procedure, it was decided to perform the recanalization procedure because there was significant disease in the BTK arteries.

When previous articles were reviewed, it was observed that the patent artery lumen was often used in the retrograde approach. However, in some patients, there may be no patent lumen for retrograde entry, or it may not be possible to enter the patent lumen if it is in a more distal localization. Even when the tibial artery lumen is totally occluded, it may be relatively easy to enter the lumen under US guidance as the vessel diameter is wider at the ankle level than distally. Direct puncture of the occluded artery may be a rescue strategy if the BTK arteries are occluded and other techniques are inadequate.

There are some technical aspects which should be emphasized. First, there should be a support wire used in the procedure, which will ideally pass the occlusion. Second, the combination of US and fluoroscopy will increase technical success, as multiple interventions may cause arterial puncture site complications. Third, multiple wiring techniques using a support catheter or balloon can be associated with a higher success rate in providing access to the target arteries. Finally, routine double antiplatelet therapy is used to help maintain vessel patency in such interventions.

A limitation of this study was its retrospective nature. It can be considered that use of this procedure as a primary intervention strategy will contribute to technical success. In addition, the use of drug elluting balloon or stent in elastic recoil or occlusive dissection may assist in revascularization and improve technical success in patients who have access but do not respond to angioplasty.

In conclusion, the results of this study demonstrated that percutaneous direct puncture of a totally occluded anterior or posterior tibial artery for endovascular revascularization can be a safe and effective procedure in high-risk patients. The puncture can be performed using US for noncalcified vessels and US-fluoroscopy guidance for calcified vessels. The findings of this retrospective study suggest that combined percutaneous direct puncture of occluded artery – antegrade intervention is an alternative revascularization technique that can achieve limb salvage in patients with CLI when other techniques are not a viable option.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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