Diagn Interv Radiol 2022; DOI: 10.5152/dir.2022.21844

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Ultrasound-guided retrograde tibial access through chronically occluded tibial arteries: a last resort recanalization technique

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PURPOSE
We aimed to demonstrate the feasibility of ultrasound (US)-guided retrograde tibial access through chronically occluded tibial arteries as a bailout endovascular recanalization procedure in patients with critical limb ischemia (CLI).

METHODS
Fifty-one CLI patients with failed conventional antegrade tibiopedal recanalization required retrograde tibiopedal access in the same session. In all of these patients, the target tibial artery was chronically occluded in at least the distal half of the cruris. Access attempts were made under real-time US by a single operator experienced in image-guided vascular access procedures. Fluoroscopy was used only as an adjunct during advancement of a 0.018 inch guidewire. If access to the artery was successful by the retrograde route, the occluded artery was usually predilated with a 2 mm balloon, and the standard endovascular treatment was mostly performed through the antegrade route.

RESULTS
Patients had athereosclerosis (n = 35) or Buerger's disease (n = 32) and presented with Rutherford category IV and category V. Successful placement of a guidewire in the occluded artery lumen was achieved in 81% of all patients, whereas, treatment success, i.e. angiographic demonstration of in-line flow at the end of procedure, was achieved in 49%. No significant procedure-related complications were observed. Of 33 limbs with initially successful endovascular treatment, 6 required minor and 1 required major amputation during follow-up.

CONCLUSION
US-guided retrograde access through completely occluded tibial arteries is difficult but feasible. Half of the tibial arteries that could not be recanalized otherwise were converted to successful recanalization by this method.

Advanced occlusive disease of tibiopedal arteries often presents with critical limb ischemia (CLI). Surgical treatment in patients with advenced occlusive disease is frequently impractical or is of a very high risk, making endovascular revascularization the sole plausible option for limb salvage.[1-3] Crossing through the occluded segments, a prerequisite for recanalization, is commonly destined for both technical and clinical failure during conventional antegrade treatment of occluded infrapopliteal arteries. When antegrade recanalization fails, retrograde ultrasound (US)-guided percutaneous access techniques provide one last opportunity for recanalization.[1,4-11] Retrograde tibial access increases the technical success of failed antegrade recanalization of femoropopliteal or tibial occlusions and therefore improves the clinical outcome of these patients. However, for a successful retrograde tibial puncture, the access artery should be patent. There are times where the target femoropopliteal or tibial artery occlusion could not be recanalized in an antegrade fashion and the tibial artery around the ankle is also occluded. Such patients are usually not amenable to bypass surgery or endovascular treatment. In such circumstances, we started to try to get access to the occluded tibial artery with the use of ultrasonography guidance and become successful in some of these patients. Feasibility and safety of retrograde percutaneous access of completely occluded tibiopedal arteries are yet unclear in

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Received 1 November 2021; revision requested 4 April 2022; last revision received 23 June 2023; accepted 7 August 2023.

Publication date: 1 December 2022.

DOI: 10.5152/dir.2022.21844

You may cite this article as: Aygun MS, Tureli D, Deniz S, Oguzkurt L. Ultrasound-guided retrograde tibial access through chronically occluded tibial arteries: a last resort recanalization technique. *Diagn Interv Radiol.* 2022;28(6):621-626.

the literature. This study aims to report the technical outcome of US-guided retrograde access through completely and chronically occluded tibial arteries.

Methods

Institutional review board approval was obtained for this retrospective evaluation of prospectively maintained clinical database (REC number: KA12/127). Patients receiving urgent endovascular treatment at the interventional radiology clinic within December 2015-December 2017 period were included after consenting to usage of relevant medical information either verbally by telephone calls or in written form during regular control visits. Case profile queried from database was as follows: all had CLI with Rutherford category IV and V. All patients had failed conventional antegrade recanalization attempts for femoropopliteal or tibial artery occlusion. There was no patent tibial artery to be used for retrograde recanalization. Therefore, any 1 of the 2 chronically occluded tibial artery was chosen for US-guided retrograde recanalization. Chronic occlusion of the tibial arteries was documented with angiography as well as color Doppler ultrasonography. CLI was due to atherosclerotic peripheral arterial disease (PAD) or Buerger's disease. Diagnosis of Buerger's disease was based on the criteria proposed by Shionoya.[12] Tibiopedal access was sought after failed antegrade passage attempts through occluded femoropopliteal or crural arteries. There were no cases with failed antegrade passage through iliac and femoral arteries; such occlusions were treated with the standard approach. Target arteries for retrograde access were specific wound-related angiosome arteries and chosen for revascularization of the main feeding vessel of the corresponding angiosome.[4,13,14]

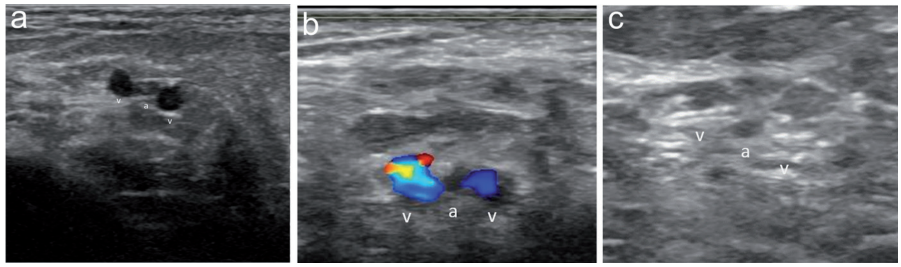

Figure 1. a-c. Linear high-frequency transducer placed transversely over the target artery to visualize and locate optimal access site **(a)**. Posterior tibial artery **(a)** lies at the center of the sonographic field of view between 2 posterior tibial veins (v). Arterial occlusion is demonstrated by color Doppler imaging **(b)**. Arterial flow is absent while there is venous flow. Veins are collapsed due to deliberate compression of the transducer while artery remains incompressible like a cord **(c)**.

Aseptic technique was observed with ankle or foot prepped and draped separately, patient lying supine on angiography table, and feet oriented according to the target artery: anterior tibial or dorsalis pedis artery access required foot neutrally positioned with minimal flexion; posterior tibial artery access, on the other hand, was sought with foot laterally rotated and knee slightly bent. All tibiopedal access attempts were made under real-time US visualization by the same operator who had formal training and more than 10 years of experience in image-guided vascular access procedures.

A linear 9-15 MHz transducer (Logiq S8, GE Healthcare) was placed transversely over the target artery to visualize and locate the optimal access site (Figure 1), and a small skin wheal was raised with 1 mL of prilocaine 1% (Citanest 10 mg/mL, AstraZeneca). Under real-time sonographic visualization, a 4 cm 21G echogenic puncture needle (Micropuncture Pedal Introducer Set, Cook Medical) was inserted through the anterior wall of the artery, avoiding the posterior wall or tibial veins on both sides of the artery; then, a 200 cm 0.018 inch guidewire (V-18 ControlWire, Boston Scientific) with a hydrophilic tip was advanced (Figure 2). The short platinum tip wire of the micropuncture set was not used. A bright red blood return from the needle was not expected since target arterial segments are already occluded; thus, confirmation of arterial access depends on direct sonographic visualization of the needle in the midportion of the occluded lumen and tactile feedback from the guidewire. US guidance with a high-frequency transducer not only helps avoiding heavily calcified plaques but also helps visualize whether the guidewire is inside the lumen or not. Fluoroscopy was used only as an adjunct during wire advancement through occluded distal segments into the proximal patent lumen. In case a 0.018 inch guidewire required extra support, the operator advanced a straight-tip 90 cm 2.6 F support catheter (CXI, Cook Medical). After negotiation of the guidewire through the occluded lumen into the most proximal patent lumen, the support catheter or a low-profile balloon catheter was advanced, and a contrast was injected to confirm that the catheter is in the patent lumen. Then, bareback predilatations with 2 to 3 mm balloons were performed enabling antegrade crossing of a guidewire through the occluded segments; employment of a snare or flossing was not required after predilatations. However, techniques such as rendezvous technique were used

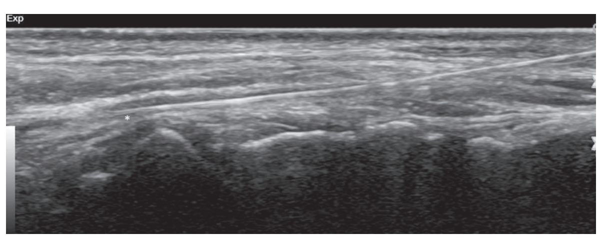

Figure 2. Under real-time ultrasound visualization, a short 21G echogenic puncture needle is inserted through the anterior wall of artery avoiding posterior wall or tibial veins. Longitudinal view of 0.018 inch guidewire with a hydrophilic tip (*) advanced through the needle tip within the occluded lumen. Confirmation of arterial access depends on direct sonographic visualization of the needle and tactile feedback from the guidewire within the occluded lumen.

Main points

- Endovascular therapy has become the first-line approach in the treatment of critical limb ischemia, partly because of its lower morbidity and mortality compared to open surgery.
- Retrograde tibial access through the patent tibial artery has been a well-defined technique that improves the technical success of unsuccessful antegrade recanalization of femoropopliteal or tibial occlusions.
- In occlusions less than a few months or a year, the lumen can be visible as a thin line on ultrasound, and its success is higher than in cases with chronic occlusion.

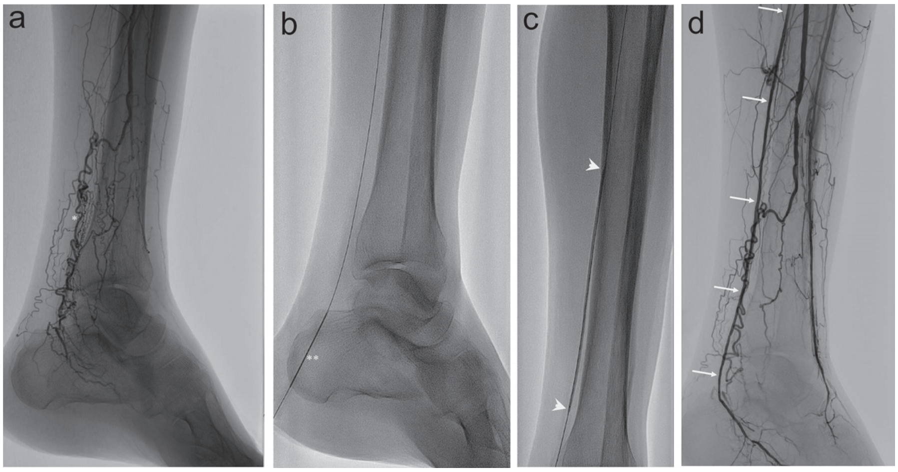

Figure 3. a-d. Initial angiogram showing completely occluded distal posterior tibial artery (**a**). Note the abundance of corkscrew-shaped collaterals, presumably vasa vasorum and vasa nervosa, around the occluded artery (*). There is no evidence of distal reconstitution of the posterior tibial artery. Fluoroscopic image as the 0.018 inch guidewire is advanced within the occluded artery lumen (**b**). There is no discernible wall calcification. The introducer needle is still in place (**). Access is in a totally occluded PTA without skip lesion. A slightly more anteroposterior (AP) view showing bareback balloon angioplasty of the occluded segment with an Over The Wire (OTW) 2.0 mm balloon (*between arrowheads*) (**c**). Same patient post-treatment—angiographic demonstration of in-line flow with patent arterial contrast column in the treated artery (*arrows*) (**d**).

to be able to unite 2 different subintimal place if necessary. Standard endovascular treatment was then commenced from an antegrade fashion, comprising routine angiographic runs, standard dose medications, angioplasty with regular balloons for infrapopliteal arteries, angioplasty with plain or drug-eluting balloons and bailout stenting for femoropopliteal arteries, and access site hemostasis. Based on the operator's preference, an introducer sheath was never placed in the tibiopedal access site. A 4F dilator, included in the pedal introducer set mentioned above, was placed only as a temporary means of hemostasis in the vascular access site after predilatation.

Assessment of outcomes was based on following definitions: technical success is to be able to get access to the most proximal patent lumen, and treatment success is defined as angiographic demonstration of in-line flow at the end of procedure with <50% residual stenosis with angiography, i.e., at least 1 patent arterial contrast column from the groin to the toes (Figures 3 and 4). Complications related to tibiopedal access and retrograde tibial interventions were reported in accordance with standard guidelines. All patients underwent routine control duplex examinations within the first month postintervention and then at 6-month intervals. Restenosis was defined as >50% reduction in the patent luminal diameter in target tibiopedal arteries with color Doppler ultrasonography on follow-up. Primary patency was defined as successfully treated segments without restenosis or occlusion, thus not requiring any re-intervention.[15,16] Temporal classification of outcomes was assigned as follows: "early" events were those occurring before the 30th day postprocedure and "late" events pertained to those taking place further from the end of the first to the end of the sixth months. Data were examined using a per-protocol analysis.

Results

Fifty-one patients, a total of 67 limbs, referred for CLI required US-guided transpedal access through completely occluded tibial artery for the management of complex PAD. Patients were predominantly male (n = 41) with a mean age of 53.4 years (range 29-81). Patients presented with Rutherford category IV and category V (14 and 37 patients, respectively). CLI was due to atherosclerotic PAD (n = 35) or Buerger's disease (n = 32). Risk factors present in atherosclerotic PAD cases were hypertension (85%), poorly controlled type 2 diabetes (65%), smoking (57%), renal disease (31%), and hyperlipidemia (14%).

Technical success was achieved in 81% (54 out of 67 target arteries) of the limbs. Once luminal entry is achieved, 45 target arteries required bareback balloon predilatations for advancement of a support catheter. Thirty-three target arteries were recanalized; treatment success was 49%. Arterial distribution of tibiopedal access and outcomes of endovascular treatment are presented in Table 1. No significant procedure-related complications were observed.

All patients were reevaluated within the first month postprocedure. Seven cases, 5 Buerger's disease and 2 atherosclerotic PAD, presented with early restenosis. All 7 underwent early repeat interventions with total recanalization success; none presented with restenosis within the next 6 months period. Five patients out of 33 were lost to follow-up after their first control visits. Among the remaining 28, 11 limbs presented with late restenosis; 4 were Buerger's disease and 7 were atherosclerotic PAD. Of those 11 target arteries, 5 could be recanalized successfully (Figure 5). The remaining 6, all Buerger's patients, had to undergo amputations. All documented amputations were minor, i.e., sparing the ankle and heel, with the exception of a single case which had to be revised to a below-the-knee-level amputation due to poor healing. Follow-up results of 33 successfully treated target arteries are summarized in Table 2.

Discussion

US-guided retrograde percutaneous access techniques provide one last treatment opportunity for occluded crural arteries when conventional antegrade recanalization attempts fail. Endovascular recanalization via US-guided retrograde access through occluded distal tibiopedal segments had not been assessed previously in the setting of CLI. With no significant procedure-related complications in this series, the technique offers promising results as a bailout alternative in the treatment of selected patient group. Technical and clinical success in this patient population is lower than patients who had retrograde tibiopedal access through patent arteries. However, retrograde tibial access through chronically occluded tibial arteries is often the last chance or option for successful recanalization in these patients to improve, because endovascular treatment had been failed otherwise and surgical bypass was also impossible.

Timing of chronic occlusion poses a great difficulty in some of these patients. In recent occlusions (several months or a few years), it is possible to discern the intimal layer and

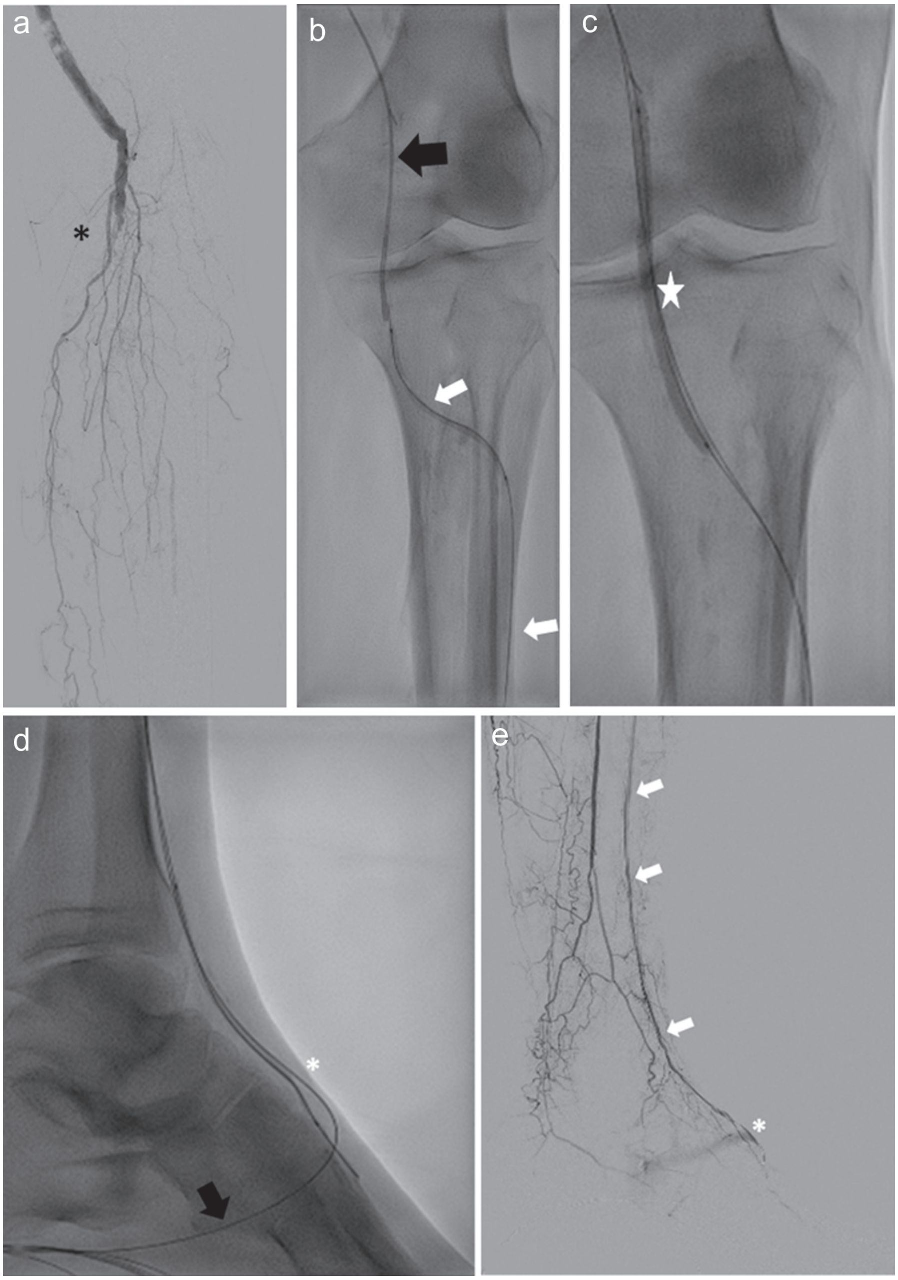

Figure 4. a-e. Diagnostic angiogram demonstrates occluded distal femoral artery and popliteal artery (**a**). All the crural arteries are also occluded without any skip lesion (*). Popliteal artery and peroneal artery were recanalized by antegrade femoral approach, but vascularization of the anterior or posterior tibial artery failed (**b, c**). Occluded anterior tibial artery was catheterized by retrograde approach; after negotiation of the guidewire (*white arrow*) through the occluded lumen, the predilatations with 2-3 mm balloons were performed (*star*). Proximal catheter is also visible (*black arrow*). Antegrade and retrograde guidewires are visible on the lateral view of ankle [antergrade guidewire (*black arrow*), entrance (*)] (**d**). Vascularization of the anterior tibial artery (*arrows*) is shown in the lateral view (* symbolizes contrast leakage from puncture) (**e**).

occluded lumen from the wall of the artery which increases technical success in these patients. Otherwise, the lumen was very tiny, so puncture and access to the lumen became very difficult. This was especially true for patients with Buerger's disease who had tibial artery occlusion probably years before.

Endovascular treatment options, partly due to lower morbidity and mortality, have become the first-line management approach to CLI in this specific subset of patients, with a concomitant decline in open surgical procedures. Patients with shorter life expectancy are more routinely offered endovascular treatment rather than bypass surgery.[17,18] For especially challenging cases, novel techniques have been devised with varying degrees of adoption and resistance. These include retrograde tibiopedal access, subintimal arterial flossing with antegrade–retrograde intervention (SAFARI), retrograde percutaneous trans-metatarsa l/plantar arch access, trans-collateral retrograde approach, and pedal–plantar loop via tibial arteries.[1,4,5,7,19-22] Despite introduction of better equipment and gradual buildup of experience, on the other hand, current comprehensive meta-analysis of studies published between 2005 and 2015 assessing long-term results of infrapopliteal posterior tibial artery (PTA) has not shown a significant improvement of outcomes over a previous meta-analysis of similar studies from 1990 to 2006. Primary patency was 63% in the recent meta-analysis versus 58% in the previous one; major amputation and all-cause mortality rates were not significantly different either (15% vs 14%, and 15% vs 13%, respectively). With comparable baseline characteristics and technical success rates of both meta-analyses, this lack of improvement in outcomes was probably due to treatment of increasingly comorbid patients with more complex lesions.[23,24] In this regard, immediate and intermediate outcomes in our series, i.e., 49% treatment success and 67% patency rate by the sixth month, are not unexpectedly low.

Technically, tibiopedal access through patent tibial artery is not very easy, but with increasing experience, it gets more and more simple. However, tibiopedal access into occluded tibial artery is technically much difficult compared to access into patent arterial lumina. In practice, tibiopedal access into patent arterial segments requires just as much, if not more, finesse and attention to detail in order to avoid complications. However, unlike the latter case, the target artery is already occluded; so, local vessel damage and failure of access do not jeopardize a single patent distal artery supplying the foot.[11] Thus, since our aim is basically to delay, if not altogether to avoid, limb loss or improve and fasten wound healing, seasoned endovascular interventionists may at least consider this as one last option before referring the patient for amputation. Once tibiopedal access is gained, retrograde tibiopedal access presents certain inherent advantages during revascularization procedure: Proximal cap of chronic total occlusions basically comprises collagen-rich fibrous tissue and is markedly softer distally; thus, it is easier to

Table 1. Arterial distribution of tibiopedal access and outcomes of endovascular treatment

Target artery	Posterior tibial	Anterior tibial	Dorsalis pedis	Total
Total number (n)	46	3	18	67
Technical success, n (%)	38 (83)	2 (67)	14 (78)	54 (81)
Wall calcification, n (%)	12 (26)	1 (33)	5 (28)	18 (27)
Bareback balloon predilatations, n (%)	33 (72)	0	12 (67)	45 (67)
Treatment success, n (%)	20 (43)	1 (33)	12 (67)	33 (49)
Major procedural complications (n)	0	0	0	0

All percentages are within group and rounded to the nearest integer.

push through via retrograde access. In addition, tibial arteries are of small caliber, and this augments the pushability of the guidewire through the more proximal occluded segments. Since collateral vessels arise with a caudal angle, there is also lower risk of entering, and damaging, these vessels with a retrograde approach.[1] An advantage of US-guided access is the significantly lower risk of direct operator hand exposure due to fluoroscopy being used only as an adjunct during wire advancement, and not being required for vessel entry. Radiation exposure can be significant if fluoroscopy is used for access instead because the need for a "working room" requires image receptor to be raised, increasing source-to-image distance, hence increasing scatter radiation.[11] Furthermore, in this series, wall calcification suitable for fluoroscopic guidance was present in a mere 27% of cases. If not for US-guided access, this leaves majority of cases with no other option than a standard cutdown which creates a surgical wound in the distal part of an already ischemic limb.[25] Compared to groin access, hemostasis at the tibiopedal puncture site is considerably easier to achieve; thus, tibiopedal access does not inherently lengthen the time to postprocedure ambulation and may even shorten the overall recovery time if utilized instead of femoral artery access.[26]

Frankly, when there is no distal runoff of a vessel, it does not sound logical that blood flow will be restored by balloon angioplasty. However, blood flow can really be restored after balloon dilatation even there is no distal runoff would be proved clinically. Since many of these patients have desert foot, this is the rationale for treating patients with Buerger's disease in particular. But this does not mean that they all respond well to balloon dilatation after you negotiated and dilated the occlusion successfully.

Some of our patients had desert foot, especially patients with Buerger's disease tend to have occlusion of all the foot arteries. Even in these patients, plantar arch blood flow restoration was achieved in some cases; however, trial and success rates of plantar arch angioplasty were not collected in the study, since plantar arch blood supply was not targeted as our primary goal. Even though according to our experience the cases with no runoff vessel or desert foot might be a bad prognostic factor to consider before attempting this technique, we do not find it appropriate to make a definite comment about this situation without more research on this issue.

Another limitation of this study is that all tibiopedal access procedures were performed by a single operator experienced in US-guided vascular access; so, reproducibility of outcomes, interoperator differences for general applicability, and learning curve of the technique remain to be addressed. The absence of Rutherford category VI patients in the series, which implies that our results may not be safely extrapolated to this patient subgroup, can be another limitation. Though the results of this single-center preliminary series are encouraging, 15% of successfully treated patients being lost to follow-up and the rather small number of cases may also be considered as a limitation. This approach will find more common use as a potential prospect in the treatment

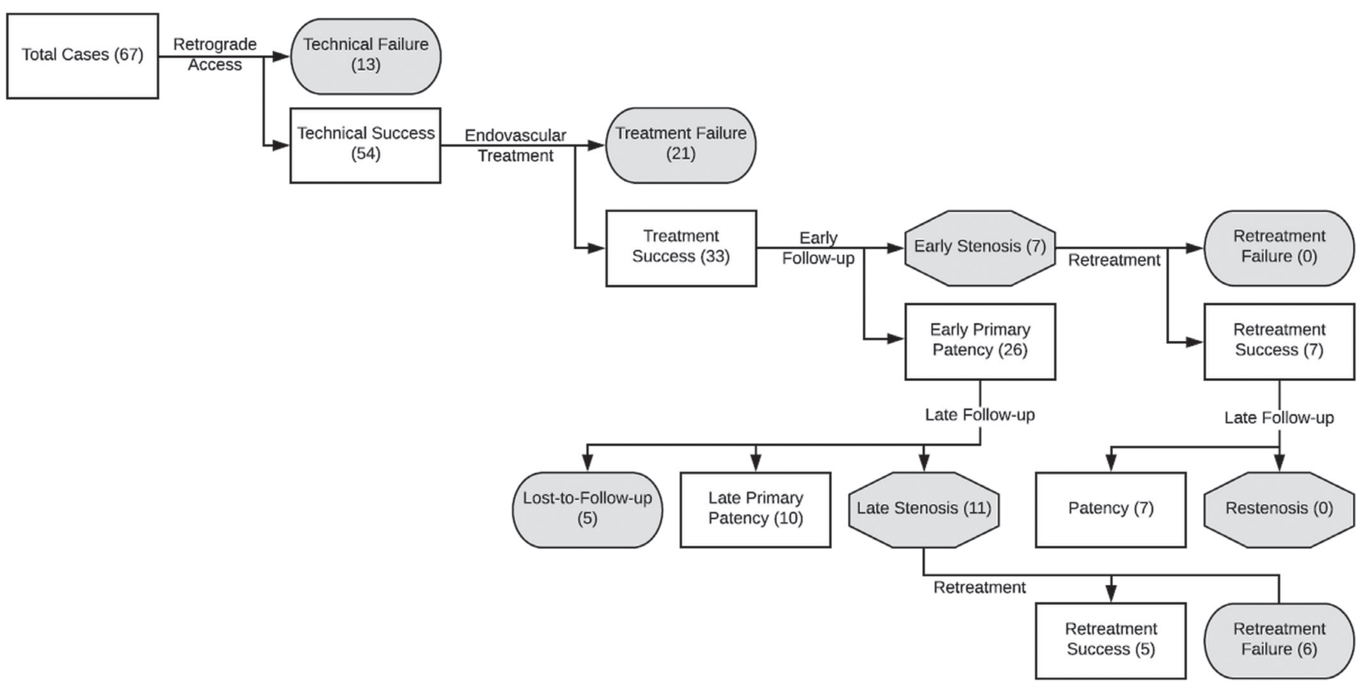

Figure 5. Summary of treatment outcomes in this series comprising 67 cases. Unfavorable events are denoted as *shaded boxes* with numbers of cases in parentheses.

Table 2. Patient follow-up results

Treated target artery	Posterior tibial	Anterior tibial	Dorsalis pedis	Total
Total successful treatment (n)	20	1	12	33
Early primary patency, n (%)	15 (75)	1 (100)	10 (83)	26 (79)
Early restenosis, n (%)	5 (25)	0	2 (17)	7 (21)
Early successful re-intervention, n (%)	5 (100)	0	2 (100)	7 (100)
Lost to follow-up within 6 months (n)	4	0	1	5
Late primary patency, n (%)	10 (50)	1 (100)	6 (50)	17 (52)
Late restenosis, n (%)	6 (30)	0	5 (42)	11 (33)
Late successful re-intervention, n (%)	2 (33)	0	3 (60)	5 (45)
Major amputation, n, (%)	1 (5)	0	0	1 (3)
Minor amputation, n (%)	3 (15)	0	3 (25)	6 (18)

All percentages are within group, including lower extremity ulceration (LFU) cases, and rounded to the nearest integer. The terms "early" and "late" denote occurrences within first 30 days and those within the following 5-month period postprocedure, respectively.

of CLI, with increasing experience and larger scale research establishing its reliability.

In conclusion, US-guided retrograde access through completely occluded tibiopedal segments is feasible as part of bailout endovascular recanalization procedures for CLI management. This practice has potential to improve angiographic and clinical outcomes, and with routine training and widespread utilization, this may decrease otherwise inevitably higher amputation rates in CLI.

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