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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Factors effecting the success of retrograde tibiopedal access and recanalization in infrapopliteal artery occlusions

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PURPOSE

Peripheral arterial disease (PAD) is increasingly prevalent, particularly among the aging population. Retrograde tibiopedal access (RTPA) has emerged as a useful endovascular treatment for PAD. However, there is limited research examining factors that influence the efficacy of RTPA. To investigate factors affecting the access, crossing, and recanalization success rates of RTPA for infrapopliteal PAD treatment.

METHODS

A retrospective study was conducted on 720 patients who underwent endovascular treatment for PAD. Of these, 104 patients (mean age: 65.5 ± 16.2; 89 men) with 131 RTPA trials were included in the final evaluation. The disease and its duration, Rutherford score, smoking status, access site, and its occlusion status, access, crossing, and recanalization success were noted. Data were analyzed using Pearson's chi-square and Mann–Whitney U tests and multivariate logistic regression to evaluate the impact of various factors on success rates.

RESULTS

The access success rate was 82.6%, the crossing success rate was 95.4%, and the recanalization success rate was 74%. Access success was significantly higher when the dorsal pedal artery (DPA) was the access artery compared with the posterior tibial artery (91.3% vs. 74.2%, $P = 0.009$). Access success was notably lower in patients with thromboangiitis obliterans compared with patients with diabetes mellitus (DM) and non-DM atherosclerosis (68.6% vs. 90.3% and 80.3%, $P = 0.019$). Recanalization success was higher when the puncture site was non-occluded (76.7% vs. 53.5%, $P = 0.023$).

CONCLUSION

The study suggests that RTPA is a generally effective and safe technique for infrapopliteal PAD treatment. The most favorable outcomes are observed in individuals with DM who have a non-occluded DPA at the puncture site. Recanalization success is only affected by the patency of the artery at the puncture site.

CLINICAL SIGNIFICANCE

These findings offer targeted guidance for clinicians and highlight areas requiring further investigation.

KEYWORDS

Angiography, atherosclerosis, diabetes, retrograde tibiopedal access, thromboangiitis obliterans

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Peripheral arterial disease (PAD) is a cardiovascular disorder distinguished by a stenosis or occlusion of peripheral arteries, typically impacting the lower extremities.[1,2] Recent studies highlight that PAD is a burgeoning concern in contemporary hospital admissions, particularly among the aging population.[3-5] It has been estimated that up to 20% of individuals aged 80 and above suffer from PAD, reflecting a substantial clinical and public health concern.[6]

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Among the therapeutic options for PAD, endovascular interventions have been steadily rising in prominence.[7,8] These minimally invasive procedures serve as an alternative to open surgical approaches, often offering advantages in terms of shorter hospital stays, reduced morbidity, and quicker recovery times. Endovascular treatments have become an initial treatment modality of choice for many clinicians dealing with patients with PAD, especially those at high surgical risk or those who have failed other treatment options.[9]

One of the more recent advances in the realm of endovascular interventions for PAD is the utilization of retrograde tibiopedal access (RTPA). This method has proven particularly useful in cases where antegrade access is not feasible or the occluded segment of the artery is not easily traversable through standard methods.[2,10] The technique can facilitate the crossing of long intraluminal complex lesions and may provide additional options for limb salvage in otherwise challenging scenarios. Despite the growing body of evidence supporting the benefits of RTPA, there is a notable paucity of research exploring the variables that influence its efficacy.[10-13] Most studies have primarily focused on technical success and safety profiles, with limited attention to how patient-specific factors and the anatomical characteristics of occlusions may affect the procedure's outcome. Furthermore, there is no clear data on the effect of the occluded access artery on recanalization success, while the success of RTPA in treating infrapopliteal arteries is not well established.

Therefore, the present study aims to address this gap by investigating various factors that may have an impact on the effectiveness of RTPA, such as patient demographics, underlying diseases, and the access artery and its condition. By contributing to this underexplored area of research, more targeted guidance for clinicians is offered, thereby potentially improving patient outcomes in the management of PAD.

Main points

- There is very limited data on the effect of the occluded access artery on recanalization success.
- Retrograde tibiopedal access (RTPA) success in treating infrapopliteal arteries is not well-established.
- The access success rate was 100% in 30 cases in which the access artery was patent.
- The target vessel at the puncture site was occluded in 101 (77.1%) RTPA trials. The access success rate was 82.6% (109/131), the crossing success rate was 95.4% (104/109), and the recanalization success rate was 74% (77/104).
- The most favorable outcomes were observed in individuals with diabetes mellitus who had a non-occluded dorsal pedal artery at the puncture site.

Methods

The present retrospective study was conducted in accordance with the ethical standards outlined by the World Medical Association in the Declaration of Helsinki. Approval for the study was obtained from the Ethics Committee of Koç University Ethical Board (reference number/date: 2023.131.IRB.043/12.04.2023). Prior to the procedure, written informed consent was obtained from all patients.

Of the 720 patients who had endovascular treatment for PAD in a tertiary referral center between November 2015 and February 2023, 129 patients with 158 RTPA trials were included in this retrospective study. A total of 26 patients were excluded from the study, with 13 patients undergoing RTPA for the treatment of acute thromboembolism on top of chronic atherosclerotic occlusions, and the remaining 13 patients undergoing RTPA specifically for occluded suprapopliteal arteries (Figure 1). A total of 131 access trials in 104 patients (89 men and 15 women; mean age: 65.5 ± 16.2) with infrapopliteal artery disease were evaluated using procedural images and reports. Patients' diagnoses, disease duration, Rutherford scores, and smoking status were collected from the hospital records.

Retrograde tibiopedal access technique

All endovascular treatment procedures were performed either with sedation or with ultrasound (US)-guided sciatic nerve blockage in addition to local anesthesia. The access sites, including the femoral and ipsilateral ankle, were prepared in a sterile fashion prior to the procedure in all patients. All patients in whom there was an attempt to use RTPA were first approached in an antegrade way via ipsilateral common femoral or superficial femoral artery access. If the infrapopliteal artery occlusion could not be crossed by way of an antegrade approach, RTPA was performed. The patients were placed in a supine position on the angiography table. To obtain access to the dorsal pedal artery (DPA), the foot was held in a neutral position with minimum flexion. On the other hand, access to the posterior tibial artery (PTA) was achieved by rotating the foot laterally and gently bending the knee. All RTPA's were conducted under US guidance by a single interventional radiologist with over 20 years of expertise in performing procedures that necessitate image-guided vascular access.

A transverse placement of a linear 9–15 MHz transducer (Logiq S8, GE HealthCare Technologies, Inc., Chicago, Illinois) was performed to visualize and identify the most suitable access site for the target artery (Figure 2). Subsequently, a small skin wheal was induced using 1 mL of 1% prilocaine (Citanest 10 mg/mL, AstraZeneca). In this procedure, a 4-cm 21G micropuncture needle (Micropuncture Introducer Set, Cook Medical) is carefully inserted into the artery's anterior wall, ensuring avoidance of the posterior wall, before a 200-cm-long, 0.018-inch

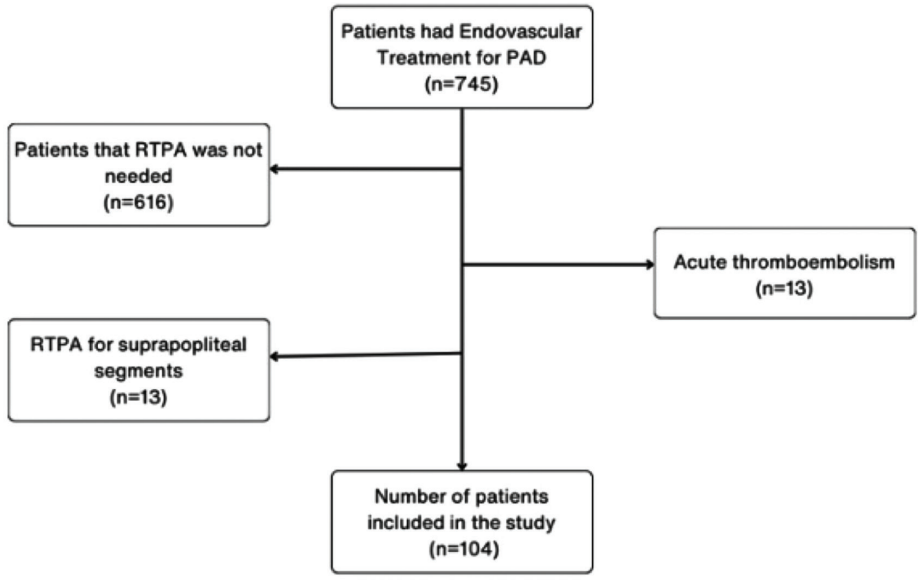

Figure 1. Flowchart of patient selection. PAD, peripheral arterial disease; RTPA, retrograde tibiopedal access.

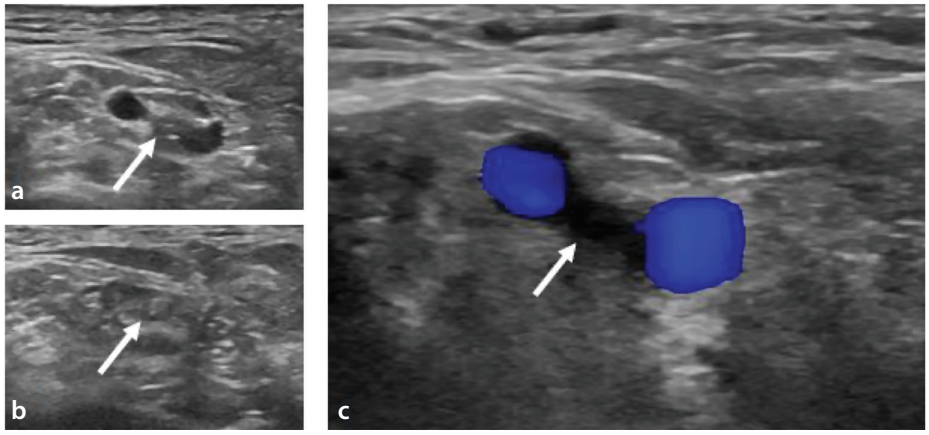

Figure 2. Ultrasound visualization of the occluded posterior tibial artery (PTA) with a linear high-frequency transducer placed transversely in a 46-year-old male patient with thromboangiitis obliterans. **(a)** The PTA (arrow) is seen at the center of the image between the posterior tibial veins. **(b)** The posterior tibial veins are compressed because of pressure applied with the transducer, whereas the PTA (arrow) cannot be compressed. **(c)** In color Doppler imaging, the venous flow can be observed, but there is no arterial flow, which reveals the presence of occlusion.

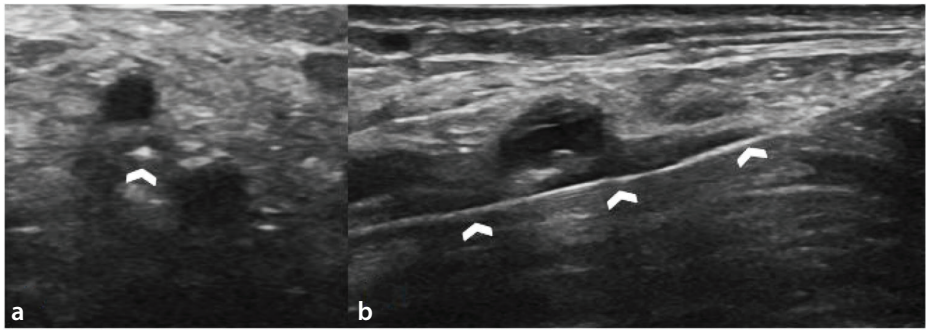

Figure 3. Retrograde tibiopedal access procedure. Using real-time ultrasound (US) imaging, a 21G needle is inserted, and the posterior wall or veins are carefully observed. Transvers **(a)** and longitudinal **(b)** US images indicate 0.018-inch guidewire (arrowheads) with a hydrophilic tip being inserted into the distally occluded posterior tibial artery. Using US to visualize the needle and the guidewire's tactile feedback, the arterial access is confirmed.

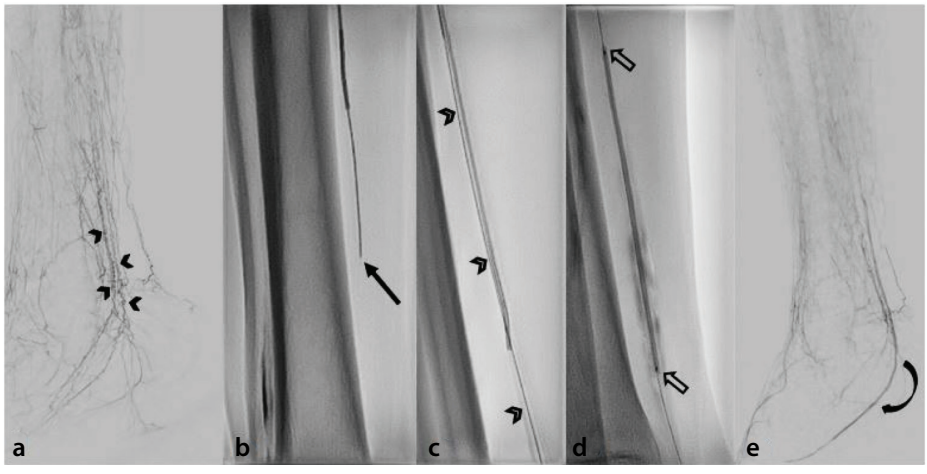

Figure 4. Initial angiogram of the patient and successful recanalization of infrapopliteal arteries. **(a)** The angiogram indicates corkscrew-shaped collaterals (arrowheads) compatible with thromboangiitis obliterans. (**b**) The occluded segment of the posterior tibial artery (PTA) is crossed with the anterograde approach (arrow) using a 014-inch guidewire. **(c)** When the anterograde crossing is unsuccessful, retrograde tibiopedal access (RTPA) is performed, and a 0.018-inch guidewire (arrowhead) is advanced within the occluded PTA lumen. **(d)** Balloon angioplasty is performed with an over-the-wire 2-mm balloon (between arrows). **(e)** The final angiogram demonstrates patent tibial artery flow (curved arrow) and successful recanalization with RTPA.

hydrophilic tip guidewire (V-18 ControlWire, Boston Scientific) is then advanced (Figure 3). Since the targeted arterial segments might be occluded, the verification of arterial access relies on other factors, including direct sonographic observation of the needle within the middle section of the occlusion, tactile feedback obtained from the guidewire, and fluoroscopic or sonographic visualization of the guidewire. A 90-cm support catheter with a straight tip and a diameter of 2.6 F (CXI, Cook Medical) was inserted in cases requiring additional support. Following the successful crossing of the guidewire through the obstruction, the support catheter, or a low-profile balloon catheter was advanced. To ensure accurate placement within the patent lumen, a contrast injection was administered. Subsequently, the procedure involves the utilization of bareback pre-dilatations utilizing balloons with a diameter ranging from 2 to 3 mm. This facilitates the advancement of a guidewire in an antegrade manner through the occluded segments. In most cases, the use of a snare or flossing was not needed following pre-dilatations. Nevertheless, methodologies such as Controlled Antegrade and Retrograde subintimal Tracking (CART) can be employed if deemed required. The subsequent course of treatment involved the continuation of standard endovascular procedures in an antegrade manner. This included the use of routine angiographic imaging, administration of standard medication dosages, angioplasty using balloons ranging from 1.5 to 3 mm for the infrapopliteal and required inframalleolar arteries, and angioplasty using either plain or drug-eluting balloons (Figure 4). The placement of an introducer sheath in the RTPA site was avoided, and a temporary hemostasis measure in the form of a 4F dilator in the 21G introducer set was placed at the RTPA site following pre-dilatation.

Technical success parameters

The evaluation of technical success parameters included the following criteria. The ability to achieve percutaneous access to a distal artery, and successful insertion of a support or a balloon catheter over a wire was considered as achieving access success. The ability to pass the wire to the proximal patent segment of the occlusion was regarded as crossing success. Finally, the successful restoration of flow in the occluded segment as confirmed by angiography was defined as recanalization success. The puncture site complications were assessed via US prior to discharge and on the 7th-day clinical follow-up.

Statistical analysis

Categorical variables were presented as counts and percentages. Successful and unsuccessful RTPA and recanalization attempts were compared in terms of patients' gender, diagnoses, and smoking status using Pearson's chi-square test. A Mann–Whitney U test was performed to compare continuous data, such as age, disease duration, and Rutherford's score, between successful and unsuccessful access and recanalization attempts. Multivariate logistic regression analyses were used to calculate the effects of confounders on RTPA and recanalization success. Two logistic regression statistical models were employed to analyze the access and recanalization success rates of RTPA. In Model A, the effects of all confounders were evaluated. Confounders that did not have a significant effect on the regression model were removed from Model B to obtain optimal results.

A confidence level of 95% was selected, and $P < 0.05$ was considered statistically significant. The data analysis was preformed using IBM SPSS Statistics 22 software.

Results

A total of 87% of the patients had chronic limb-threatening ischemia. The remaining had severe claudication. Fifty-seven (54.8%) patients had diabetes mellitus (DM), 26 (25%) had thromboangiitis obliterans (TAO), and 21 (20.2%) had non-DM atherosclerosis. Fifty-seven (54.8%) patients were active smokers. The DPA, or distal anterior tibial artery, was the access artery in 69 (52.3%) RTPA trials, whereas the PTA was the access artery in 62 (47.7%). The target vessel at the puncture site was occluded in 101 (77.1%) RTPA trials. The access success rate was 82.6% (109/131), the crossing success rate was 95.4% (104/109), and the recanalization success rate was 74% (77/104). Five crossing failures were due to extravasation of the wire in three cases and the inability to traverse the occlusion in two cases. The access success rate was 100% in 30 cases in which the access artery was patent.

A snare was used in four cases from the antegrade access to create an intraluminal through-and-through guidewire. The CART process was required in two cases and was performed successfully in one. Reverse CART was never used.

Patients' age, gender, smoking status, Rutherford scores, and disease duration were not found to be different between successful and failed RTPA trials. Access was significantly more successful when the access artery was DPA when compared with PTA (91.3%, 74.2%, $P = 0.009$, respectively). The access success rate was significantly lower in patients with TAO compared with those with DM and non-DM atherosclerosis (68.6%, 90.3%, and 80.3%, $P = 0.019$, respectively) (Table 1). On the other hand, the recanalization success rate was found to be associated with only the occlusion of the entry site. The recanalization success rate was higher when the puncture site was non-occluded (76.7%, 53.5%, $P = 0.023$) (Table 2).

In the study, two logistic regression statistical models were employed to analyze the access and recanalization success rates of RTPA. A 1.025-fold increase in access success was associated with each unit increase in age for Model A, as measured by an odds ratio (OR) of 1.025 and a 95% confidence interval (CI) ranging from 1.011 to 1.040. Furthermore, compared with PTA access, DPA access increased the successful access rate by 3.185 times, as indicated by an OR of 3.185 and a 95% CI of 1.120 to 9.057. Model B followed a comparable structure, wherein a 1.033-fold increase in access success was observed for every unit increase in age (OR: 1.033, 95% CI: 1.020–1.045). Moreover, DPA access increased access success rates by 2.773 times compared with PTA access in this model, with an OR of 2.773 and a 95% CI ranging from 1.028 to 7.482 (Table 3). The non-occluded access artery increased recanalization success rates by 2,760 times compared with cases with an occluded access artery, with an OR of 2.773 and a 95% CI ranging from 1.117 to 6.817.

Vasospasm at the puncture site was seen in 11 (10.5%) patients. A self-limiting hematoma was seen in two (1.9%) patients. A pseudoaneurysm, or arteriovenous fistula, was not seen in any patients.

Discussion

The findings of this study reveal insights into the outcomes of RTPA trials in patients with infrapopliteal artery involvement but different underlying conditions. Most prominent of all, the access success rate was highest among patients with DM who had a non-occluded DPA at the puncture site. However, the recanalization success rate was broadly influenced only by the occlusion status of the puncture site, regardless of other patient-specific factors or underlying conditions.

Table 1. Comparison of patient-related factors in successful and unsuccessful retrograde tibiopedal access attempts

	Successful RTPA	Unsuccessful RTPA	*P*
Sex			
Male	90	19	
Female	19	3	0.471[a]
Age*	68 (26–93)	64.5 (39–89)	0.344[b]
Current smoking status			
Smoker	58 (84.1)	11 (15.9)	
Non-smoker	51 (82.3)	11 (17.7)	0.783[c]
Access artery			
DPA	63 (91.3)	6 (8.7)	
PTA	46 (74.2)	16 (25.8)	0.009[c]
Access site			
Occluded	80 (79.2)	21 (20.8)	
Non-occluded	29 (96.7)	1 (3.3)	0.025[c]
Diagnosis			
DM	65 (90.3)	7 (9.7)	
TAO	24 (68.6)	11 (31.4)	
AS	20 (80.3)	4 (16.7)	0.019[c]
Disease duration*	15 (2–40)	20 (8–30)	0.391[b]
Rutherford score*	5 (3–6)	4 (3–6)	0.508[b]

*, Median (min-max); [a], Fisher's exact test; [b], Mann–Whitney U test; [c], Pearson's chi-square test. RTPA, retrograde tibiopedal access; DPA, dorsal pedal artery; PTA, posterior tibial artery; DM, diabetes mellitus; TAO, thromboangiitis obliterans; AS, non-diabetic atherosclerosis.

The study found that a high percentage of patients (87%) had chronic limb-threatening ischemia, suggesting that this intervention is often considered for severe cases and as limb salvage. Over half of the patients had DM, aligning with the high prevalence of vascular complications in this patient group. Notably, a significant number of patients (54.8%) were active smokers, further accentuating the comorbid factors often seen in patients with vascular disease. This observation aligns with prior research that has demonstrated a notable prevalence of smoking among individuals with PAD.[12,14]

This study shows an overall access success rate of 82.6%, a crossing success rate of 95.4%, and a recanalization success rate of 74%, indicating that RTPA is generally a reliable technique. The study by Montero-Baker et al.[12] examined the application of RTPA in the treatment of 51 infrapopliteal segment occlusions. The authors reported that the overall success rate of this approach was 86.3%, which is slightly higher than the success rate observed in the present study. However, in Montero-Baker's study, the puncture artery was patent in RTPA, and the guidance was performed using a C-arm, not US.

Access success varied significantly among different underlying conditions. To the best of our knowledge, this study is the first to examine the predictive value of the diagnosis of DM or TAO, access sites, including DPA and PTA, and access artery occlusion status in relation to the technical success achieved in the occlusion of an infrapopliteal artery through RTPA. Notably, patients with TAO had a significantly lower success rate in comparison with those with DM and non-DM atherosclerosis. This could indicate that the etiological factors underlying TAO may present unique challenges to successful vascular access, warranting further investigation.

Interestingly, the DPA was a more successful access route compared with the PTA, with success rates of 91.3% and 74.2%, respectively. In a previous study conducted by Grözinger et al.[11], which examined the parameters influencing the recanalization success of the superficial femoral artery and infrapopliteal artery using RTPA, the impact of the access artery on technical success did not yield any statistically significant results. Furthermore, the study by Grözinger et al.[11] categorized the access artery into two categories: infrapopliteal arteries and superficial femoral-popliteal arteries. In the present study, the access artery was evaluated in terms of two categories, DPA and PTA, which are both located below the knee (around the ankle), and this provides a more precise anatomical delineation. The study's results imply that clinicians should carefully evaluate the selection of the access artery as a crucial element in the planning of these operations.

The recanalization success rate was shown to be influenced by the occlusion status of the entry site, notwithstanding the high success rate seen in terms of access. The results indicated that recanalization was more effective in cases where the puncture site was patent, hence supporting the significance of maintaining vascular patency at the puncture site and the selection of the access artery to achieve good outcomes.

Table 2. Comparison of patient-related factors in successful and unsuccessful recanalization attempts

	Successful recanalization	Unsuccessful recanalization	*P*
Sex			
Male	90	19	
Female	19	3	0.471[a]
Age*	68 (30–93)	65.5 (26–91)	0.420[b]
Current smoking status			
Smoker	41 (59.4)	28 (40.6)	
Non-smoker	36 (58.1)	26 (41.9)	0.875[a]
Access artery			
DPA	45 (65.2)	24 (34.8)	
PTA	32 (51.6)	30 (48.4)	0.114[a]
Access site			
Occluded	54 (53.5)	47 (46.5)	
Non-occluded	23 (76.7)	7 (23.3)	0.023[a]
Diagnosis			
DM	43 (59.7)	29 (40.3)	
TAO	16 (45.7)	19 (54.3)	
AS	18 (75)	6 (25)	0.078[a]
Disease duration*	15 (2–40)	19 (3–30)	0.804[b]
Rutherford score*	5 (3–6)	5 (3–6)	0.860[b]

*, Median (min-max); [a], Fisher's exact test; [b], Mann–Whitney U test; [c], DPA, dorsal pedal artery; PTA, posterior tibial artery; DM, diabetes mellitus; TAO, thromboangiitis obliterans; AS, non-diabetic atherosclerosis.

Table 3. Logistic regression analysis of factors affecting success of retrograde tibiopedal access attempts

	Model A				Model B			
	OR	%95 CI Lower	%95 CI Upper	*P*	OR	%95 CI Lower	%95 CI Upper	*P*
Age	1.025	1.011	1.040	0.001	1.033	1.020	1.045	0.000
Access artery (DPA)	3.185	1.120	9.057	0.030	2.773	1.028	7.482	0.044
Access site (non-occluded)	2.962	0.620	14.149	0.174	3.401	0.762	15.185	0.109
Sex (male)	2.898	0.718	11.696	0.135				
Diagnosis (ref: TAO)				0.462				
Diagnosis (DM)	2.292	0.617	8.516	0.216				
Diagnosis (AS)	1.386	0.371	5.185	0.628				

DPA, dorsal pedal artery; TAO, thromboangiitis obliterans; DM, diabetes mellitus; AS, non-diabetic atherosclerosis; OR, odds ratio; CI, confidence interval.

The research findings indicated that there were no statistically significant variations in outcomes when considering factors such as patients' age, gender, smoking status, Rutherford score, and disease duration. The study conducted by Okuno et al.[1] examined the potential impact of gender, age, and current smoking status on the risk of restenosis following endovascular therapy. The results indicated that none of these factors demonstrated a statistically significant association with the risk of restenosis. Another study conducted by Grözinger et al.[11] did not yield any statistically significant evidence, indicating that the Rutherford score has an impact on the technical success of endovascular treatments with RTPA. Similarly, the present study suggested that these factors lack statistical significance in relation to technical success. This observation suggests that the efficacy of the technique may not be greatly impacted by these variables.

The present investigation documented a rather modest incidence of complications, with vasospasm observed in 10.5% of the patient cohort and a self-resolving hematoma in 1.9% of cases. No major complications were noted related to RTPA. In the multicenter prospective study performed by Walker et al.[13] involving 197 patients, in which the researchers included all occlusions in the infra-inguinal region, no major complications related to RTPA were observed; the overall rate of minor complications remained below 6% and consisted of local pain, infection, ecchymosis, bleeding, and acute vessel dissection. In another study conducted by Goltz et al.[10], significant complications were not detected. However, minor complications consisting of hematoma and vasospasm were observed in 12.5% of the patients, aligning closely with the findings of the present study. Significantly, the absence of more serious complications such as pseudoaneurysms and arteriovenous fistulas suggests that RTPA is generally safe when performed with proficiency and accuracy.

The present study is subject to certain limitations, including the limited number of participants, the retrospective methodology, and the single institution setting. Furthermore, the restricted sample size may potentially limit the generalizability of its findings to wider groups. Further research is warranted to validate these findings and to explore the enduring effects of RTPA, including the inclusion of a broader range of patients. Since the technical aspects and determinants of successful RTPA were the main objective of this study, patency periods and long-term patency rates were not included in the results. However, the success of a method cannot be measured by its technical success alone. Due to the study group's heterogeneity, any assessments of the clinical severity of PAD, such as the WIfi Classification,[15] were excluded from the analysis. However, the primary goal of the study was to compare the success of RTPA in various diseases and clinical circumstances to guide clinicians toward the best decision when contemplating RTPA.

One further limitation of the study pertains to the fact that the retrograde access, crossing, and recanalization procedures were conducted exclusively by a proficient interventional radiologist with expertise in this domain. Achieving access, crossing, or recanalization success and the results of the present study can vary among procedures conducted by various professionals.

In conclusion, this study elucidates the determinants impacting the efficacy of RTPA, emphasizing that the most favorable outcomes were observed in individuals with DM who had a non-occluded DPA at the puncture site. The success rates often exhibit a high level of efficacy; however, it is important to consider that several factors, including the selection of the access artery and the underlying medical condition, might exert an influence on the resulting outcomes. The findings provide valuable insights for clinicians in customizing their strategy based on the unique qualities and situation of each patient. Additional research is needed to further elucidate these observations and formulate more precise clinical recommendations.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Okuno S, Iida O, Shiraki T, et al. Impact of calcification on clinical outcomes after endovascular therapy for superficial femoral artery disease: assessment using the peripheral artery calcification scoring system. *J Endovasc Ther*. 2016;23(5):731-737. [CrossRef]
2. Htun WW, Kyaw H, Aung YL, Maw M, Kwan T. Primary retrograde tibio-pedal approach for endovascular intervention of femoropopliteal disease with chronic total occlusion. *Cardiovasc Revasc Med*. 2020;21(2):171-175. [CrossRef]
3. Malyar NM, Freisinger E, Meyborg M, et al. Low rates of revascularization and high in-hospital mortality in patients with ischemic lower limb amputation: morbidity and mortality of ischemic amputation. *Angiology*. 2016;67(9):860-869. [CrossRef]
4. Schmidt A, Bakker OJ, Bausback Y, Scheinert D. The tibiopedal retrograde vascular access for challenging popliteal and below-the-knee chronic total occlusions: literature review and description of the technique. *J Cardiovasc Surg (Torino)*. 2017;58(3):371-382. [CrossRef]
5. Kersting J, Kersting J, Kamper L, Das M, Haage P. Guideline-oriented therapy of lower extremity peripheral artery disease (PAD) - current data and perspectives. *Rofo*. 2019;191(4):311-322. English, German. [CrossRef]
6. Ali NMOS, Alsaffar MHAAA. Transpedal and tibiopedal retrograde revascularization for peripheral vascular disease. *Cureus*. 2022;14(2):e22082. [CrossRef]
7. Ortiz D, Jahangir A, Singh M, Allaqaband S, Bajwa TK, Mewissen MW. Access site complications after peripheral vascular interventions: incidence, predictors, and outcomes. *Circ Cardiovasc Interv*. 2014;7(6):821-828. [CrossRef]
8. Mustapha JA, Saab F, McGoff T, et al. Tibiopedal arterial minimally invasive retrograde revascularization in patients with advanced peripheral vascular disease: the TAMI technique, original case series. *Catheter Cardiovasc Interv*. 2014;83(6):987-994. [CrossRef]
9. Agarwal S, Sud K, Shishehbor MH. Nationwide trends of hospital admission and outcomes among critical limb ischemia patients: from 2003-2011. *J Am Coll Cardiol*. 2016;67(16):1901-1913. [CrossRef]
10. Goltz JP, Planert M, Horn M, et al. Retrograde transpedal access for revascularization of below-the-knee arteries in patients with critical limb ischemia after an unsuccessful antegrade transfemoral approach. *Rofo*. 2016;188(10):940-948. English. [CrossRef]
11. Grözinger G, Hallecker J, Grosse U, et al. Tibiopedal and distal femoral retrograde vascular access for challenging chronic total occlusions: predictors for technical success, and complication rates in a large single-center cohort. *EurRadiol*. 2021;31(1):535-542. [CrossRef]
12. Montero-Baker M, Schmidt A, Bräunlich S, et al. Retrograde approach for complex popliteal and tibioperoneal occlusions. *J Endovasc Ther*. 2008;15(5):594-604. [CrossRef]
13. Walker CM, Mustapha J, Zeller T, et al. Tibiopedal access for crossing of infrainguinal artery occlusions: a prospective multicenter observational study. *J Endovasc Ther*. 2016;23(6):839-846. [CrossRef]

14. 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. [CrossRef]

15. de Athayde Soares R, Matielo MF, Brochado Neto FC, et al. WIfI classification versus angiosome concept: a change in the infrapopliteal angioplasties paradigm. *Ann Vasc Surg*. 2021;71:338-345. [CrossRef]