Bi-directional Approach for Multilevel Chronic Total Occlusions in Peripheral Artery Disease: An Effective Treatment Strategy

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Abstract

An 82-year-old man with multiple comorbidities, including hemodialysis and dyslipidemia presented with gangrene and infection in the first and second digit of the left foot. Due to critical limb ischemia (CLI), percutaneous transluminal angioplasty (PTA) was planned after the patient declined surgical intervention. Initial angiography revealed severe calcifications and tortuosity in the iliac arteries, along with chronic total occlusion (CTO) in the left common femoral artery (CFA), superficial femoral artery (SFA), and popliteal artery. The contralateral approach was not feasible for the three CTO lesions, prompting the use of an ipsilateral bi-directional approach with distal puncture technique. We used three different approaches to address the three CTOs in sequence. Sheath site bleeding occurred during the procedure, which was ultimately resolved by the deployment of a Viabahn® covered stent. Balloon angioplasty resulted in significant lumen gain, and the final angiogram revealed good flow in the left femoropopliteal artery. Despite financial constraints precluding rotational atherectomy and drug-coated balloon angioplasty, the patient's gangrene did not progress and amputation remained unnecessary at the six-month follow-up. This case highlights the usefulness of combining bi-directional strategies in PTA for peripheral artery disease (PAD) with multilevel CTO to enhance technical success rates.

Keywords: peripheral arterial disease, chronic total occlusion, bi-directional approach, knuckle wire technique

INTRODUCTION

Peripheral artery disease (PAD) is an undertreated and debilitating condition associated with high morbidity and mortality rates. If PAD is not diagnosed early, the disease can advance to critical limb ischemia (CLI), the most severe form of PAD, resulting in amputation in 20-45% of patients and a 20-25% mortality rate within one year of diagnosis.[1-3] The cumulative amputation and mortality rates for diabetic CLI patients in a 10-year nationwide population-based follow-up study in Taiwan were 5.75% and 18.62%, respectively.[4] Another prospective multicenter

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study with median follow-up period of 3.3 years found the event rate for amputation or PAD-related death among hemodialysis patients with newly diagnosed CLI is approximately 38.5% (25 out of 65 CLI patients).[5] The most significant challenge in endovascular revascularization is chronic total occlusion (CTO), which constitutes 40% of lesions in patients with peripheral artery disease (PAD).[6] The failure rate of CTO crossing can be 20% or higher, depending on the operator's experience,[7] whereby previous studies have demonstrated comparable outcomes in bypass surgery and endovascular approaches in patients with CLI,[1,8] enabling interventionists to more proactively select suitable patients for endovascular revascularization. Therefore, as a vascular interventionist, it is crucial to utilize advanced techniques to improve crossing success rates. The traditional endovascular approach is the contralateral crossover approach, which is limited by poor pushability, torqueability, and maneuverability. Hence, an increasing number of interventionists are adopting the retrograde approach utilizing distal puncture, or a trans-collateral strategy. Meanwhile, a combined antegrade and retrograde (bi-directional) approach has gained popularity and enhanced success rates. A crossing algorithm has been proposed for the endovascular treatment of peripheral chronic total occlusion lesions (CTOs).[9] As a result, interventionists must familiarize themselves with several techniques, including retrograde wire escalation strategies, controlled antegrade and retrograde subintimal tracking (CART) technique, reverse CART technique, knuckle wire technique, snare technique and rendezvous technique for externalization, etc. Here, we present a case of an elderly patient with complex comorbidities and critical limb ischemia in the first and second digit of the left foot, who underwent endovascular revascularization using four vascular access routes: retrograde superficial femoral artery (SFA), antegrade SFA, retrograde distal puncture at PTA, and antegrade common femoral artery (CFA). This bidirectional approach aimed to shorten the distances between the target lesions and the vascular access points, enhancing pushability, torqueability and maneuverability.

CASE REPORT

An 82-year-old man presented with pain, redness and progressive gangrenous change in the first and second digit of the left foot over several weeks. He had complex medical history, including coronary artery disease post coronary intervention, moderate aortic stenosis, end-stage renal disease, dyslipidemia, complete AV block post pacemaker implantation and old stroke. He was started on empiric antibiotics for the foot infection. A plastic surgeon and a cardiovascular surgeon were consulted to evaluate possible amputation or surgical revascularization. The patient declined surgical intervention. Under the indication of critical limb threatening ischemia, percutaneous transluminal angioplasty was planned for revascularization.

We built up 6 Fr vascular access at the right CFA for diagnosis, and the angiography showed calcified and tortuous right external iliac artery (EIA), left common iliac artery (CIA) and EIA, indicating difficulty in the cross-over approach (Figure 1). There were chronic total occlusions with heavy calcification at the left CFA, distal SFA and popliteal artery (Figure 2). The lesions below the knee (BTK) showed 80% stenosis at the middle part of the posterior tibial artery (PTA), CTO at the proximal part of the anterior tibial artery (ATA) and patent peroneal artery. The distal runoff of the ATA received flow from the collateral vessels of the peroneal artery (Figure 3). We did not consider a contralateral approach due to the extreme tortuosity of the iliac arteries. We started the ipsilateral retrograde approach with distal puncture technique from the peroneal artery using echo-guided distal puncture. We used a retrograde wire escalation technique, from V-18® wire (0.018-inch, 300 cm) with the support of a CXI catheter (0.018 inch) to Astato® 30 (0.018-inch, 300 cm). However, the patient was

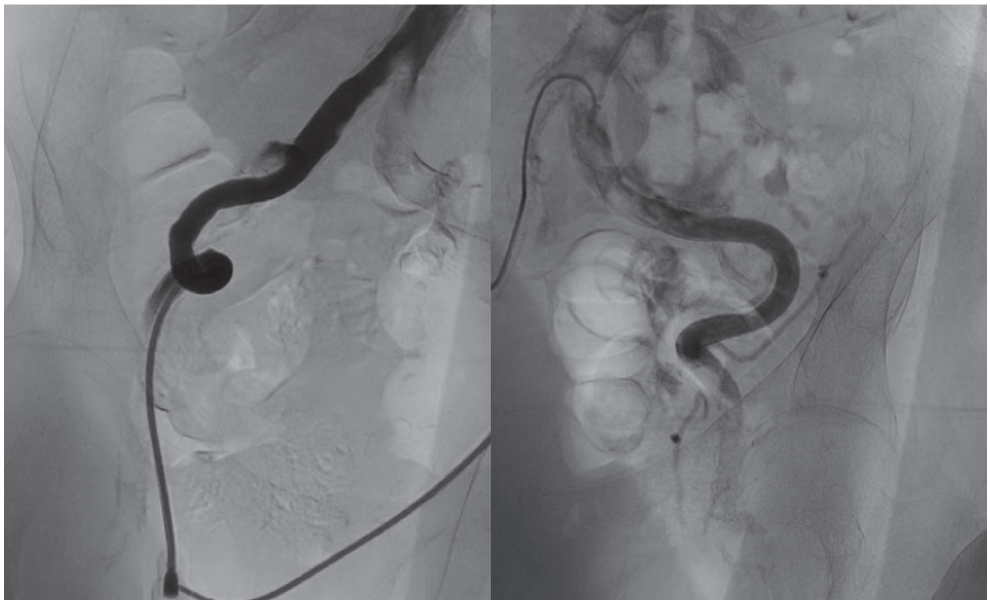

Figure 1. Bilateral tortuous and calcified iliac arteries without significant stenosis.

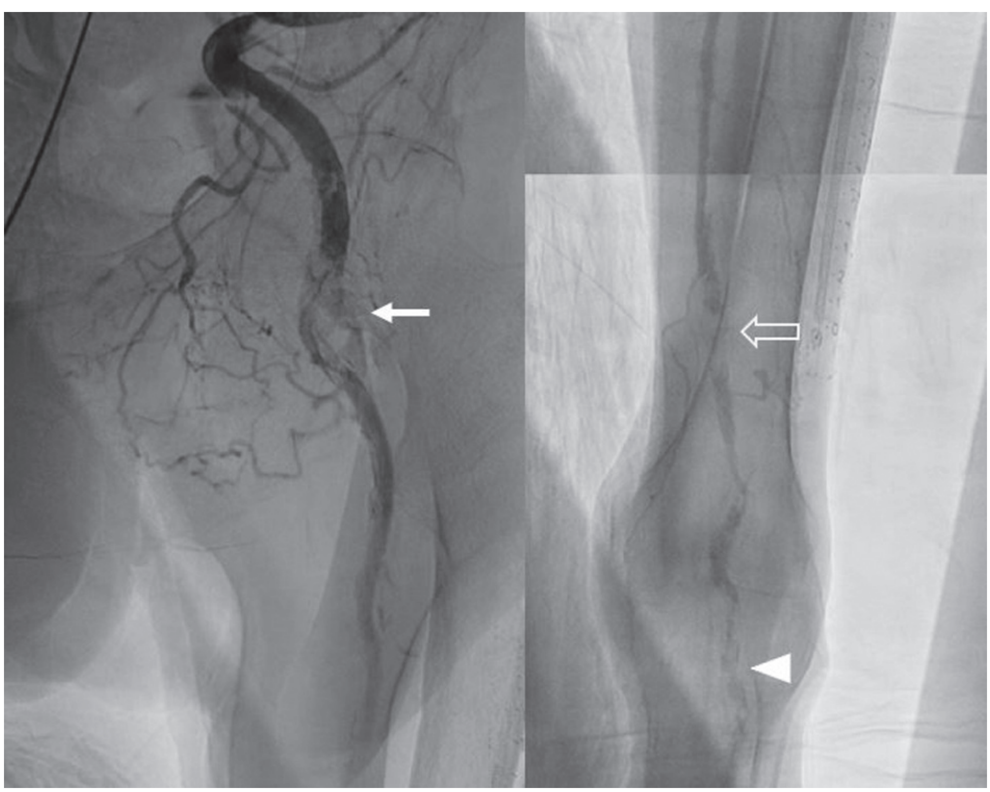

Figure 2. Chronic total occlusion with heavy calcification at the left CFA (solid white arrow), distal SFA (hollow white arrow) and popliteal artery (white arrowhead).

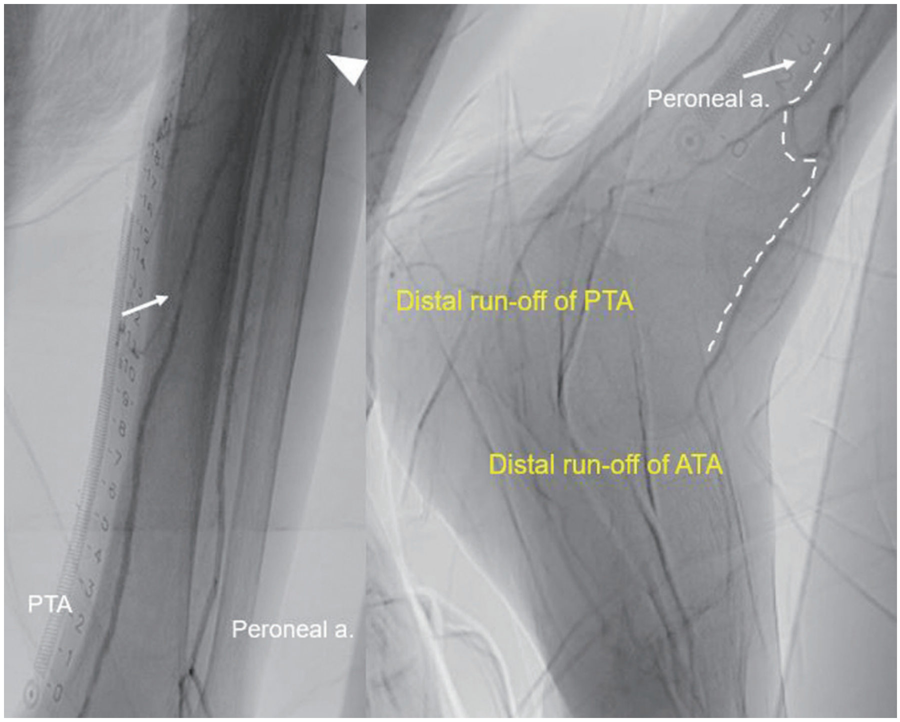

Figure 3. Posterior tibial artery with 80% stenosis at the middle part (white arrow); ATA CTO stump (white arrowhead); The distal run-off from the ATA received collateral flow from the peroneal artery.

unable to maintain knee extension, exacerbating the tortuosity of the already twisted vessel, and the stiff wire failed to enter the true lumen of the popliteal artery (Figure 4). We therefore revised our strategy to utilize multiple vascular access routes to approach the CTO lesion from various sites. The wounds from both the distal puncture and the right femoral access were free of complications, and three days later, the procedure was performed. Our procedural steps were as follows.

First, we started with retrograde wire escalation. An Astato® 30 wire (0.018-inch, 300 cm) supported by CXI® support catheter was passed through the left CFA via retrograde SFA vascular access. The CXI couldn't pass the calcified CTO lesion, so we used a low-profile semi-compliant (SC) coronary balloon (1.5/20 mm) to dilate the lesion. Subsequently, the CXI catheter was able to cross the tight lesion and we replaced the wire with Hi-Torque™ connect wire, followed by SC balloon angioplasty (5.0/80

Figure 4. The Astato® 30 wire (0.018-inch, 300 cm) supported by a CXI® support catheter failed to retrogradely enter the true lumen of the popliteal artery.

mm and 6.0/40 mm in sequence) for the left CFA calcified lesion, whereupon we achieved adequate acute luminal gain (Figure 5).

Second, we established a 5 Fr antegrade vascular access at the left proximal SFA, and performed antegrade wire escalation technique using an Astato® 30 wire (0.018-inch, 300 cm) with CXI support, which successfully penetrated the calcified left SFA CTO lesion. We then used an SC balloon (5.0/80 mm) to dilate the left distal SFA, resulting in significant lumen gain (Figure 6). Shortly thereafter, hypotension occurred due to bleeding at the left SFA retrograde sheath site. We performed prolonged balloon inflation for three

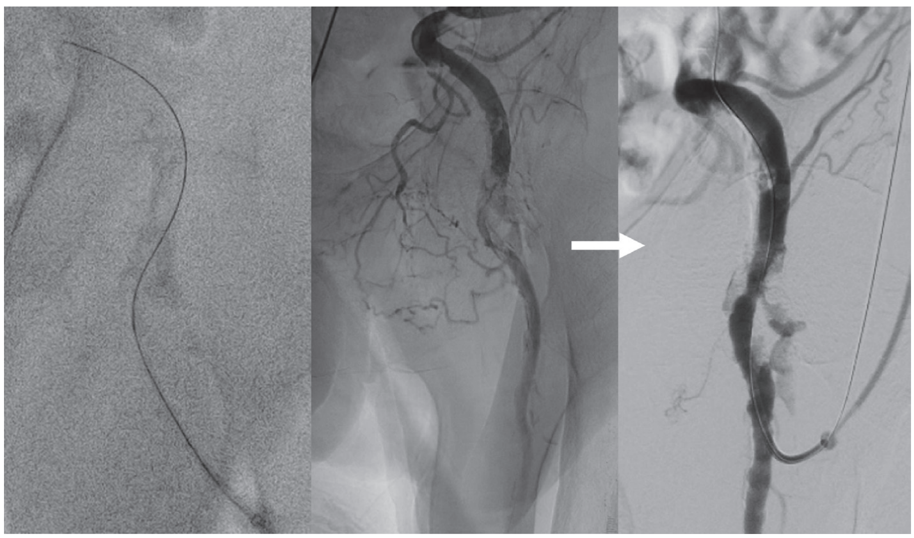

Figure 5. The retrograde Astato® 30 wire (0.018-inch, 300 cm) crossed the CFA CTO, followed by 6.0-mm balloon angioplasty with adequate lumen gain.

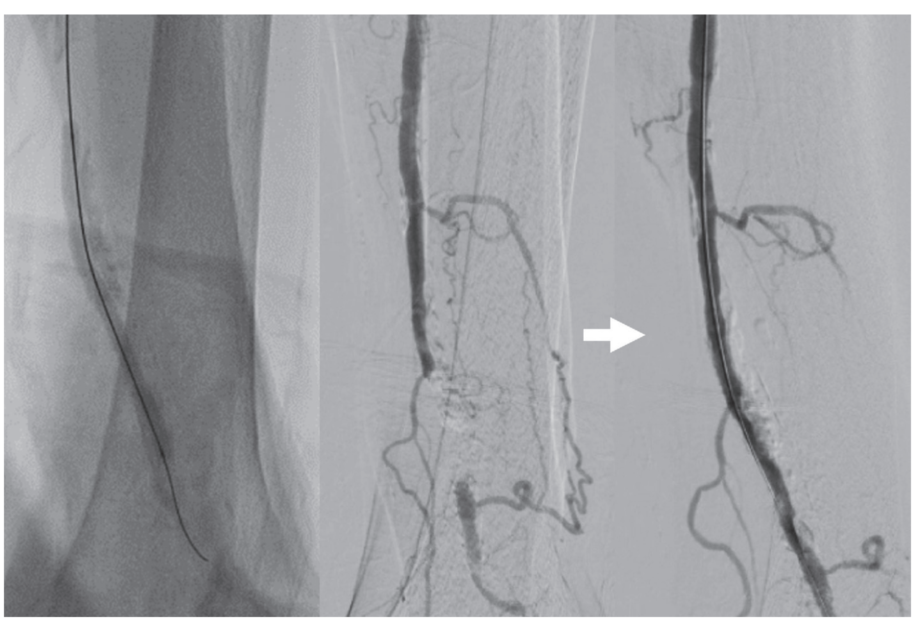

Figure 6. The antegrade Astato® 30 wire (0.018-inch, 300 cm) supported by a CXI® support catheter passed through the distal SFA, followed by 5.0-mm balloon angioplasty with good lumen gain.

minutes but the bleeding persisted. The retrograde SFA sheath was removed, and hemostasis was achieved after a second prolonged balloon inflation for an additional three minutes.

Third, we addressed the popliteal CTO lesion using ipsilateral antegrade wire escalation technique. However, due to extremely poor maneuverability, both the V-18® wire (0.018-inch, 200 cm) and Astato® XS 20 wire (0.014-inch, 300 cm) failed to enter the distal true lumen of the popliteal artery and the wire tip remained distant from the true lumen (Figure 7). We therefore started the retrograde approach using distal puncture technique from the left PTA. After successful echo-guided distal puncture, we used knuckle wire technique with Hi-torque Connect™ wire (0.018-inch, 195 cm) supported by CXI® catheter to successfully pass through the popliteal CTO, as confirmed by rotational fluoroscopy (Figure 8). The retrograde CXI support catheter passed through the popliteal CTO and we replaced the Hi-torque Connect™ wire (0.018-inch, 195 cm) with V-18 Control wire (0.018-inch, 300 cm) thereafter.

Figure 7. The antegrade Astato® XS 20 wire (0.014-inch, 300 cm) tip remained distant from the true lumen of the popliteal artery due to poor torqueability.

Unexpectedly, hypotension occurred again but prolonged inflation failed to achieve hemostasis. We therefore deployed a Viabahn® covered stent (6.0/50 mm) to achieve hemostasis via a new antegrade 7 Fr vascular access from the left CFA. After the knuckle wire passed the popliteal CTO, we performed "rendezvous" procedures at the proximal SFA with a 0.035-inch lumen catheter (Judkin Right 6 Fr) (Figure 9) and retrograde V-18 control wire (0.018-inch, 300 cm), followed by externalization. We used an SC balloon (4.0/80 mm) to dilate the popliteal artery, advanced another V-18 control wire (0.018-inch, 200 cm) to the left PTA, and performed SC balloon angioplasty (2.0/120 mm) for the left PTA. Our original plan was to perform rotational atherectomy on the distal SFA and popliteal artery, followed by drug-coated balloon angioplasty to maintain long-term patency. However, due to the patient's financial constraints, we were unable to proceed with this plan. The

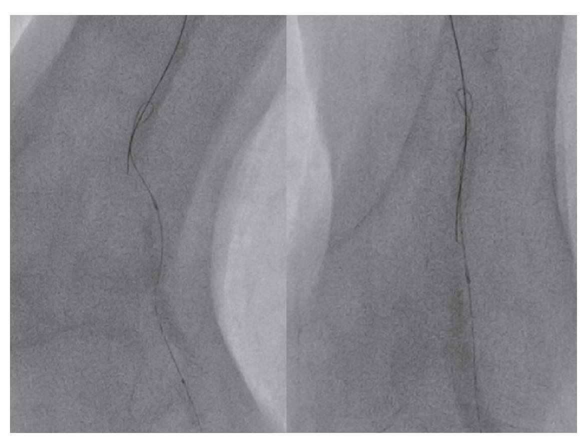

Figure 8. Retrograde knuckle wire technique with a Hi-Torque™ connect wire (0.018-inch, 195 cm) crossed the popliteal artery and entered the true lumen in the distal SFA, as confirmed by orthogonal projection.

final angiogram showed good flow in the left femoropopliteal artery (Figure 10). At the 6-month follow-up, the left foot infection and gangrene were controlled, becoming dry gangrene without the need for amputation.

DISCUSSION

It is well known that multilevel chronic total occlusion (CTO) presents the greatest challenge in endovascular revascularization, often resulting in a high rate of treatment failure due to the difficulty of crossing the lesion from a single access.[10] A bi-directional approach offers some advantages. First, combining antegrade and retrograde approaches (can be through distal puncture or collateral channels) allows for more flexibility in maneuvering through complex lesions. Second, dual access provides better control and visualization, decreasing the risk of unintentional subintimal passage. However, the disadvantages are longer procedure times and the potential risk of access-related complications, as in our case. The success rates reported in the literature for the dual-access, combined bi-directional approach to PAD CTO range from 82% to 100%.[11-13]

A retrospective study reported that using dual antegrade and retrograde access significantly improves the rate of successful CTO crossings, compared to single access (92.5% vs. 73.6%, P = 0.010). Dual access strongly predicted success (P < 0.001), while going subintimal predicted failure (P < 0.001). Both methods in the study had a low rate of complications, with no significant difference between them.[10]

Figure 9. V-18 control wire (0.018-inch, 300 cm) entered the Judkin Right 6Fr catheter (“Rendezvous” technique).

Microcatheter uncrossable calcified lesion

When it comes to CTO lesions in PAD that are uncrossable with a CXI catheter, we can use a 1.0-1.5 mm low-profile balloon (over-the-wire balloon or monorail coronary balloon). If a low-profile balloon fails to cross through the CFA calcification, we can proceed to percutaneous direct needle puncture of the calcified plaque

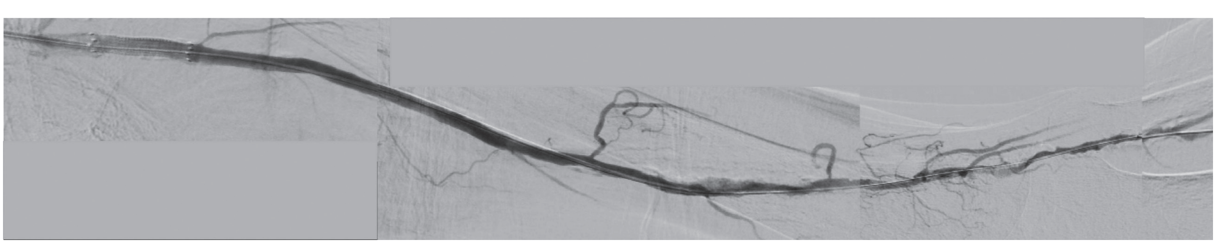

Figure 10. The final angiogram showed patent flow in the femoropopliteal arteries (the left-hand side is the cranial side)

(PIERCE),[14] or a novel inner PIERCE technique using a 20-gauge, long puncture or biopsy needle.[15,16] Our previous experience shows a guidewire introducer can be an alternative to a 20-gauge needle. Hematoma at the puncture site of the PIERCE technique should be carefully monitored after the procedure. In one retrospective study, the inner PIERCE technique was used to treat severely calcified below-the-knee (BTK) and below-the-ankle (BTA) arterial lesions. Among 18 cases, including 83.3% with chronic total occlusion, this method allowed successful needle and balloon catheter passage in all instances, demonstrating that the inner PIERCE technique is a safe and effective approach.[16]

Knuckle wire technique

The knuckle wire technique is indicated for long segment lesions and severe calcification. A low-tip load and polymer-sleeve guidewire is intentionally looped upon itself to form a small loop at its tip, which is then used to create a subintimal dissection plane. This loop is continuously advanced through the subintimal plane until it naturally reenters the true lumen, allowing it to navigate through complex and resistant lesions,[7] with a high success rate and a favorable safety profile, highlighting its utility in challenging endovascular procedures. Nonetheless, operators should be aware of possible complications, such as subintimal dissection or vessel perforation, and take appropriate precautions to minimize these risks.

Strategies for sustained patency after endovascular revascularization

There are two major factors affecting long-term patency to observe when performing endovascular revascularization for femoropopliteal disease. The first is the residual plaque burden and the mechanical forces it exerts on the flow lumen. The second is the biological phenomenon of re-stenosis caused by intimal hyperplasia after balloon angioplasty. Directional or rotational atherectomy reduces plaque volume, potentially facilitating a more homogenous drug delivery to the vessel wall and enhanced drug penetration. Combining directional atherectomy with DCB angioplasty offers a compelling strategy for femoropopliteal revascularization and theoretically leads to better long-term patency. The DEFINITIVE AR randomized controlled trial,[17] a pilot study evaluating the TurboHawk atherectomy system in conjunction with DCB angioplasty, demonstrated there is no significant difference in primary patency between combination therapy and DCB alone at 12 months, due to the low power. It is crucial to note that directional atherectomy (DA) plus DCB has potential advantages for severely calcified lesions and long lesions (>10 cm). TheVIVA REALITY,[18] a prospective, multicenter study enrolling 102 patients with 8-36 cm femoropopliteal occlusions with calcification treated with DA followed by DCB angioplasty, demonstrated a 76.7% rate of 12-month primary patency and a 92.6% rate of freedom from clinically driven target lesion revascularization (CD-TLR). A retrospective study including 226 significantly calcified femoropopliteal lesions reported even higher rates of freedom from TLR in the rotational atherectomy plus DCB group (112 lesions) compared to the DCB alone group at 12 months (95.2% vs. 76.3%; P = 0.002) and 24 months (93.4% vs. 63.7%; P = 0.002).[19] Another retrospective observational cohort including 311 patients (348 limbs; 82 limbs treated with atherectomy plus DCB and 266 limbs with DCB alone) demonstrated a higher technical success rate in the atherectomy plus DCB group (80.5% vs. 62.2%, p = 0.015) but no significant difference in primary clinical patency (73.8% vs. 82.6%, p = 0.158) or TLR-free survival (84.3% vs. 88.2%, p = 0.261) at 2 years.[20] A meta-analysis including two randomized controlled trials and four retrospective cohort studies enrolled 470 patients and showed that the atherectomy plus DCB group was associated with lower rates of bail-out stenting, without significant differences in terms of primary patency, TLR, leg amputations and mortality at 12 months.[21] Overall, atherectomy combined with DCB was safe and effective with higher technical success rate and lower incidence of bail-out stenting.

Two RCTs reported the primary patency rate after POBA was 52.6% at 12 months[22] and 45.1% at 36 months,[23] respectively. Converted to primary patency duration, this corresponds to a range of 6 to 16 months. A meta-analysis of 22 RCTs including 3217 patients reported that DCB was associated with a 51% reduction in TLR, as compared to POBA, at a mean follow-up of 21.6 ± 14.4 months.[24]

CONCLUSION

We successfully penetrated multiple chronic total occlusions (CTOs). In the common femoral artery we used a retrograde wire escalation technique with direct wire puncture. In the distal superficial femoral artery, we used an ipsilateral antegrade approach with direct wire puncture and in the popliteal artery we managed a CTO through a retrograde knuckle wire technique. These varied approaches allowed us to address each CTO effectively, one after the other. At the same time, we managed a vascular complication by deploying a covered stent in the SFA. Economic considerations prevented the use of atherectomy and drug-coated balloons (DCB) for the distal SFA and popliteal artery. This case highlights the importance of mastering the bidirectional approach and multiple techniques for managing peripheral CTOs, as well as the strategic selection of vascular access routes tailored to specific lesions.

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