Endovascular Limb Salvage Therapy of Densely Calcified Femoropopliteal Disease Using Excimer Laser Atherectomy

Sagger Mawri, MD; Andres M. Vargas Estrada, MD; Pradeep Nair, MD; Craig Walker, MD

Cardiovascular Institute of the South, Houma, Louisiana

VASCULAR DISEASE MANAGEMENT 2021;18(1):E9-E14.

Introduction

Critical limb threatening ischemia (CLTI) is the manifestation of advanced lower extremity peripheral arterial disease (PAD), typically afflicting patients with underlying significant comorbidities. Regrettably, CLTI continues to be associated with high risk of mortality, major amputation, impaired quality of life, and increased healthcare costs.[1] CLTI is characterized by increased anatomical complexity including severe arterial calcifications and chronic total occlusions (CTO), which pose technical challenges to the success of interventional revascularization strategies.[2] Heavily calcified recipient vessels hinder surgical revascularization. Furthermore, severely calcified, recalcitrant lesions pose a major challenge from an endovascular standpoint, increasing the risk for complications such as flow-limiting dissections and perforations during angioplasty.[3] In addition, calcified lesions have been shown to be less responsive to drug-coated balloons, and associated with higher rates of provisional stenting.[4]

Case presentation

A 93-year-old woman with history of hypertension, permanent atrial fibrillation, prior cigarette smoking, chronic stage 3 kidney disease, and moderate aortic stenosis, presented to an outside hospital with disabling rest pain, discoloration and swelling of her right lower extremity. Physical examination revealed pale and cool right foot, absent dorsalis pedis and faint posterior tibial pulses, and gangrenous changes involving her second and third toes (**Figure 1A**). An urgent peripheral angiogram showed severely calcified, diffusely diseased superficial femoral artery (SFA) with CTO in the mid SFA segment, a second CTO in the distal popliteal artery, an occluded peroneal artery, densely calcified and diffusely diseased anterior tibial artery, and a patent but calcified posterior tibial artery with minimal antegrade flow.

An endovascular treatment strategy was attempted; however, the procedure was unsuccessful after multiple crossing attempts to penetrate the proximal calcified CTO had failed. The patient was evaluated by the vascular surgery team and, two days later, she was taken to the operating room for femoral-tibial bypass surgery. However, given dense calcifications in the vessel, attempts to place distal anastomosis were unsuccessful. Furthermore, vessel closure with a Prolene suture were unsuccessful with persistent bleeding, thus the posterior tibial artery was subsequently ligated proximally with a silk suture and the surgical site closed (**Figure 1B**). She was then transferred to our facility for a second opinion.

The patient was evaluated and a shared decision was made to proceed with a repeat intervention attempt to revascularize her leg in an attempt to prevent amputation and relieve her symptoms. She was promptly taken to the catheterization laboratory. Antegrade access was obtained under ultrasound guidance using a micropuncture access set (Cook Medical), and up-sized for a 6Fr x 10 cm Pinnacle sheath (Terumo Interventional Systems). Therapeutic anticoagulation was administered and activated clotting time (ACT) was maintained at more than 200 seconds. Digital subtraction angiography of the right lower extremity with runoff was obtained (**Figure 2**).

A 0.018-inch Gladius wire (Asahi) was used with an 0.035-inch Quick-cross support microcatheter (Philips); however, the lesion could not be crossed. Next, a 0.014-inch Confianza Pro 12 wire (Asahi) was chosen for its greater penetrance through which successful antegrade crossing of the mid SFA CTO was established. However, the Quick-cross microcatheter could not advance. This was switched to a 0.014-inch Corsair Pro microcatheter (Asahi), which was spun and advanced successfully to the distal popliteal occlusion. The 0.014-inch Confianza Pro 12 wire was used again to cross the second calcified CTO lesion, with careful attempts to remain intraluminal, and subsequently switched to a 0.014-inch Choice PT extra support guidewire (Boston Scientific), then advanced down the anterior tibial artery to the dorsalis pedis artery (the posterior tibial artery had been ligated proximally) (**Figure 3A**).

IVUS imaging was performed next, revealing extensive, circumferential intimal and medial calcifications of the tibial, popliteal and femoral vessels with no evidence of significant vessel dissection (**Figure 3B, Figure 4**). Femoropopliteal lesion modification and plaque debulking was performed using a 2.0 mm Turbo-Power excimer laser atherectomy (ELA) catheter (Philips).

Figure 1. (A) The image displays ischemic changes with necrotic gangrenous second and third toes. (B) The image shows surgical incision in the medial aspect of the right lower leg following aborted vascular surgery and ligation of the posterior tibial artery.

Four passes with slow advancements through the lesions at 0.5 to 1 mm/sec, were performed with alternating rotations of the catheter at maximal energy settings (fluence of 60 mJ/mm2 and frequency of 80 Hz) (**Figure 5**).

Post-ELA IVUS demonstrated numerous areas of fractured calcium and modified calcific plaque, and vessel sizing was determined (**Figure 6**). This was followed by percutaneous balloon angioplasty (PTA) of the SFA and popliteal arteries using a 4.0 x 220 mm Coyote balloon (Boston Scientific) followed by 5.0 x 300 mm VascuTrak focal force balloon (Bard PV), with full balloon expansions attainable at only 4 atm pressures. PTA of the anterior tibial and dorsalis pedis arteries was performed using 2.0 x 30 mm Sprinter coronary semi-compliant balloon (Medtronic) and 2.0 x 220 mm Coyote balloon (Boston Scientific). PTA was performed with slow inflations to nominal pressure for 3 minutes at a time (**Figure 7A**). Final angiographic results demonstrated good in-line flow (**Figure 7B**). Hemostasis of the antegrade access site was established using a 6 Fr Vascade vascular closure system (Cardiva Medical). Given the patient's delayed presentation and advanced gangrene, she did require local amputation of the involved toes; however, she had subsequent wound healing and resolution of her symptoms and remains on optimal medical therapy.

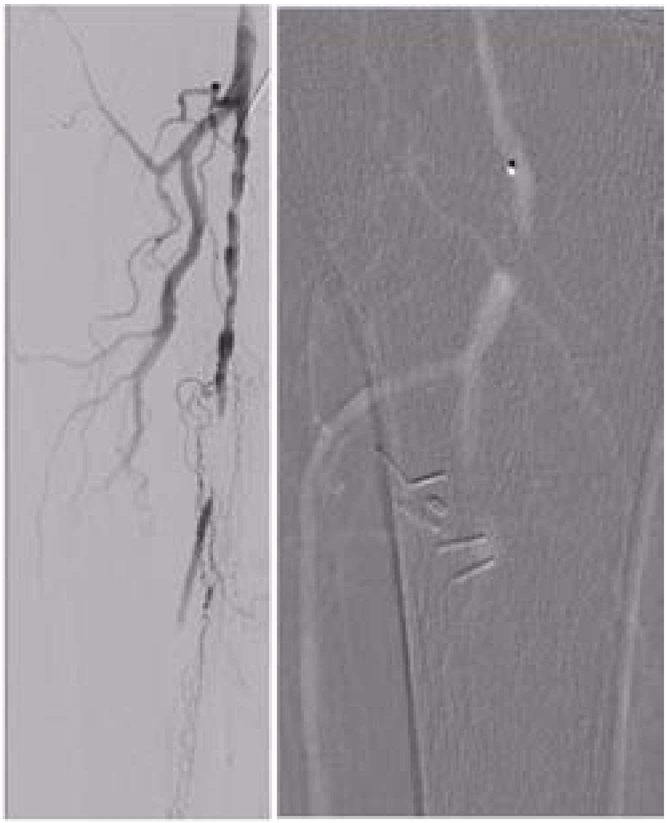

Figure 2. Digital subtraction angiogram displays diffuse SFA disease with mid segment occlusion and CO_2 angiogram shows occluded distal popliteal artery, diseased proximal AT artery, and occluded TP trunk.

Discussion

Our case highlights several important points. First, crossing of the CTOs required proper wire escalation to a high penetrance wire type, an antegrade approach for enhanced push-ability and use of a support catheter. Use of extravascular ultrasound (EVUS) could have been used to help ensure intraluminal crossing of the occlusions; although given marked vessel calcifications, we utilized angiography in this case. A retrograde approach could have also been used and was our backup strategy. Secondly, IVUS imaging was very helpful in providing thorough lesion evaluation, assessment of the extent of calcifications, and appropriate vessel sizing. IVUS helps to elucidate plaque type and composition and help direct the type of atherectomy device that may be needed. Thirdly, excimer laser was used to adequately prepare the vessel and provide plaque modification prior to angioplasty. When performed with proper technique, laser atherectomy can be effective even against dense calcifications. Adequate plaque debulking and vessel wall modification is an integral adjunctive component of endovascular therapy for CLI patients, who tend to have severely calcified, diffusely diseased arteries.[4]

There are various atherectomy devices available, each with its unique features and drawbacks.[5] A versatile atherectomy tool that can treat a wide range of lesion morphologies, such as thrombotic, fibrinous, or calcific is the excimer laser atherectomy catheter.[5-7] The word Laser is the acronym for Light Amplification by Stimulated Emission of Radiation, which is a coherent, monochromatic beam of electromagnetic radiation produced at wavelengths in the range of 180 to 400 nanometers (nm). Excimer lasers are a subset of laser in which different noble gas compounds, which are chemically inert, are then forced into an excited electronic state and upon its return to original state; it emits a photon of light.[8] The type of lasing medium determines the wavelength of light produced. For instance, a lasing medium comprised of a mixture of Xenon gas and hydrogen chloride, bombarded with high voltage, results in excitation of the XeCl dimer (ie, EXCIted diMER) and subsequent photo-emission of light at a wavelength of 308 nm.[8] It is this latter wavelength-generating laser that is currently utilized in vascular interventions, as this wavelength provides shallow absorption depth into tissue, thereby not injuring deep layers of tissue, and has minimal absorption loss.

Photoablation via ELA is generated via three distinct mechanisms: photochemical, acoustic shockwave, and photomechanical.[9,10] Firstly, photochemical effects occur at the molecular level in which the produced light pulse is absorbed by mixed morphology material, breaking its molecular bonds. Secondly, an acoustic shockwave is generated in all directions, which affects rigid material and vessel compliance, thus impacting luminal and medial arterial disease. Arterial plaque and thrombus effectively absorb 308 nm light, while dense calcifications are more resistant to absorption.[10] However, acoustic shockwave effects can impact

Figure 3. (A) Wire crossing of mid SFA occlusion with 0.014-inch Confianza Pro 12 wire. (B) IVUS catheter in the anterior tibial artery. Note the diffuse, dense vessel calcification train track-like appearance.

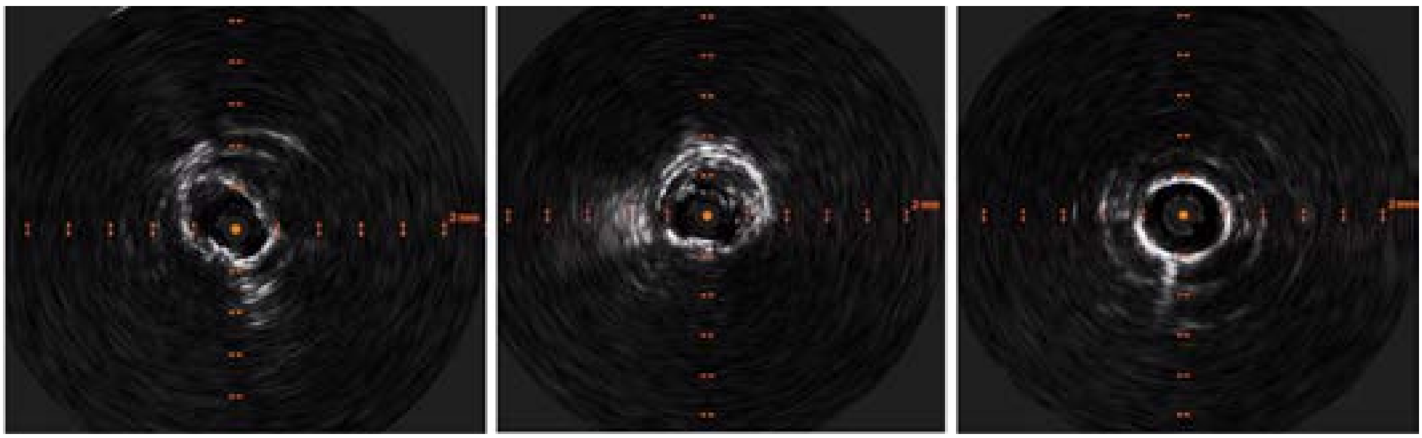

Figure 4. Pre-laser IVUS imaging demonstrates marked circumferential femeropopliteal calcification.

such calcific lesions. Thirdly, a photomechanical effect occurs due to expansion and implosion of cavitation bubbles which disrupt, macerate and debulk intra-vascular material and providing, thereby providing luminal gain. This is directly related to the amount of energy applied with the laser. The two factors that modulate energy are the fluence, a measure of energy density (mj/mm2), and rate, a measure of frequency of pulses (pulses/sec). Fluence output is between 30-80 mJ/mm2, with higher fluence used to create a larger vapor bubble, as in the treatment of thrombotic lesions. Repetition rate is between 25 and 80 Hz, with higher rate used to affect more rigid materials, such as calcific lesions.

ELA devices indicated for peripheral vascular disease interventions include Turbo-Elite and Turbo-Power (Philips) as well as Auryon (AngioDynamics, Inc). Turbo-Power catheter, which exists in 2.0 and 2.3 mm iterations, utilizes a rotating function and has an eccentric wire lumen, with densely packed fiberoptic fibers. The eccentric rotation, which is remotely controlled, allows for directing as well as spinning of the laser catheter as it advances forward. This helps negate dead space to provide more effective ablation, and provide orthogonal displacement of friction for better tracking, especially in calcified vessels. The advancement speed of the laser catheter should ideally be 0.5 to 1 mm per second to ensure the vapor bubble remains in front of the laser catheter, thereby providing optimal ablation. Furthermore, to mitigate potential risk for tissue injury, it is important to apply saline flush infusion during atherectomy to provide optimal lasing environment and prevent contrast and blood from increasing heat absorption, and a to apply a brief 5-10 second pause after every 20 seconds of treatment.

ELA has been demonstrated to be effective in the treatment of CLI.7 Furthermore, ELA with PTA showed superiority over standard PTA in the Excimer Laser Randomized Controlled Study for Treatment of Femoropopliteal In-Stent Restenosis (EXCITE ISR), demonstrating significant procedural success and a decrease in major adverse events.[10] Furthermore, excimer laser-assisted angioplasty was demonstrated to be effective for patients with critical limb ischemia who were poor candidates for surgical revascularization, as demonstrated in the Laser Angioplasty for Critical limb Ischemia (LACI) trial, in which limb salvage rate was 93% at 6 months.[11] Currently, the INTACT trial is ongoing which will be comparing conventional PTA to drug-coated balloons (DCBs) to DCB with laser atherectomy in the treatment of femoropopliteal ISR.[12]

Conclusion

CLTI continues to be associated with increased morbidity and mortality. Co-morbidities and lesion complexity make treatment

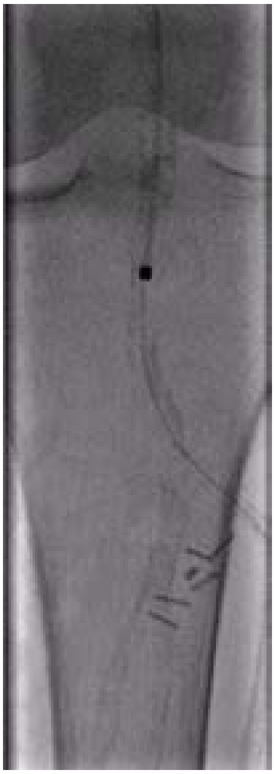

Figure 5. 2.0 mm Turbo-Power Excimer laser atherectomy catheter advanced down the popliteal artery in alternating rotations at 0.5 to 1 mm speed.

Figure 6. Post-laser IVUS imaging demonstrates luminal gain and multiple calcium fractures and fragmentation.

Figure 7. (A) The left image panels demonstrate excellent balloon expansion at nominal pressure post-laser atherectomy. (B) The right image panels demonstrate brisk antegrade flow down the treated arterial segments.

of CLTI challenging. However, advancements in endovascular techniques, wire technology, intravascular imaging modalities, atherectomy devices and other interventional tools continue to push the field forward and allow for constantly improving therapeutic options and clinical outcomes for CLTI patients. As illustrated in our case, when combined together, proper wire selection, intravascular imaging, lesion preparation and proper angioplasty, can ensure successful CLTI therapy and limb salvage. ■

Disclosure: The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest. The authors report no financial relationships or conflicts of interest regarding the content herein.

Address for Correspondence:
Sagger Mawri, MD
Email: sagger.mawri@cardio.com

REFERENCES

1. Reinecke H, Unrath M, Freisinger E, et al. Peripheral arterial disease and critical limb ischaemia: still poor outcomes and lack of guideline adherence. *Eur Heart J.* 2015;36(15):932-938.
2. Zettervall SL, Marshall AP, Fleser P, Guzman RJ. Association of arterial calcification with chronic limb ischemia in patients with peripheral artery disease. *J Vasc Surg.* 2018;67(2):507-513.
3. Mustapha JA, Diaz-Sandoval LJ. Balloon angioplasty in tibioperoneal interventions for patients with critical limb ischemia. *Tech Vasc Interv Radiol.* 2014;17(3):183-196.
4. Fanelli F, Cannavale A, Gazzetti M, et al. Calcium burden assessment and impact on drug-eluting balloons in peripheral arterial disease. *Cardiovasc Intervent Radiol.* 2014;37:898-907.
5. Mustapha JA, Diaz-Sandoval LJ, Karenko B, Saab F. Atherectomy and critical limb ischemia: a treatment approach for severely calcified vessels. *Vascular Disease Management.* 2013;10(10):E198-E207.
6. Akkus NI, Abdulbaki A, Jimenez E, Tandon N. Atherectomy devices: technology update. *Med Devices (Auckl).* 2015;8:1-10.
7. Wissgott C, Kamusella P, Lüdtke C, Andresen R. Excimer laser atherectomy after unsuccessful angioplasty of TASC C and D lesions in

femoropopliteal arteries. *J Cardiovasc Surg (Torino)*. 2013;54(3):359-365.
8. Biamino G. The excimer laser: science fiction fantasy or practical tool? *J Endovasc Ther.* 2004;11 Suppl 2:II207-II222.
9. Stanek F. Laser angioplasty of peripheral arteries: basic principles, current clinical studies, and future directions. *Diagn Interv Radiol.* 2019;25(5):392-397
10. Dippel EJ, Makam P, Kovach R, George JC, Patlola R, Metzger DC, Mena-Hurtado C, Beasley R, Soukas P, Colon-Hernandez PJ, Stark MA, Walker C; EXCITE ISR Investigators. Randomized controlled study of excimer laser atherectomy for treatment of femoropopliteal in-stent restenosis: initial results from the EXCITE ISR trial (EXCImer Laser Randomized Controlled Study for Treatment of FemoropopliTEal In-Stent Restenosis). *JACC Cardiovasc Interv.* 2015;8(1 Pt A):92-101.
11. Laird JR, Zeller T, LACI Investigators, et al. Limb salvage following laser-assisted angioplasty for critical limb ischemia: results of the LACI multicenter trial. *J Endovasc Ther.* 2006;13(1):1-11.
12. ClinicalTrials.gov. Comparison of angioplasty/drug coated balloon/ laser + drug coated balloon for femoropopliteal artery in-stent restenosis. Accessed 8 September 2020. https://clinicaltrials.gov/ct2/show/study/NCT02599389