Long Chronic Total Occlusions: Revascularization Strategies

Daniel Sheeran, MD¹ Luke R. Wilkins, MD¹

¹ Division of Vascular and Interventional Radiology, Department of Radiology and Medical Imaging, University of Virginia Health System, Charlottesville, Virginia

Address for correspondence Luke R. Wilkins, MD, Department of Radiology and Medical Imaging, University of Virginia School of Medicine, Box 800170, Charlottesville, VA 22908 (e-mail: lrw6n@virginia.edu).

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Abstract

Keywords

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The treatment of chronic total occlusions (CTO) in patients with peripheral arterial disease (PAD) is a complex topic with multiple treatment techniques and treatment strategies. The interventionalist treating patients with PAD should have both a defined treatment algorithm and multiple techniques available for crossing these challenging lesions. This article will cover techniques for treating CTOs and provide an overview of current available evidence.

Objectives: Upon completion of this article, the reader will be able to identify the role of interventional radiologic techniques, as well as patient selection and potential complications of such techniques, in the patient with chronic total arterial occlusions.

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Peripheral arterial disease (PAD) has seen an increase in prevalence, attributed to several comorbid factors as well as the aging U.S. population. Prevalence of PAD surpasses 10% in those in the 60s and 70s, and it is strongly related to con-

comitant diabetes and smoking.¹ PAD typically first presents as intermittent claudication (IC). However, those with PAD as defined by an ankle-brachial index (ABI) ≤ 0.9 is even more common. More severe patient presentations can include rest pain with or without tissue loss (Rutherford classes 4–6). Outcomes in these two patient populations are quite different, with only 1 to 2% of patients with IC developing critical limb ischemia (CLI) over a 5-year period, whereas those presenting with CLI have a 25% 1-year amputation rate.^{2,3}

The goal of PAD management is to alleviate symptoms and mitigate progression that can result in tissue loss and amputation. To date, few medical therapies are available beyond exercise regimens, cilostazol, and antiplatelet therapy. Controlling comorbid illnesses with the use of ACEIs and statins has also shown promise.^{4,5} Thus, treatment strategies often also involve restoration of flow to the affected extremity. Endovascular treatment options for restoration of flow are dependent on establishing wire access through the affected limb. In a significant number of patients, this can involve a chronic total occlusion (CTO). While endovascular options for the treatment of a CTO can be complex in both clinical decision making and technical skills, they represent an essential tool for the interventionalist. Conventional wire and catheter

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technique have a high failure rate in these lesions (40–60%).⁶ Furthermore, even retrograde and advanced reentry techniques may be limited and some trials have shown an unacceptably high rate of overall failure to cross CTO lesions.⁷ Success in treatment of the PAD and CLI patient populations requires that the physician have a defined treatment algorithm for approaching these complex lesions and is familiar with the full extent of CTO tools and techniques.

Evaluation

Preprocedural evaluation should include noninvasive testing such as ABI, toe-brachial index, pulse volume recordings, and transcutaneous oxygen measurements. Imaging modalities such as duplex ultrasound, computed tomography angiography (CTA), and magnetic resonance angiography are essential to assist in intervention planning. While limited in smaller vessels with advanced degrees of atherosclerotic calcification, CTA provides important diagnostic and endovascular planning information including CTO morphology, lesion length, distal target vessels, degree of vessel calcification, and location of collateral vessels.

A thorough and complete discussion with the patient regarding treatment options and expected outcomes should occur prior to the intervention. Restoration of flow and alleviation of symptoms is dependent on the presenting clinical scenario (Rutherford classification) and physiologic anatomy (Trans-Atlantic Inter-Society Consensus [TASC] classification). Treatment can be through surgical bypass or an endovascular approach, with no discrete consensus on the best revascularization strategy.^{8,9} Endovascular approaches can become more difficult dependent on the level and extent of occlusive disease. This becomes especially true in the setting of CTOs (TASC C and D lesions), where surgical bypass has historically outperformed endovascular treatment.^{9–12} However, given patient comorbidities and surgical risk, an increasing number of interventionalists approach CTOs with a “percutaneous first” approach despite the lower primary and primary-assisted patency rate.¹³ While this is often the preferred treatment option for the patient, a discussion regarding the likelihood and timeframe of reintervention associated with endovascular versus bypass treatment options will benefit both the patient and the interventionalist with appropriate management of expectations.

Crossing the Occlusion

Arterial Access and Diagnostic Arteriogram

The procedure may be performed with moderate conscious sedation. Either a contralateral or ipsilateral approach may be performed. Prior to accessing either ipsilateral or contralateral femoral artery, careful evaluation of preprocedural CTA, if available, is recommended to assess need for treatment of any lesions within the iliac arteries. Contralateral approach has the advantage of easier access in overweight patients and increased working room on the angiography table. Ipsilateral access may help improve chances of crossing a long segment occlusion and improve device pushability and required device

length. Prior to arterial access, it is beneficial to determine if there is a high likelihood for retrograde access. In such cases, sterile preparation of the ankle and foot is best performed prior to the start of the procedure rather than after initial antegrade failure.

A complete diagnostic arteriogram is performed after achieving arterial access. Meticulous attention to imaging technique is essential for appropriate assessment of lesion length, lesion morphology, patency of distal target, and health of tibial vessels. These preintervention images are essential to improve the ability to plan the optimal approach, determine treatment success, and diagnose complication. After planning the approach and intervention, an appropriate dose of intravenous or intra-arterial heparin is administered to achieve a target activated clotting time (ACT) of greater than 250 seconds.

Approach to Chronic Total Occlusion

A CTO may be crossed in a true-lumen or subintimal fashion. There are both practical and theoretical advantages to both techniques. True-lumen crossing may decrease the risk of losing side branch patency in cases of long-segment dissection that may occur with the subintimal approach. In addition, the true-lumen approach will not require a reentry device and may have a decreased overall procedural cost. Lastly, true-lumen crossing preserves the option of using an atherectomy device to increase luminal gain. Disadvantages of true-lumen crossing include potential increased procedure time and theoretical increased risk of distal embolization.

Advantages to a subintimal approach include a high technical success and limb salvage rates.^{9,14,15} While the subintimal approach can have a steep learning curve, the method is often faster than attempting to stay true lumen. As discussed earlier, disadvantages of choosing a subintimal approach include extending the dissection plane across the origin of critical vessels (e.g., common femoral bifurcation, distal popliteal artery, and trifurcation of the runoff arteries).

True-Lumen Technique

There are a variety of true-lumen crossing wires that come in 0.035-, 0.018-, and 0.014-in hydrophilic tip wires. Hydrophilic coating can aid in navigation through the “microchannels” found in CTOs. Weighted tip CTO wires are specialty wires designed to maintain true-lumen crossing. Many designs offer increasing tip loads (12–30 g) for control and a range of pushability. Escalating the level of tip load can aid in crossing hard and calcific lesions.

True-lumen support catheters are used to aid in wire support for crossing difficult lesions and have flexible, low-profile, and hydrophilic shafts. This allows greater catheter support and pushability.

The interventionalist should be familiar with the wide array of true-lumen crossing devices that can aid in achieving wire access across a CTO while staying intraluminal. The general method of device function is a boring mechanism that has enough force to cross the occlusion but not enough force to traverse the vessel wall. Devices can include a rotatable tip with sloped wedges that is manually activated

to corkscrew through the CTO. Alternatively, imaging guidance through with optical coherence tomography (OCT) may also be used. Other devices may use a nitinol-core wire to transmit mechanical vibration (via a separate generator) to the metal tip of the catheter.

Subintimal Technique

The subintimal approach may be used after unsuccessful attempts using conventional wire and catheter techniques. As detailed earlier, this technique can have a steep learning curve and recommendations are for caution in using this technique at vessel branch points. In addition, care should be exercised so as not to eliminate surgical bypass options. In patients who may be candidates for an above knee bypass, extending the dissection plane into the popliteal artery should be avoided.

Subintimal access may be achieved using a 4- or 5F angled-tip catheter directed at the vessel wall at the level of the occlusion. An angled hydrophilic guidewire is then used to enter the subintimal plane. Careful fluoroscopic visualization of the guidewire loop will show the wire freely traversing the occlusion with minimal resistance. Spontaneous reentry to the true lumen will occur in a majority of cases with little to no guidewire or catheter manipulation. However, extensive atherosclerotic calcification may render reentry challenging. A reentry device may be used to facilitate guidewire passage to the true lumen. Several devices are available that all utilize sharp reentry to the true lumen. Highly visible L and T markers (►Figs. 1 and 2) are used to fluoroscopically direct the cannula toward the true lumen. This device is typically used in vessels with extensive atherosclerotic calcification. Other devices may use intravascular ultrasound (IVUS) guidance to the true lumen. This may be used in noncalcified vessels where fluoroscopic guidance is challenging. Disadvantages include a capital investment for the IVUS console if not already available. Alternate devices use balloon assistance with a flat or conically shaped balloon that self-oriens in the subintimal space and an angled reentry probe.

SAFARI Technique

Subintimal arterial flossing with antegrade and retrograde intervention (SAFARI) may be used when advanced reentry techniques fail.¹⁶ There are multiple techniques that may be used for achieving retrograde arterial access. Initial diagnostic angiographic images should be evaluated for an appropriate access vessel and location. Ultrasound is done to ensure a healthy segment of appropriate diameter. The dorsalis pedis artery is frequently accessed at the middle navicular or slightly superior to the ankle mortise. The posterior tibial artery is accessed posterior to the medial malleolus or immediately superior to the ankle joint. The peroneal artery is usually approached at the lower third of the interosseous membrane using fluoroscopic guidance. Rarely, ultrasound guidance may be used if there is an acoustic window. It should be noted that it is more difficult

to achieve hemostasis of the peroneal artery after completion of the procedure. Even with balloon-assisted closure, there is an increased risk of bleeding and potential compartment syndrome.

A 21-gauge needle and a 0.018- or 0.014-in guidewire are used to access the chosen vessel. A 3F transitional dilator from a micropuncture set is advanced over the wire. Access is then confirmed with contrast injection. An exchange length 300-cm 0.018- or 0.014-in guidewire is then advanced in a retrograde fashion. Often times, the occlusion may be crossed through the retrograde access while staying true lumen. However, subintimal recanalization from the retrograde access is frequently required. A crossing catheter may be used for additional support and maneuverability. A 4F catheter or a 4F sheath may be used to maintain access if the vessel diameter is adequate. Administering vasodilators through the retrograde access and ensuring an ACT greater than 250 seconds may decrease the risk of access vessel occlusion in patients with small (<1.5 mm) tibial vessels.

After the retrograde wire has crossed the occlusion and is within the proximal vessel, the wire may be snared from the antegrade access. The wire is then pulled through the antegrade sheath for through-and-through access. Alternatively, the antegrade crossing attempt will have stopped in the midportion of the occlusion within the subintimal space. The retrograde crossing wire can then enter the antegrade catheter within the subintimal space (►Fig. 3). Again, the wire can then be advanced through the antegrade sheath to achieve through-and-through access. However, frequently the retrograde and antegrade accesses, while both within the subintimal space, do not communicate. There are different techniques to overcome this obstacle. A new antegrade access may be attempted to establish through-and-through access. If unsuccessful, a 4-mm angioplasty balloon may be advanced over the antegrade access and inflated within the subintimal plane. This can disrupt the intimal layers prohibiting communication between antegrade and retrograde access and is called the reverse CART (controlled antegrade and retrograde subintimal tracking) maneuver.¹⁷ Alternatively, sharp recanalization may be performed through either the retrograde or antegrade access. This is performed by advancing the support catheter to the leading edge of the occlusion and utilizing the back end of the 0.018- or 0.014-in guidewire with snaring provided by the opposite access. Alternatively, a reentry device may be advanced over the antegrade access and used to target a snare that has been advanced from the retrograde approach. The reentry device will change the subintimal plane of the antegrade wire and allow communication of the access points.

Treatment Considerations

Management of CTOs once wire access is established remains uncertain. Treatment options include percutaneous transluminal angioplasty, drug-coated balloon (DCB), selective stenting, and primary stenting of the crossed segment. Several authors have described primary nitinol stenting of

Fig. 1 A 64-year-old woman (Rutherford 4). Initial arteriography (a) demonstrates long-segment occlusion through the SFA (arrow) with reconstitution at the adductor canal (arrowhead). An Outback reentry device was advanced over a 0.014-in Spartacore wire (b). The device was oriented to direct the sharp cannula medially toward the atherosclerotic calcifications (arrow). After PTA through the SFA, residual narrowing of >30% was identified (c, arrow). Drug-eluting stents were placed through the SFA with good angiographic result (d and e). PTA, percutaneous transluminal angioplasty; SFA, superficial femoral artery.

Fig. 2 A 72-year-old man (Rutherford 5). Initial arteriography (a) demonstrates long-segment occlusion of the SFA with previously placed stents (arrow) and occluded bypass (arrowhead). Initial arteriography at the level of the knee (b) shows reconstitution of the proximal AT. After failed antegrade attempt (c, arrowhead), retrograde access was achieved in the anterior tibial (AT) artery and advanced to the AT origin (arrow). The antegrade and retrograde access would not communicate in the subintimal space of the SFA and the retrograde access was advanced to the CFA (d, arrow). A snare was advanced through the antegrade access and used to externalize the retrograde wire (E, arrow). Post-stent placement arteriographs (f and g) show in-line flow through the SFA to the AT. CFA, common femoral artery; SFA, superficial femoral artery.

the occluded segment, with 1 year primary patency approaching 80% for TASC C and D lesions.^{9,18} However, the durability of this patency is questioned given the risks of in-stent restenoses (ISR) and fracture of long-stented segments. Others have examined the use of DCB as an alternative, demonstrating similar patency and clinically driven TLR rates to those of primarily stented lesions, albeit with an 18% provisional stenting use.¹⁹ Hong et al further examined this use of selective stenting versus primary stenting in subintimally crossed CTOs, finding that primary stenting of the entire crossed occlusion resulted in increased ISR and decreased primary patency.²⁰ Additional investigations into the use of endoprostheses have been performed, given the putative decrease in ISR and stent fracture. However, long-term outcomes at 3 years demonstrated similar primary and secondary patencies.²¹ If able, provisional stenting may be beneficial to primary stenting given the available data and the problems faced, especially with longer

CTOs. High radial strength stents with an interwoven design may be considered in the setting of severe calcification and have shown promising data.²² In addition, the efficacy of angioplasty and DCB has now been demonstrated whether crossing in the true lumen or subintimal plane.

Revascularization of the lower extremities requires some combination of vessel preparation, angioplasty, and/or stenting. Throughout the process of this therapy, there is an ever present risk of distal embolization. The significant clinical sequelae of embolic events is well described in the coronary and carotid literature.²³ However, it is less well studied in peripheral vascular beds. Data would suggest that symptomatic embolic events are uncommon; however, when they do occur, can result in an increase in early reintervention and amputation rates.²⁴ Embolic risk appears to correlate with disease burden (TASC C and D lesions), ISR, and with the use of atherectomy.²⁵ The clinical significance of embolization remains unknown, with some authors finding primary

Fig. 3 A 79-year-old woman (Rutherford 4). Initial arteriography (a) demonstrates long-segment occlusion through the SFA (arrow) with possible reconstitution at the adductor canal (arrowhead). A subintimal plane was started for revascularization (b, arrow). An attempt at reentry was performed with the Outback device (c, arrow). After achieving retrograde access through the AT, the retrograde wire was advanced through the antegrade access catheter within the subintimal plane (d, arrow). Post-stent placement arteriographs show patent SFA with in-line flow (e and f). SFA, superficial femoral artery.

Fig. 4 Algorithm for endovascular CTO strategies. CTO, chronic total occlusion; PTA, percutaneous transluminal angioplasty.

patency and limb salvage rates to be similar when comparing infrainguinal interventions with and without embolic events.²⁵ Others have found limb salvage to be adversely affected in the setting of distal embolization.²⁶

Several devices now exist on the market, and utilization of these embolic protection devices (EPDs) has been found to be safe, and macroscopic emboli are a common finding in EPD baskets upon removal from the patient (from 55 to 100%).^{24,27} While clinical efficacy remains debated, use of an EPD may be particularly applicable in CLI patients with single vessel runoff, or patients with acute thromboembolic occlusions.^{28,29}

Treatment Algorithm

Approach should be tailored to both the patient and the operating physician. Clearly, given lack of convincing, prospective data, there is no clinical superiority of one technique (subintimal, true lumen, retrograde, etc.) and device selection will largely be based on availability and familiarity on the part of the operator. An algorithm used by the authors is shown in ► Fig. 4.

Conclusion

Treatment of CTOs can be daunting and complex with a variety of lesions and crossing techniques. What may work within one vascular territory will have very little success in another and it behooves the interventionalist to have several techniques and devices to use in the likely event that they are unable to cross a given occlusion. Even after wire access is achieved, the treatment of CTOs is complex with multiple treatment options available and no clear superiority. The complex anatomy and heterogeneous disease pattern makes comparison within the medical literature challenging. Within these limitations, the interventionalist should consider the available data and develop a definable treatment algorithm that can be altered as optimal device selection and patient response continues to evolve.

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