Wired for Success

Guidewire escalation and techniques for successful crossing of chronic total occlusions.

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Chronic total occlusion (CTO) of the coronaries has long been a known challenge for percutaneous coronary intervention. As the prevalence of peripheral arterial disease escalates, we are increasingly being confronted with complex superficial femoral artery (SFA) and below-the-knee CTO interventions. Our characterization of how CTOs develop is limited by the late stage of diagnosis and lack of data on the initial formative basis. Animal studies have attempted to develop a better understanding of the composition of CTOs. From these studies, we have theorized that the common initiating event is an acute arterial occlusion due to atherosclerotic plaque rupture with thrombus formation that triggers an inflammatory reaction. During the first 2 weeks of this process, an acute complex is formed that contains platelets and erythrocytes within a fibrin mesh with an influx of acute inflammatory cells.[1]

During the intermediate stage at 6 weeks, negative arterial remodeling and disruption of the internal elastic lamina ensues, with intense neovascularization and CTO perfusion.[2] The subsequent 12- to 24-week time period demonstrates decreased microvessel formation and CTO perfusion with progressive gradual replacement of proteoglycans by collagen and calcium. The density of the fibrocalcific tissue is highest at the proximal and distal ends of the lesion: the proximal fibrous cap is characteristically composed of densely packed type I, III, V, and VI collagen, which is the initial barrier to the CTO,[3] whereas the distal fibrous cap tends to be a thinner and softer, yet densely packed collagen structure (Figure 1). Within the main body of the CTO, organized thrombus and recanalization channels are observed (Figure 2) in 60% of lesions.[2] CTOs that are < 1 year old are usually composed of "soft" or cholesterol-laden foam cell lesions. In contrast, older CTOs typically contain "hard plaque" that is composed of fibrocalcific iron and hemosiderin deposits within the lesions (Figure 3).

GUIDEWIRE SELECTION

A foundational knowledge of the composition of CTOs is essential for the selection of an appropriate guidewire (Figure 4), which can consecutively increase success rates to cross CTOs, improve device delivery, control cost, and limit the risk of vascular injury.[4] Although crossing a CTO alone may require a progressive escalation of guidewire choice, subsequent guidewire exchanges may be further required during the procedure to achieve optimal or safer device delivery. Ultimately, a fundamental understanding of guidewire selection (see *Peripheral Guidewires* insert at the end of this article) and performance characteristics (Table 1) is of paramount importance to successful completion of a complex endovascular CTO intervention.

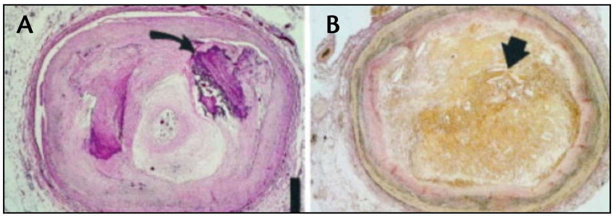


Figure 1. Hard or fibrocalcific CTO with extensive calcification (arrows; A). Soft or lipid-laden CTO intimal plaque with extensive cholesterol deposition (arrow; B).[2]

First, the core diameter of the wire must be decided upon, which is the functional guidewire diameter with standard sizes of 0.014, 0.018, and 0.035 inches. Large-diameter wires, such as the 0.035-inch Magic Torque™ guidewire from Boston Scientific Corporation (Natick, MA) generally have greater rail support and can be used to straighten vessels and improve torque, whereas small-diameter wires have increased flexibility and trackability through tortuous segments. Second, the core material composition of the wire further corresponds to guidewire rigidity, torquability, and flexibility. Stainless steel is easier to torque and is more rigid, providing better columnar support compared to nitinol, which offers more flexibility and kink resistance. Meanwhile, hybrid wires have the benefit of high-tensile stainless steel shafts with nitinol tips to impart high torquability and columnar shaft strength with kink-resistant tips.

Third, core taper enables acute angulated vessel access and improved tracking. Abrupt or short tapers create support in shorter distances and have a greater tendency to prolapse compared to long, gradual tapers, which track well around bends but do not provide as much support in short distances. A core that extends to the tip of the wire (core to tip) increases the transmission of force, is more durable and steerable, improves tactile feedback, and is ideal for use in peripheral vessels. A core that does not extend to the tip (shaping ribbon) is delicate, flexible, easier to shape, can be

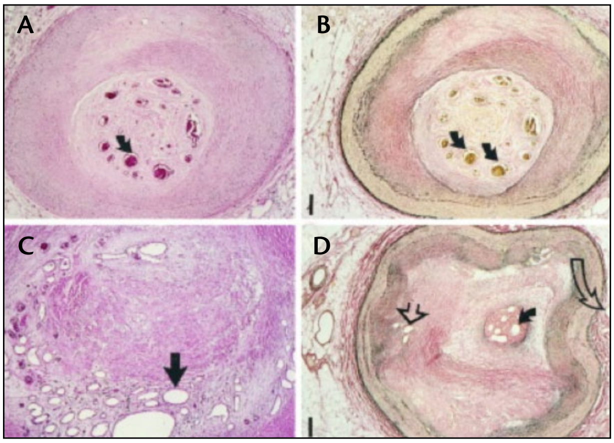


Figure 2. CTO lumen recanalization by large central neovascular channels (arrows; A, B). Extensive small, medium, and large intimal plaque neovascular channels (arrows; C). Central lumen, intimal plaque and adventitial neovascular channels formation (solid, open, and curved open arrows, respectively; D).[2]

easily prolapsed, and is ideal for navigating tortuous and distal anatomy such as the pedal arteries. Different levels of tip penetration (tip stiffness) provide the wire with more or less push force or "tip load" to cross challenging lesions. Guidewire covers are sleeves of polymer to enhance lubricity, resulting in less drag, enhanced lesion crossing, and smooth tracking in tortuous vessels. Straight tips or small angles increase tip penetration, while a secondary bend allows for a better angle to navigate tortuous segments.[4]

TECHNICAL TIPS AND CONSIDERATIONS

Intraluminal Crossing

Technical success in crossing long (> 10 cm) SFA occlusions ranges from 50% to 90%. The variability in success depends largely upon lesion length, calcification, distal vessel runoff, and operator experience. Based on the complexity and morphology of the peripheral CTO composition, an escalating guidewire approach needs careful consideration while attempting to cross the CTO. When choosing the first wire to cross this type of lesion from an antegrade approach, a soft wire should be introduced to determine whether the occlusion is an early thrombotic versus a late calcified chronic occlusion. If it is a thrombotic occlusion, then the soft-tipped wire should navigate across the lesion without overt resistance. However, if the wire meets resistance, the next consideration would be a hydrophilic polymer-coated wire, such as the V-18™ ControlWire™ (Boston Scientific Corporation), which allows the operator to direct the wire into a neovascularization microchannel within the CTO. If the operator does not have enough support to navigate through the microchannels, then upgrading to a stiffer core wire will allow the ability to torque through the "hard plaque" or a high tip load wire to penetrate the hard calcific lesions. The Victory™ guidewire from Boston Scientific is one example of a high tip load guidewire with gram loads ranging from 12 g up to 30 g.

Once a thrombotic occlusion has been excluded and the decision to proceed to a stiffer wire has been made, then careful consideration of crossing techniques, guidewire size, and high tip load comes into play. The operator must first choose between intraluminal versus subintimal crossing for the proximal CTO cap. Finessing a guidewire through microchannels of the CTO may decrease the likelihood of severe dissections after balloon inflations compared to looping a guidewire through the proximal cap, which will routinely take a subintimal course. If finessing the guidewire through microchannels is unsuccessful, then guidewire escalation to the high tip load wires will afford further penetration into the CTO proximal cap but at the increased risk of forming subintimal dissection tracts if the guidewire tip does not penetrate the cap. Careful consideration of the appropriate high tip load wire will ensure increased intraluminal crossing success. Typically, an operator will want to start out with a 12-g tip load guidewire and only escalate to a higher tip load (such as a 30 g) if needed.

Subintimal Crossing

Once attempts at crossing have failed with the previous options, then a stiff hydrophilic wire with a crossing catheter, such as the Rubicon™ (Boston Scientific Corporation), will supply additional support to facilitate wire passage around the calcified proximal cap in the subintimal space, with the plan to re-enter the true vessel lumen in the distal segment of the CTO. The solid-core, hydrophilic wire possesses resilient properties that allow initial entry into the occlusive lumen,

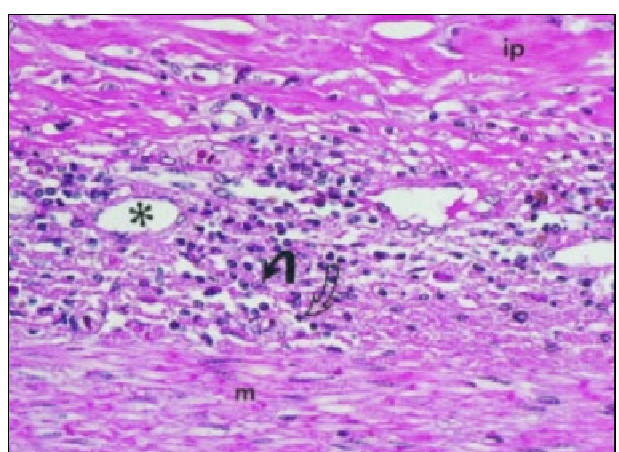


Figure 3. Dense cellular inflammation consisting of lymphocytes (open arrow) and macrophages (closed arrow) within the intimal plaque ("ip") and media ("m") of a CTO immediately adjacent to intimal plaque neovascular channels (asterisk).[2]

followed by purposeful creation of a wire loop to pass into the subintimal space.[5] This re-entry technique involves advancing the support catheter past the proximal CTO cap into the subintimal plane and exchanging the larger-diameter stiff wire for a smaller-diameter stiff wire with a shallow bend to assist in navigating back into the true vessel lumen.

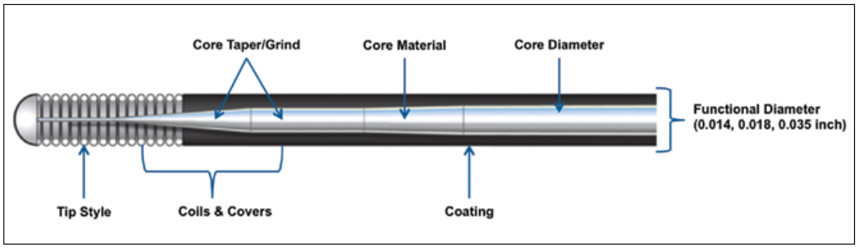


Figure 4. Guidewire composition.

Alternative Access Points

Not all CTOs are the same, as the location of the proximal and distal CTO caps, as well as appearance and morphology, all play a major role in the decisions on how to successfully navigate the lesion. For example, a flush ostial SFA occlusion without a visible beak makes an antegrade approach difficult, because the plane of entry into the cap cannot be ascertained. In such cases, retrograde pedal, popliteal, or direct SFA access with guidewire crossing has improved success rates due to the morphology and often "softer" composition of the distal cap. The choice of access site depends on the length of the CTO, location of reconstitution, and distal vessel runoff.

The longer a CTO has been present imparts increasing complexity to the procedure. As the proximal cap hardens over time, retrograde access via a pedal or popliteal artery may be necessary. Once a retrograde sheath has been placed, this often allows for a softer, small-diameter guidewire to penetrate the thinner distal CTO cap and traverse the occlusion to the patent proximal vessel. When the wire is confirmed to be intraluminal proximal to the occlusion, varying techniques can be employed including finessing the wire retrograde into the antegrade sheath, or snaring the wire using a guidewire retrieval device, to externalize the wire through the femoral sheath and provide a railing for subsequent therapies. If the operator is unable to externalize the wire, then the retrograde access can be converted to a sheathless access to allow for entry of bulkier devices.

Advanced Wiring Techniques

More complex balloon and wiring techniques for challenging lesion subsets include controlled antegrade and retrograde subintimal tracking (CART) and reverse CART. The CART technique requires that the antegrade wire remain in true lumen at the proximal cap while the retrograde wire is advanced across the distal cap into a subintimal track, utilizing balloon inflation to dissect the subintimal tract until the retrograde wire can be advanced to the proximal wire location for externalization of the retrograde wire. Reverse CART is the same technique except in the reverse direction. Other complex techniques include inflation of a balloon in one subintimal track and puncturing the inflated balloon

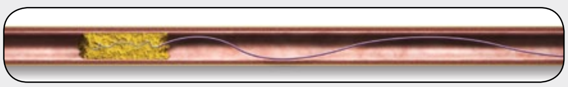
TABLE 1. GUIDEWIRE CHARACTERISTICS: IMPACT ON CLINICAL PERFORMANCE

Feature	Performance Characteristics	Clinical Relevance
Tip: Shape (straight, angle, J)	Steerability	Vessel access/selection, safety of positioning within vessels
Tip: Material	Shaping, shape retention	Durability and pushability
Tip: Taper	Tip stiffness	Lesion crossability, penetration power
Tip: Covers (coils, polymer sleeve)	Tactile feedback and torque response	Vessel access, lesion crossability
Core: Material (stainless steel, nitinol)	Torque (steering) and durability	Technique to advance/cross, wire durability
Core: Diameter	Support	Device deliverability/pushability
Core: Taper length	Trackability and support	Vessel access, device delivery/pushability
Coating (hydrophilic, silicon, PTFE)	Lubricity	Lesion crossing, smooth tracking of devices

TIPS FOR OPTIMIZING WIRE SUCCESS

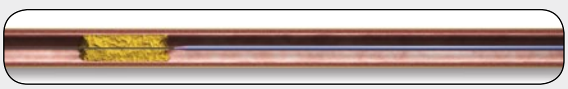
If the wire tip prolapses at the cap, use a wire with a higher tip gram load, or advance the support catheter near the tip.

If the proximal segment of the tip buckles, use a wire with a higher tip gram load, a hydrophilic-coated wire, or advance a support catheter near the occlusion.



If the wire enters the subintimal space and fails to re-enter true lumen, shape/angle the guidewire tip to facilitate re-entry, change support to the wire tip by exchanging to a different catheter tip shape, or utilize a re-entry device.

If the wire crosses but the device fails to cross, change to a wire with higher rail support, advance the sheath closer to the occlusion, create a wiggle wire, or exchange for a lower-profile system.



with a high-tip-load guidewire from the reverse access to create a continuous path from true-to-true lumen. A variation of this technique involves balloon inflation in two subintimal tracks from the antegrade and retrograde approach at the same level to allow dissection of the two planes into a single communicating channel that can be wired in one direction to create a single lumen.

Re-Entry Challenges

Various re-entry strategies may need to be employed for successful revascularization of CTOs. Re-entry has the highest degree of success in lesions that reconstitute above the adductor canal, where the vessel is relatively large. If the occlusion does not collateralize until the popliteal artery or lower, re-entry becomes more challenging.

In SFA CTOs involving the adductor canal, a combination of antegrade and retrograde crossing is utilized, with a preference toward remaining intraluminal, as re-entry in this vascular location has its own challenges. When considering a below-the-knee CTO, finesse from a retrograde approach is paramount to high success rates with a smaller-diameter, soft guidewire, highly torqueable guidewire, such as the Journey™ guidewire (Boston Scientific Corporation, Natick, MA) for navigating tortuous, small-caliber, and difficult-to-access anatomy while remaining intraluminal. If this technique is unsuccessful with a small-diameter guidewire, escalate the wire in a similar stepwise fashion as an antegrade approach by attempting a hydrophilic wire followed by a high tip load wire. If guidewire re-entry fails, the use of a niche device such as the OffRoad™ Re-entry Catheter System (Boston Scientific Corporation, Natick, MA) may facilitate the passage of the guidewire into the true lumen via an antegrade or retrograde approach.

CONCLUSION

As endovascular interventionists continue to treat peripheral arterial disease, CTOs will comprise a significant subset of infrainguinal disease. Although newer technologies aim to facilitate crossing of CTOs, the mainstay of endovascular interventions is wiring techniques and fundamentals of wire escalation (see the Tips for Optimizing Wire Success sidebar). The ultimate goal of procedural success and long-term patency is likely related to the success of crossing CTOs while preserving true vessel lumen. ■

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