Critical limb ischemia (CLI) chronic total occlusions (CTOs) are the most complex and unpredictable of all CTOs. There is no one-treatment-fits-all scenario. In fact, when it comes to CLI CTOs, the approach to each should be unique.

There are many different types of CTOs and CTO caps. The discussion starts with understanding the morphology of the CTO caps, and learning the best tips and tricks to increase chances of successful CTO crossing.

Almost all CTO caps are composed of two types of geometric morphology known as convex and concave. Figures 1a–d show the most common combination of concave and convex CTO types, and are referred to as PRIME CTO Types I, II, III, and IV.

Access

Before discussing how to cross concave vs. convex CTO caps, let’s discuss the best method of access to ensure the highest rate of successful CTO crossing. Newer sheaths such as the Slender sheath (Terumo Medical) have significantly increased the options for access and delivery of crossing tools from an alternative route. A low-profile 4/5 Fr Slender sheath can be safely placed where needed, allowing the operator to take advantage of the CTO crossing support by advancing crossing tools into the concave caps of the CTO. With this simple alternative access, the operator can increase the crossing success rate, lower the complication rate, and decrease contrast and radiation utilization.

In this author’s practice, retrograde access in combination with antegrade access is the most common form of CLI crossing—but it’s far from the only approach. CLI CTOs are typically multilevel and impact multiple vessels, so to ensure revascularization to the intended target vessel, obtaining retrograde access in that targeted vessel is essential before proceeding with a retrograde angiogram. Next, the operator progresses to antegrade access, followed by an angiogram and finally crossing.

Of course, not all cases require retrograde tibial access. However, if the proximal CTO cap is in the SFA/popliteal region, and reconstitution is in the mid to distal tibials, retrograde tibial access can be an optimal approach.

Tips and Tricks in Crossing a Convex CTO Cap

The attempt to cross a CTO should be taken very seriously. To achieve a high rate of successful CTO crossing, one must align the CTO crossing tool into the concave portion of the CTO cap. It makes sense to attempt to cross a cap that is already shaped in a way that is going to welcome the crossing tool, rather than redirecting from the center of the CTO. A sure way to cross the concave CTO cap is by placing an angled, robust catheter, such as the Navicross 0.035” (Terumo Medical) followed with a preferred crossing wire. The Navicross possesses the ability to deliver one-to-one dependable pushability. Combining torque and pushability are two of the most valuable fundamentals of CTO crossing.

The convex CTO cap scenario is definitely far more challenging to cross than a concave CTO cap, but is far from impossible. One should be realistic when attempting to cross a convex CTO cap. Any forces exerted onto the convex cap will immediately direct the crossing tool into the path of least resistance, which in this case will be the junction between the base of the CTO cap and the vessel wall. From this starting point, the procedure becomes somewhat more predictable and realistic. Focus should now shift to using the torque and pushability to the operator’s advantage.

Again, using the angled Navicross, take it down to the junction as mentioned above. Take multiple views to orient to the direction of the tip of the Navicross toward the base of the convex cap, and the center of the target artery or vein. Now the operator is ready to advance the wire of choice to cross the most complex portion of the CTO.
In this scenario, the preferred technique is to use stiff wires with high-gram tips, such as the Approach 25 CTO 0.014” wire (Cook Medical), Astato 20 0.014” wire (Asahi Intecc) or the Astato 30 0.018”. If one of the wires penetrates the base of the cap into the center of the vessel, follow it with the Navicross. Once in the center of the vessel, switch to a stiff-angled glide wire such as the Glidewire Advantage 0.018” or 0.035” (Terumo Medical), depending on the amount of calcium and the length of the lesion.

- If the lesion is short (< 150 mm) with mild to moderate calcification, continue with the Glidewire Advantage 0.018” (Terumo Medical).
- If the lesion is long (> 150 mm) and/or shows severe calcification, switch to the 0.035” Glidewire Advantage.
- If the wire advances straight, make certain the Navicross is always close to the tip (within 40 mm).
- If the wire tip is looped, take extra precaution to keep the wire loop < 7 mm to lower the wall dissection rate.
- Lastly, if the wire enters the subintimal spaces, most re-entry tools perform better when subintimal swelling is < 7 mm.

**Therapy Delivery**

After access and CTO crossing, the next step is to deliver therapy from the main access—the preferred method—or if necessary, an alternative access. Access reversal is a crucial step in CTO crossing, especially as it pertains to CLI CTOs.

Optimal access reversal is performed by simply parking an angled Navicross proximal to the CTO cap, and advancing a retrograde wire—such as Glidewire Advantage 0.018”—into the antegrade Navicross. Keep pushing the retrograde wire until it is externalized from the groin access, essentially flossing the wire from the retrograde access through the antegrade sheath. Next, advance the Navicross over the wire distal to the distal cap and remove the retrograde wire.
Access reversal happens after the CTO is crossed and the retrograde wires are snagged and externalized from the antegrade CFA access. The therapy wire is delivered and can be flossed via the retrograde access for extra support or parked in the distal tibials. This author’s personal preference is to keep the wire flossed over a micropuncture dilator.

Antegrade CFA access should be the primary access for CLI CTO crossing and treatment. Antegrade access provides significant efficiency in wire torque, pushability, trackability and the ability for treatment devices to reach the tibial-pedal junction in case the pedal loop needs to be reconstructed.

Antegrade access is not recommended in the presence of a flush SFA CTO, high-level SFA/profunda bifurcation, or a diseased ipsilateral CFA.

The Schmidt Technique

The Schmidt technique (Figures 2a–c) is defined as direct access into an occluded artery or vein, preferably under ultrasound guidance. Following access, the next step is to advance the access wire either in the occlusion material or preferably in the subintimal space. The Schmidt technique can result in successful crossing of complex CLI CTOs after a previous failed attempt.

The Schmidt technique has value, especially in long (> 400 mm) CTOs in that it can provide access much closer to the CTO cap that has been difficult to cross. Most commonly, Schmidt technique access is used to cross a CTO cap via the concave portion. Most Schmidt technique access attempts require only a small caliber or low-profile sheath or dilator with crossing wire alone or with a catheter. Either combo is acceptable, but the latter is preferred.

Once the cap is crossed, the access is reversed and the Schmidt access is removed in the presence of a balloon tamponade. In this author’s experience, the Schmidt access site often tends to get hemostasis primarily from the luminal plaque, which tends to recoil into place after the entry element is removed. The Schmidt technique is valuable, and can be obtained in all target vessels as needed. It can be performed under direct fluoroscopy or ultrasound. This author personally prefers ultrasound guidance, but the pioneer of this technique, Andrej Schmidt, MD, prefers fluoroscopy.¹

As we dive into more complex CTO crossing in CLI patients, one type of complex CTO that has been identified is the occlusion of all tibial arteries beyond the ankle strap. What can be done with this type of CTO? One option is to attempt dual retrograde tibial Schmidt access above the ankle and below the gastrocnemius head, followed by antegrade CFA access. The retrograde access provides a much needed source of controlled pushability, supporting retrograde crossing of the long CTO.

What can be done if both the retrograde and antegrade crossing tools are in different intimal and subintimal spaces? First, be aware that the entire CTO segment is a non-contributing vessel segment. Therefore, an operator can do any of the following connecting procedures: SAFARI, CART, RE-CART, and RE-BACK.

All of these connecting procedures allow the operator to complete the most viable task of CTO crossing, which is the flossing of a wire or wires. Once the flossing is present, the procedure moves into the second stage of crossing—luminal creation in the flossed segment. This can be accomplished by simple balloon angioplasties, including dual antegrade/retrograde kissing angioplasty or dual antegrade kissing angioplasty. Once flow is established, move to the final stage: crossing beyond the retrograde Schmidt access sites. It is best to attempt this approach via telescoping combined with sequential angioplasty.

The telescoping approach is used to combine multiple catheters to create enough antegrade support to cross the final segment between the tibial-pedal segment and the pedal circulation. There are multiple combinations that can be used. This author’s approach is as follows:

1. Place an antegrade, 90 cm Navicross catheter in a 6 Fr, 35 cm Pinnacle Destination sheath (Terumo Medical).

2. Once the Navicross is in the target tibial artery, add a microcatheter (0.014”), which has a low profile, including the same outer diameter (OD) from tip to base. Note: non-tapered crossing catheters are crucial in CTO crossing, especially when utilizing the flossing technique. tapered-up catheters do not allow for telescoping due to the large mid-to-proximal catheter OD. Once the microcatheter is at the level of the retrograde Schmidt access, pull back the flossing wire into the microcatheter, and proceed to crossing into the pedal circulation.

3. At this point, no one wire suffices for all. Be prepared to use multiple wires and escalate appropriately. Start with a 0.014” Glidewire and escalate incrementally in the tip gram as needed. In many situations, the crossing calls for the combination of “wire escalation and de-escalation,” which refers to escalating to high-gram tip wires in straight segments and back to low-gram tips in tortuous segments. It is necessary to go back and forth until the crossing is done.

4. Once in the distal pedal circulation, switch back to floppy-tip wires, and take extra caution not to dissect the pedal arches. Sequential balloon angioplasty allows a chronically occluded
artery to slowly expand to its natural lumen diameter. Therefore, in tibio-pedal reconstruction, consider starting with 2.0 mm long balloons, and escalate in a sequential fashion with two-minute inflation times.

AV Reversal

In situations where pedal arterial conduits do not exist, there is a last-resort approach—arterial venous (AV) flow reversal. This technique is performed via antegrade arterial access and retrograde venous access. An Outback Elite Re-Entry Catheter (Cordis) is advanced in the artery via an antegrade approach and a retrograde 5.0 mm x 60 mm balloon is advanced in the vein.

Once in position, the venous balloon is inflated and the Outback catheter is directed to the balloon. The needle is fired from the artery to the balloon. Once balloon rupture is seen, an antegrade wire is immediately advanced into the retrograde venous balloon. The balloon is pulled out with the antegrade wire, and an arterial venous connection and flossing is created.

Proceed to breaking the venous valves with high-pressure balloon angioplasty. Venous branches are coiled as needed, and covered stents can be used. The goal of this procedure is to create flow reversal via the venous conduits into the capillary trees with tissue oxygenation to follow. Over time, venous arterialization can occur. This procedure is in its infancy, and continues to evolve as the need for end-stage CLI therapy grows.

Conclusion

Complex CTO crossing in CLI patients is one of the most challenging procedures, and the demand for such procedures is on the rise. Luckily, new low-profile tools and techniques have allowed operators to excel in these type of procedures. Successful crossing will require a combination of tools, as there is no one tool suitable for all patients at this point. Therefore, operators must become familiar with the current tools and techniques for successful completion of complex CLI procedures. The future will continue to bring more challenges, but hopefully more tools as well to combat this tyrant of a disease known as CLI.

Bibliography