Balloon Angioplasty in Tibioperoneal Interventions for Patients With Critical Limb Ischemia

J.A. Mustapha, MD, and Larry J. Diaz-Sandoval, MD

Tibial arterial disease represents the final frontier in the battle against critical limb ischemia (CLI). Isolated infrapopliteal (IP) disease is mainly seen in the elderly (>80 years old), diabetic, and dialysis-dependent patients with CLI. With the development and evolution of catheter-based technology, endovascular therapy (mainly balloon angioplasty) has become the method of choice for revascularization in these patients. The most common challenges are the severely calcified lesion recalcitrant to dilation (as calcium is heterogeneously distributed in the arterial wall) and the long tibial chronic total occlusions. Percutaneous transluminal angioplasty achieves a technically successful result (<30% residual stenosis) in most cases, but it is limited by high restenosis rates. Although several devices have been used in the IP arena (including orbital and directional atherectomy, laser atherectomy, “contact” atherectomy [CROSSER, Bard], and re-entry devices), percutaneous transluminal angioplasty with plain old balloons has been the subject of most studies with several modified iterations, that is, cryoplasty, cutting balloons, focal force balloons, nitinol-“cage”–constrained balloons, tapered balloons, and most recently drug-coated balloons. In this article, we share our current approach to endovascular IP endovascular interventions. We cover the spectrum from pathophysiology, clinical indications, equipment choices, and procedural steps used in our laboratory when treating patients with CLI (which is synonymous with complex anatomy). Regarding what represents the “gold standard” for the treatment of IP disease, a definite answer is currently not available, as multiple studies looking at new generation drug-coated balloons used alone or in combination with different forms of atherectomy are currently under way. We anxiously wait for these results and in the meantime continue to design newer approaches.

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collaterals. These types of collaterals can sustain a limb but cannot heal a wound. Re-establishing blood flow to the affected area is the mainstay of therapy. Until recently, a surgical bypass to relieve inflow disease was considered the gold standard. However, patients with CLI tend to have severely calcified arteries, which represent a challenge for both surgical and endovascular revascularization techniques. Surgical bypass is feasible in ambulatory patients with a reasonable surgical risk, long occlusions, a patent IP artery that provides direct flow to the foot, and an adequate autologous venous conduit. The candidacy of patients with CLI for bypass is often compromised by poor or inadequate length of autologous vein, poor skin nutrition, significant medical comorbidities, and calcified, diseased targets. With the development and evolution of catheter-based technology, the Trans-Atlantic Inter-Society Consensus II document states that “there is increasing evidence to support a recommendation for angioplasty in patients with CLI and infrapopliteal artery occlusion.” A hybrid approach where major vascular conduits can be bypassed (mainly the superficial femoral artery [SFA]) and an endovascular technique to re-establish flow in the outflow vessels (most commonly tibial arteries) is one of the newly proposed global strategies.

From the endovascular standpoint, one of the most common challenges is the severely calcified lesion that is difficult to dilate by balloon angioplasty. The distribution of calcium in the arterial wall is heterogeneous: there are different densities of calcium deposits in all 4 quadrants of a given arterial cross section, which are randomly distributed in all 3 arterial layers. We have observed isolated intimal, medial, and adventitial calcium foci, which occur either independently or in random combinations. The presence of calcium in the arterial wall makes it resistant to the opposing force generated by the increase in barometric pressure offered by balloon inflations. The heterogeneous distribution of calcium densities is synonymous with a heterogeneous distribution of resistance, which during interventions leads to an unpredictable distribution of pressure vectors that follow the “path of least resistance” increasing the risk of dissection, plaque rupture, and embolization with the ensuing “no-flow” phenomenon (Fig. 1 depicts variations in calcification in the cross section of an artery).

CTOs of the tibial arteries add yet another major obstacle to operators in their quest to save limbs while treating patients with CLI.

Based on the angiosome concept, patent tibial arteries are of utmost value to patients with Rutherford classification V-VI. Operators who consider the angiosome concept would be driven to attempt revascularization of totally occluded tibial arteries, in the setting of a patent single-vessel runoff to the foot (with or without disease). A patient with this anatomy does not have sufficient flow to provide necessary nutrition to support wound healing. Ischemic wounds do much better and heal much faster when they have the appropriate artery supplying the territory of the ischemic ulcer in a direct manner. When this is not feasible, attempts should be made to open as many conduits as possible, as the volume of blood that reaches the foot has been postulated as “second best” when direct in-line flow to the wound is not attainable.

Indications and Contraindications

The primary goal of IP endovascular therapy is to obtain relief from the ischemic rest pain, facilitate healing of ulcer or gangrene, prevent limb loss or limit the extent of amputation, and permit wound healing after any type of amputation. Amputation above the ankle is generally defined as a major amputation, whereas amputation at or below the ankle is a minor amputation. In critically ill patients, those unable to cooperate, and those with recent myocardial infarction, severe arrhythmia or electrolyte imbalance treatment should be discussed and undertaken in the presence of a cardiologist, an anesthesiologist, or both. In patients with impaired renal function, alternative CO2 use instead of standard contrast media can be considered. The clinical scenarios where endovascular infrapopliteal interventions are considered appropriate or rarely appropriate are listed in the Table.

Equipment for IP Interventions

A complete array of dedicated BTK equipment is essential to perform tibial interventions in an effective and safe manner. The choice of wires to be used in treating tibial occlusions spans the spectrum from “work horse wires” to dedicated, specialized “CTO crossing wires.” The operator will alternate between the 2 groups depending on the stage of CTO crossing. The dedicated CTO wires are mainly used to actually cross the CTO caps, while the work horse wires are used to deliver catheters to their desired location, after the caps have been crossed. The idea is to minimize the use of the more aggressive dedicated CTO wires, therefore decreasing complications.

Wire Selection Features

(1) Platform: 0.014, 0.018, and 0.035 in
(2) Tip stiffness (gram weight)
(3) Length

Figure 1 Variability of calcium densities in arterial wall. Peripheral plaque is composed of variable layers and islands of different densities that are mildly, moderately, and severely calcified. These densities have a different depth, width, shape, and location. (Color version of figure is available online.)
These features determine the transmission of force at the tip of the wire and the control in its maneuverability. Another important factor in choosing a wire is the location of the target lesion location (proximal or distal).

A sample of the most utilized wires and catheters in our CLI program is given here:

**Work Horse 0.014-in Wires**
- Runthrough (Terumo) hydrophilic wire with hydrophobic cap for tactile feedback; nitinol shaping ribbon provides tip durability.
- Journey (BSC) steerable wire; works well with the CROSSER device (Bard Medical).
- Regalia (ASAHI).
- Mailman (BSC) stiff wire used for support.

**CTO Crossing 0.014-in Wires**
- Approach (Cook Medical) 12, 18, and 25 g.
- Astato XS 20 g ASAHI
- Porter (Bard Medical): 3, 6, and 12 g; 195 and 300 cm length

**Work Horse 0.018-in Wires**
- Glidewire Gold (Terumo)
- SV5 (Supportive rail) (Cordis)
  - Length (cm): 60, 145, 180, 260, and 300

**CTO Crossing 0.018-in Wires**
- Treasure 12 g (ASAHI) 1-piece steerable tip.
- Astato 30 g (ASAHI)

**Work Horse 0.035 in**
- Glidewire (soft and stiff) (Terumo) used mainly to traverse major vascular conduits.
- Magic Torque (BSC) stiff wire, which provides support that is used to advance sheaths from a contralateral approach and to advance catheters through tight stenoses or occlusions in the supragenicular vessels.
- Glide Advantage (0.035 in): Atraumatic tip and supportive body.

**Crossing Catheters**

**0.035 in Catheters**
- (1) Navicross (Terumo) (angled and straight), 90-135-150 cm. Double-braided catheter. Provides excellent support and its hydrophilic, atraumatic tip allows its advancement without necessarily having a wire in front of it.
- (2) CXI (Cook) (angled and straight), 90-150 cm.
- (3) Trailblazers
- (4) Sleek
- (5) Glide Catheter (angled and straight)
- (6) Quick Cross
- (7) Valet Microcatheter (Volcano)

**0.018-in Catheters**
- (1) CXI (angled and straight)
- (2) Quick Cross

**0.014-in Catheters**
- (1) Trailblazer
- (2) Quick Cross
- (3) Seeker
- (4) Valet Microcatheter (Volcano)
- (5) Fine Cross
- (6) ASAHI Corsair Crossing catheter: This is a specialty catheter that we are applying in the Pedal vessels.

**Re-entry Catheters**
- (1) Enteer (Covidien).
Tibial Revascularization

Low-Profile Balloons

Percutaneous transluminal angioplasty or balloon angioplasty (the current “gold standard”) achieves a technically successful result (<30% residual stenosis) in most cases but is limited by high restenosis rates. Flexible, low-profile balloons (Advance Micro 14 by Cook, Ultraverse by Bard) have enhanced the ability to cross, and successfully treat, focal, multifocal, diffuse, and occlusive tibiopedal lesions. The Advance Micro 14 balloons can be used through the 2.9-F Cook tibial-pedal sheath (Fig. 2), and therefore, it can be used to perform retrograde tibial angioplasty from tibiopedal access points.

Balloon catheters are available in different lengths and mounted in different shafts to allow treatment of the entire IP artery with 1 or 2 inflations. Unfortunately, efficacy data are lacking, as clinical studies are limited by the heterogeneity of disease, lack of randomized trials, multiplicity of techniques used, exclusion of early treatment failures, crossover to open bypass during follow-up, lack of long-term patency, and less-than-optimal limb salvage rates. Restenosis after IP balloon angioplasty is common within the first year and is dependent on the size of the artery and length of diseased segment. Negative predictors include diabetes mellitus, chronic kidney disease, nonambulatory status, and increasing severity of ischemia at the time of presentation.

Cutting Balloon and Focal Force Angioplasty

Balloon angioplasty has been the subject of most studies, but several modified balloons have been used, that is, cryoplasty and cutting balloons. There are no comparative data for these newer modalities vs balloon angioplasty for IP arteries, although studies in other vascular territories have been negative. Cutting balloon angioplasty (Boston Scientific, Natick, MA) may be appropriate for undilatable or resistant lesions that are fibrous or calcified, but the added cost and lack of comparative evidence make these balloons not ideal for routine use. Anecdotal evidence exists for its use in ostial and anastomotic lesions. Focal force balloons such as the Vascutrak (Bard) and Angiosculpt (Angioscore) are designed to apply localized and focal force to the arterial wall in an attempt to distribute the pressure vectors that interact with the plaque in a more homogeneous pattern. The desired result is a decrease in the barotrauma induced to the vessel wall, and by creating a more homogeneous distribution of the barometric vectors generated by the balloon inflation, there is a decrease in the likelihood of dissections and perforations. We typically use these balloons in long calcified SFA and tibial lesions of patients with diabetes and renal disease either as stand-alone therapy or after plaque modification with different atherectomy devices.

Nitinol Constraining Structure

The Chocolate balloon (TriReme Medical) features a unique nitinol constraining structure design that reduces dissections by shielding the vessel wall from the typical torsional stress caused by standard balloons. The “nitinol cage” creates “pillows” that uniformly distribute the pressure along the entire balloon surface, decreasing the likelihood that certain parts of the balloon in contact with more heavily calcified portions of the lesion could lead to barotrauma, dissection, and even perforation, thus resulting in greater safety and less recoil with excellent angiographic results in complex and calcified lesions (Fig. 3).

Tapered Balloons

The NanoCross (Covidien) balloons come in different sizes with the distal end of the balloon being tapered 0.5-mm smaller than the proximal end. These combinations (2.5 to 2.0, 3.0 to 2.5, and 3.5 to 3.0) allow for treatment of the...
The entire limb is exposed on top of a sterile ulcerated wounds, these are covered with sterile materials. To be intervened on is “painted” with Betadine or chlorhexidine all the way from the groin to the toes. If there are any restenosis. The latest published study is drug-eluting arterial injury can potentially limit the amount of clinical inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks. The inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks. The inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks. The inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks. The inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks. The inhibition of the intimal hyperplastic response to adventitia of the artery and remain detectable for weeks.

**Procedural Steps**

In our laboratory, we always recommend sterile skin preparation of both groins. In patients with CLI, the limb to be intervened on is “painted” with Betadine or chlorhexidine all the way from the groin to the toes. If there are any ulcerated wounds, these are covered with sterile materials. The entire limb is exposed on top of a sterile field to allow for extravascular ultrasound (US) imaging of the entire limb, which facilitates the retrograde US-guided access in the tibiopedal vessels as well as assists us in guiding the intervention and maximizing the chance of staying inside of the true lumen. The site and direction of the arterial access (antegrade ipsilateral or retrograde contralateral) depend on the inflow status. The contralateral retrograde common femoral artery (CFA) approach is rarely recommended, as often equipment does not reach the distal tibial vessels. Antegrade ipsilateral access provides the ability to deliver coaxial force in a unilinear vector, which increases the likelihood of successful crossing of long complex CTOs. It also provides the ability to perform distal injections to assess the status of the pedal vessels more accurately and ultimately provides the ability to potentially treat BTA vessels in the event of embolization, dissection, or other distal complications, which would be potentially impossible to perform with a contralateral approach (specially in tall patients). In our laboratory, it is common practice to use tibial or pedal access routinely, as most patients with CLI have CTOs with antegrade convex caps, which require the assistance of a retrograde wire and catheter support to actually cross the CTO and allow for complete revascularization. When concomitant ipsilateral CFA occlusive disease is present, surgical patch atherectomy and BTK revascularization can be performed simultaneously if the institution counts with a hybrid suite and CLI team. If this is not available, a contralateral puncture can be performed immediately or soon after endarterectomy or the endovascular treatment can be scheduled at least 2 weeks after surgery to facilitate the ipsilateral CFA or SFA puncture with safety. In nonobese patients without iliac, CFA, or very proximal SFA lesions, a direct antegrade puncture is preferable because it offers superior pushability and trackability of the devices used to cross hard calcified distal occlusions, while allowing easier catheter and guidewire maneuvers. It should be noted that the retrograde crossover technique can be almost impossible in cases of extremely tortuous iliac arteries, hostile aortic bifurcations, “Y” prosthesis, or abdominal aortic stent grafts. The aim of the intervention is to obtain at least one (“direct, in-line blood flow to the wound”) but preferably 2 or even 3, patent BTK vessels down to the distal foot. This approach is based on maximizing the volume of blood that reaches the foot.

The procedural steps are as follows:

US-guided puncture is used to facilitate fast and precise arterial access. With US guidance, the operator can choose to access either the CFA or the SFA selectively. Puncture of the SFA has the advantage of a more direct route but is associated with more bleeding complications. Popliteal and tibial-pedal access should be performed under US guidance. Some authors advocate the use of fluoroscopic guidance when there are vessel wall calcifications. At our institution, we routinely use US guidance as it allows precise visualization of the needle path, vessel depth, surrounding veins and nerves, and the ideal puncture site along the vessel path (depending on lumen size, calcification, occluded segments, etc). A small real-time injection of contrast should be performed after sheath placement to adjust the position of the sheath in case it is occluding the entire tibiopedal segment, positioning the smaller distal end of the balloon in the smaller distal vessel, and transitioning proximally to a larger size. We use this balloon especially when treating the tibials and below-the-ankle (BTA) vessels at the same time (Fig. 4).

**Drug-Coated Balloons**

Drug-coated balloons deliver antiproliferative drugs to the arterial wall at the time of dilation. With inflation times of 30-60 seconds, antiproliferative drug (paclitaxel, sirolimus, and everolimus) levels have been shown to reach the field to allow for maximization of the volume of blood that reaches the foot. This approach is based on maximizing the volume of blood that reaches the foot.

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Baseline selective arteriograms of the whole limb are obtained. At our institution, this tends to be done at a separate date, preceding the intervention in an attempt to minimize dye and radiation exposure and to aid in the planning of the interventional strategy, which includes the planning of the necessary ancillary staff (US technician, anesthesia support, assisting scrub nurse, and physician for dual access cases) and the “setup” of the room for the intervention. For selective angiography, the catheter is positioned at the level of the P3 segment of the popliteal or at the tibial trifurcation and super-selective digital subtraction angiography is performed. In general, optimal visualization of the upper and middle third tibial arteries is gained in an ipsilateral oblique projection. The origin of the anterior tibial (AT) artery is best visualized in the contralateral oblique projection. The body of the AT is best visualized in the ipsilateral projection. Imaging of the distal tibial arteries and the foot is best achieved in a contralateral oblique projection with foot abduction that produces a lateral arteriogram of the foot. The optimal projection to visualize the common plantar artery bifurcation, the dorsalis pedis artery, and the pedal-plantar loop is the lateral oblique projection. To visualize the pedal-plantar loop and the tarsal and metatarsal arteries, an anteroposterior projection of the foot should be obtained. The target tibial vessel is generally catheterized with a 0.014- or 0.018-in support catheter and lesions crossed with the wires of respective sizes. The 0.018-in systems provide more column strength and pushability, whereas the 0.014-in systems are less traumatic and have a lower profile. In very distal lesions, a low-profile, 2- or 2.5-mm, balloon catheter may support the wire. In cases of subintimal crossing, a 0.018-in guidewire is appropriate. Over-the-wire balloon platforms are used, given their superior pushability, ability to inject through, and ability to exchange wires if needed. Heavily calcified vessels represent a challenge for both intraluminal (suboptimal inflation) and subintimal (difficulty in reentering into the true lumen and increased risk of rupture) angioplasties. The balloon or stent dimensions are chosen according to the reference vessel diameter and lesion length by visual or quantitative vessel analysis. In our laboratory, we exchange wires if needed. Heavily calcified vessels represent a challenge for both intraluminal (suboptimal inflation) and subintimal (difficulty in reentering into the true lumen and increased risk of rupture) angioplasties. The balloon or stent dimensions are chosen according to the reference vessel diameter and lesion length by visual or quantitative vessel analysis. In our laboratory, we
traditionally use prolonged (2 minutes), low-pressure (2-4 atm) inflations. In case of suboptimal results due to inadequate dilation, elastic recoil, and dissection, a second inflation either with a larger diameter balloon or for a longer period of time can be performed. If the dissection is flow limiting, the balloon should be kept inflated for a period up to 3 minutes at the nominal balloon pressure. If the dissection persists after additional balloon dilatation, bailout stenting is the only solution. The stent types available for BTK include balloon and self-expandable bare metal stents, as well as balloon-expandable drug-eluting stents.17,18

Efforts should be made to improve the tibial runoff with additional BTA angioplasty of significant distal stenoses because the vessels may occlude rapidly without adequate outflow. Stenting in this specific area is not

![Figure 7](image1.png)

**Figure 7** Anterior tibial CTO. (A) Right AT and PT proximal CTOs. (B) The most common tibial CTO reconstitutions around the anterior and posterior communicating arteries.

![Figure 8](image2.png)

**Figure 8** Anterior tibial CTO. (A) Left AT and PT proximal CTO. (B) Distal tibial runoff from the antegrade angiogram. (C) Distal tibial-pedal runoff from simultaneous antegrade-retrograde angiogram.
recommended. A potential future surgical bypass is always an option, if an undamaged, unstented landing zone is preserved. A final angiogram that includes the foot is mandatory. Efforts should be made to treat more than 1 tibial vessel, especially in cases of little additional procedural risk, as this has been reported to improve

Figure 9 Anterior tibial CTO. A closer look shows the tibial CTO caps and the distal tibial-pedal reconstitutions. Even though the DP reconstitution is not clearly filling well, it does not mean reconstitution does not exist. Ultrasound evaluation and access usually show more hibernating pedal vessels than angiography does. DP, dorsalis pedis. (Color version of figure is available online.)

Figure 10 Selective tibial-pedal angiography. Notice the amount of hibernating vessels in the distal tibial distribution and the pedal circulation after selective tibial access and angiogram. (Color version of figure is available online.)
limb salvage. In recurrent surgical anastomotic stenosis and tight calcified lesions (typical in patients with diabetes) nonresponsive to conventional balloon angioplasty, cutting or high-pressure balloons may be used.

Types of Tibial CTO and Crossing Strategies

The choice of crossing strategy is based on the type of tibial CTO to ensure a higher crossing success rate. There are many

Figure 11 Final angiogram after revascularization of the anterior and posterior tibial arteries.

Figure 12 PT revascularization: (A) After PT CTO crossing, (B) After PT CTO angioplasty, and (C) Final runoff to the plantar and calcaneal branches.
anatomical variations in tibial CTOs that are beyond the scope of this article. Figure 5 shows the heterogeneous distribution of calcium conforming the CTO caps, and Figure 6 shows an example of the CTO cap morphology analysis.

AT Artery
The most common AT CTO is the proximal CTO cap, usually found 10-30 mm distal to the ostium of the tibial artery. The AT is frequently occluded at the site of the takeoff of its large anterolateral branch, preserving the proximal 10-30 mm of its segment. The most common distal reconstitution is located around the anterior communicating artery, which usually fills the distal AT via the peroneal artery (PA) (Fig. 7).

In this illustrating case, we demonstrate the CTO therapy of the AT and the posterior tibial (PT) by using dual retrograde tibial access and single antegrade CFA access as well as selective tibial-pedal angiography (Figs. 8-11).

These figures illustrate the value of combined antegrade-retrograde arterial access and selective angiography, which significantly enhances visualization of hibernating lumens, “real” length of occlusions, and morphology of CTO caps, which provides us with an unparalleled and unprecedented ability to plan and perform endovascular interventions for limb salvage cases. Notice the complexity of the disease process. By having antegrade and retrograde access, one can increase the “crossability” and final successful therapy by 50%.

PT Artery
The most common site of a proximal PT CTO is localized approximately 10 mm from its ostium, as shown in Figure 7. The most common reconstitution site of the PT CTO is around the posterior communicating artery, in the distal third of the leg above the ankle. This vessel also feeds the distal runoff via the personal artery (Fig. 12).

Peroneal Artery
The most common CTO of the PA includes the ostium. The reconstitution is usually in its distal one-third and mostly fills retrograde via either the anterior communicating artery...

Figure 13  PA revascularization. (A) Blue arrows show the CTO caps of the TPT and PA. The white arrow shows the PCA. (B) Improved flow in the TPT and PA after crossing the CTO caps with CROSSER 14S (Bard Peripheral Vascular). (C) White arrow shows the Chocolate balloon 3.5 mm x 80 mm (TriReme Medical) inflated at 9 atm for 2 minutes in the TPT and PA. (D) Chocolate balloon pulled back and reinflated in the TPT or PA and popliteal. Also notice the 0.014-in wire in the AT for protection. (E) Final angiogram showing excellent flow into the previously occluded TPT and PA. Also notice the intact flow in the AT. PCA, posterior communicating artery. (Color version of figure is available online.)
or the posterior communicating artery, which communicate the PA with the AT and PT, respectively (Fig. 13).

**Crossing Techniques**

The preferred access strategy for successful tibial CTO crossing is a combination of antegrade CFA or SFA with retrograde tibial single or double (AT, PT, or a combination).

**Tibial CTO Crossing Techniques**

The best working view to cross proximal AT, PT, and PA CTOs (if working with fluoroscopy guidance) is an ipsilateral oblique view at 30°. This opens the fibula and tibia and positions the AT, PT, and PA between the bones, making the arteries and crossing devices easier to visualize. This view also shows the bifurcation of the PT and PA, which helps to more accurately identify these 2 vessels. It is always best to start with a supporting device when crossing tibial CTOs such as a catheter or sheath.

The most common approach is to place a long sheath, positioning the tip around the popliteal area. Then engage the tibial artery with a variety of soft tip wires. When treating proximal PT and PA CTOs, make sure your support catheter is within the proximal PT or PA before initiating the use of heavy gram tip wires. This technique allows you to protect the section of the distal TPT and the ostial PA (if crossing PT) or PT (if crossing PA) that are in close proximity. Keep in mind that most of these patent proximal AT, PT, and PA segments do have plaque buildup in the range of 30%-50% and when crossing the ostium on the way to the CTO cap, it is necessary to avoid disruption of the nonocclusive plaque in the patent segment, which could lead to a devastating dissection or occlusion. To avoid this, start with a soft tip wire with an atraumatic tip-angled catheter, such as the 0.35 in Navicross (Terumo Medical, NJ), 0.35 in or 0.18 in CXI (Cook Medical, IN) or angled 0.18 in Quick Cross (Spectranetics, CO).

The Regalia (ASAHI, Japan), Journey (Boston Scientific), or Runthrough (Terumo) wires have an excellent 1:1 torque and atraumatic tip that are easily maneuvered to the proximal AT, PT, and PA CTO cap and provide enough support to advance the angled support catheter.

Once the support catheter is at the CTO cap, you can choose to initiate CTO crossing with CTO wires such as the Treasure 12 g, 20 g or Astato 30 g (Asahi, Japan), Approach 12 g, 18 g, or 25 g (Cook Medical), PT2 or Victory (Boston Scientific). Crossing devices such as the CROSSER 14S or 14P are an excellent choice in tibial CTOs as well. If an operator has to limit the choices to 2 work horse wires for tibial CTO crossing, the authors recommend starting with a soft tip wire and exchanging to a heavy gram tip wire of the operator's choice. Other Crossing options are presented by the CROSSER (Bard) and Viance (Covidien) catheters, which are especially helpful in long TPT, PT, and PA CTOs (given their “straighter” course).

![Figure 14](image-url) Complex CTO from distal SFA or P1 Segment without obvious reconstitution. (A) Proximal CTO cap at distal SFA or P1 segment of the popliteal. (B) No obvious popliteal or tibial reconstitution. (C) Distal complex CTO caps: C1: PT or PA bifurcation. C2: Angulated takeoff of the AT. (Color version of figure is available online.)
Figure 14 shows a complex CTO, which starts in the distal SFA or P1 segment of the popliteal. There is no obvious reconstitution, except for a very short segment of the proximal AT and what appears to be the bifurcation of the PT and PA.

This case represents the typical example of a patient who was referred for above-the-knee amputation and came to us for a second opinion. The “lack” of tibiopedal runoff “eliminates” the surgical and endovascular options. However, at our institution, we proceeded to perform detailed US mapping of the tibial vessels, and segments of “patent lumen” were seen in all the distal vessels. We then obtained US-guided antegrade CFA access and retrograde AT access. A 2.9-F Cook tibial-pedal sheath was placed in the AT and heparin (60 U/kg) and nitroglycerin (200 μg) administered. Then we manipulated a 0.014 Journey wire into the peroneal. This was followed by retrograde trans-tibial balloon angioplasty of the AT or TPT or proximal peroneal. Retrograde angiogram revealed improved tibial runoff. At this point, a 0.035 in Navicross catheter was advanced in an antegrade fashion and the proximal CTO cap crossed using a 6-gm 0.018 in wire under US guidance. The catheter was advanced under US guidance into the ostium of the AT and easily crossed with the wire. The retrograde wire in the AT was introduced in the antegrade catheter using US-guided “SYNAPSIS” and the retrograde wire exteriorized at the groin. The Navicross was removed and then a 0.018 CXI catheter was advanced in antegrade fashion into the distal AT. The retrograde wire was removed and introduced in antegrade fashion. The retrograde sheath was removed and the antegrade wire manipulated into the foot, past the point of retrograde access. Extensive antegrade balloon angioplasty was performed in the popliteal, TPT, and AT using an Ultrasound balloon. Results of antegrade angioplasty were suboptimal and stenting of the popliteal or TPT was performed. Final angiogram revealed thrombolysis in myocardial infarction III flow through the AT and peroneal into the foot (Figs. 15 and 16).

Tips and Tricks

**Tip #1:** When crossing a tibial CTO, rotate the fluoroscopy camera to ipsilateral oblique 30°, which positions all proximal tibials between the fibula and the tibia. This also helps bring out tibial wall calcification, which can help significantly while crossing long CTO segments.

**Tip #2:** After engaging the target vessel in an ipsilateral oblique view, start rotating the heavy gram tip wire back
and forth at 180° rotations with slight forward push on the wire while using a drilling motion. Try to always keep a supporting catheter at approximately 2-10 mm from the tip of the wire.

**Tip #3**: As you rotate and advance the heavy gram tip wire forward, avoid bowing of the tip of the wire especially at the last 2 cm of the tip. This can lead to (1) subintimal entry, which becomes difficult to rotate away from, and (2) perforations, which always need to be treated with proper attention to make sure compartment syndrome does not occur.

**Tip #4**: For crossing the proximal tibial CTO cap, a 12-g straight wire with angle support catheter is very helpful.

**Tip #5**: For crossing the distal tibial CTO cap, it is also helpful to cross with a 12-g tip wire and angled catheter. If this fails, place a 45° bend on the distal 1 mm of the wire tip, which tends to significantly help to cross the distal cap, especially if the wire or catheter was in the subintimal space.

**Tip #6**: After crossing the proximal and distal cap of the tibial CTO, make certain your support catheter is advanced past the distal CTO cap, confirming the intraluminal position.

**Tip #7**: Once the catheter confirms intraluminal position, exchange to soft tip atraumatic wire to advance the wire deep into the distal tibial-pedal tree to avoid losing control. The soft tip wire is then used to exchange to a second stiff wire to deliver the operator’s preferred method of therapy.

**Tip #8**: After intervention, it is not recommended to remove the wire until full selective angiogram is performed and any form of perforation, embolization, dissection, or distal sluggish flow has been ruled out.

### Potential Complication Sites

Tibial CTOs are complex arterial conduits that need to be revascularized with caution. All attempts should be made to restore flow to the pedal arches to achieve optimal CLI therapy. Complications in the interventional management of tibial CTOs can be divided by vessel thirds:

- **Proximal one-third**: These are associated with most surgical complications (ie, compartment syndrome and arterial rupture requiring exploration).
- **Middle one-third**: These are less likely to require surgical exploration or repair following endovascular intervention. Caution still is of paramount importance.
- **Distal one-third**: In this region, most if not all complications are treated with endovascular techniques.

### Re-Entry From the Tibial Subintimal Space to the True Lumen

The tibial arterial wall is thin and should be crossed primarily with a 0.14 in wire system when possible. When

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**Figure 16** Final angiogram post complex intervention. (A) After extensive antegrade popliteal stenting, there is 2-vessel runoff through the AT and PA. (B) Distal 2-vessel runoff.
crossed subintimally, re-entry is primarily accomplished with US guidance by use of an angled 0.018 in catheter with a heavy tip wire featuring a short 90° bend at the tip or by use of the Enteer catheter (Covidien, Minneapolis, MN), which is a balloon-based device. It has 2 wire exit ports that can lead to the true lumen with a specialized angled wire that comes with the device.

In summary, IP intervention has already been shown to be safe and efficacious. As with any other interventional procedure, experience correlates with improved outcomes. As acknowledged by Liistro et al14 in their study of drug-coated balloons, their results may have been in part influenced by its single-center nature in a high-volume practice with a unique patient referral pattern, interventional technique, and integrated multidisciplinary approach. Ideally, operators and teams should strive to reproduce these features, as we have in our laboratory, to make this kind of results more generalizable or “real-world” representative.

Further studies with longer follow-up are necessary to be able to answer some of the remaining queries about safety and efficacy, especially when it refers to the potential use of these technologies into the next frontier for CLI therapies, currently represented by BTA interventions.

References