

Antegrade Approach for CTO PCI

An overview of the current optimal approach regarding imaging and wire selection and manipulation.

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Restoration of normal antegrade flow can be very important for many patients with chronic total occlusion (CTO) and attributable symptoms, ischemia, and/or ventricular dysfunction/dysrhythmia.¹ Technical success remains lower for CTO PCI than for PCI of non-CTO lesions and remains a major impediment to optimally managing patients with coronary CTO. Although overall CTO PCI success rates have remain largely unchanged (approximately 50% to 70%, depending on the definition of CTO and lesion characteristics) over recent years, there have been improved success rates (approximately 90%) reported at several experienced centers with focused CTO operators who have made changes in strategy and wire design. This article focuses on the current, optimal antegrade approach for CTO PCI, specifically regarding angiographic and ultrasound imaging and wire selection/manipulation. Innovative retrograde approaches, new technologies, and biologic/pharmacologic plaque digestion will be discussed in accompanying articles in this issue. The techniques discussed in this article are an amalgam of expert opinion and my viewpoint.

PREPARATION

In ideal circumstances, CTO PCI should be a planned procedure and not performed ad hoc. This provides a more optimal circumstance for strategic planning, angiographic review, and time allocation. In addition, patient contrast load and single-setting radiation exposure may

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be minimized. The diagnostic angiograms are best performed with a focus on CTO lesion details and an emphasis on the projections that are most likely to be subsequent interventional working views. This imaging is best performed with prolonged exposure to fill collateral and distal CTO beds and minimal magnification to reduce the need for panning. Therefore, the entire vessel trees and collateral architecture can be more accurately accessed. A recent practice that I have used during diagnostic angiography is to upsize to an 8-F introducer sheath and place bilateral 4-F diagnostic catheters into the left coronary artery (LCA) and right coronary artery (RCA). These bilateral injections more clearly define the nature of the CTO and will provide a more accurate representation of the views seen by similar bilateral imaging during the interventional procedure as collateral sourcing occurs from the contralateral coronary artery. The CTO angiograms should be carefully reviewed, often by single frame-by-frame analysis, to better understand (1) the nature of proximal and distal caps, (2) the calcification and suspected angulation in the CTO segment and target

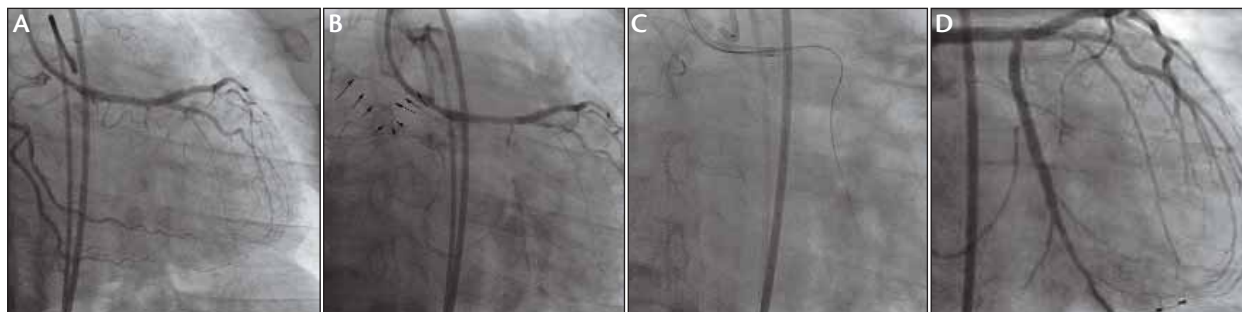


Figure 1. Supraselective collateral injection. Baseline angiograms using left coronary and right guide catheters demonstrate short segment proximal left circumflex coronary artery (LCx) CTO (A). An Excelsior (Boston Scientific Corporation, Natick, MA) microcatheter was placed into an atrial branch of the RCA (black arrows) and used for selective injection (B). The LCx and the distal cap was much better visualized (C), and contrast requirements were subsequently much reduced. An Excelsior microcatheter with Fielder XT wire (Abbott Vascular, Santa Clara, CA) was used to cross the lesion, and angiographic and clinical success were achieved with placement of two drug-eluting stents (D).

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vessel, (3) lesion length, (4) collateral vessel pattern and anatomy, (5) relationships with side branches, and (6) donor and CTO vessel characteristics for catheter selection.

CTO PCI can be performed as a transfemoral, transradial, or transbrachial procedure based on patient anatomy and operator preference. It is ideal to have 7- to 8-F access and a guide catheter for the antegrade approach. However, I believe that 8-F access provides more optimal support for equipment delivery and more options for concomitant imaging (intravascular ultrasound [IVUS]) and wire manipulation, anchoring techniques, etc. While the transfemoral access is in use, a long sheath (35 cm) may augment passive guide support and reduce the deleterious impact of iliac tortuosity on wire handling and device delivery. Guide catheter selection is a crucial part of the procedural strategy and should be individualized to each patient. In general, extra backup guides are useful for CTO PCI of the LCA, and either soft curve or aggressive curve (left Amplatz [Cook Medical, Bloomington, IN]) can be used for CTO PCI of the RCA. The soft curves may slightly improve wire manipulation, but the tradeoff is poorer support. The soft curves can be considered for CTO PCI of the RCA when the proximal side branches are available for anchoring (discussed later in this article) or when ostial disease is present. Otherwise, and

particularly when excessive calcification and tortuosity are present, more aggressive guides, such as the left Amplatz, hockey stick, and right backup should be considered to guide, support, and improve device delivery. Side hole catheters are a wise choice for CTO PCI of the RCA given the proclivity for right coronary spasm, pressure dampening, etc, and should be considered when a small or diffusely diseased left main artery is present in CTO PCI of the LCA.

Optimal angiographic technique may be the most important preparatory and procedural determinant for success in CTO PCI. In virtually all circumstances in which contralateral collaterals to the CTO vessel exist (even when ipsilateral collaterals are present), dual-catheter placement and bilateral dual-injection imaging should be performed. In the case of antegrade CTO PCI, a diagnostic 4- to 6-F catheter in the donor vessel will usually suffice. It is too often the case that operators consider the second catheter after failure mode has begun, rather than to direct wire placement correctly from the procedure outset. In the case of ipsilateral and/or bridging collaterals, it is often the case that imaging of the vessel distal to the CTO will become poorer when guide catheter engagement or CTO manipulation occurs. However, even poor contralateral collaterals can offer benefit and guidance when this occurs. Furthermore, note that contralateral imaging for wire placement can reduce the likelihood of extending dissections that occur with antegrade injections or test puffs in a vessel with dissection but without current outflow. This is a common mistake made by inexperienced operators. In addition, a dominant collateral can often be identified that lends to selective collateral imaging. A microcatheter can be placed into this collateral, and superior imaging and detail (with trivial

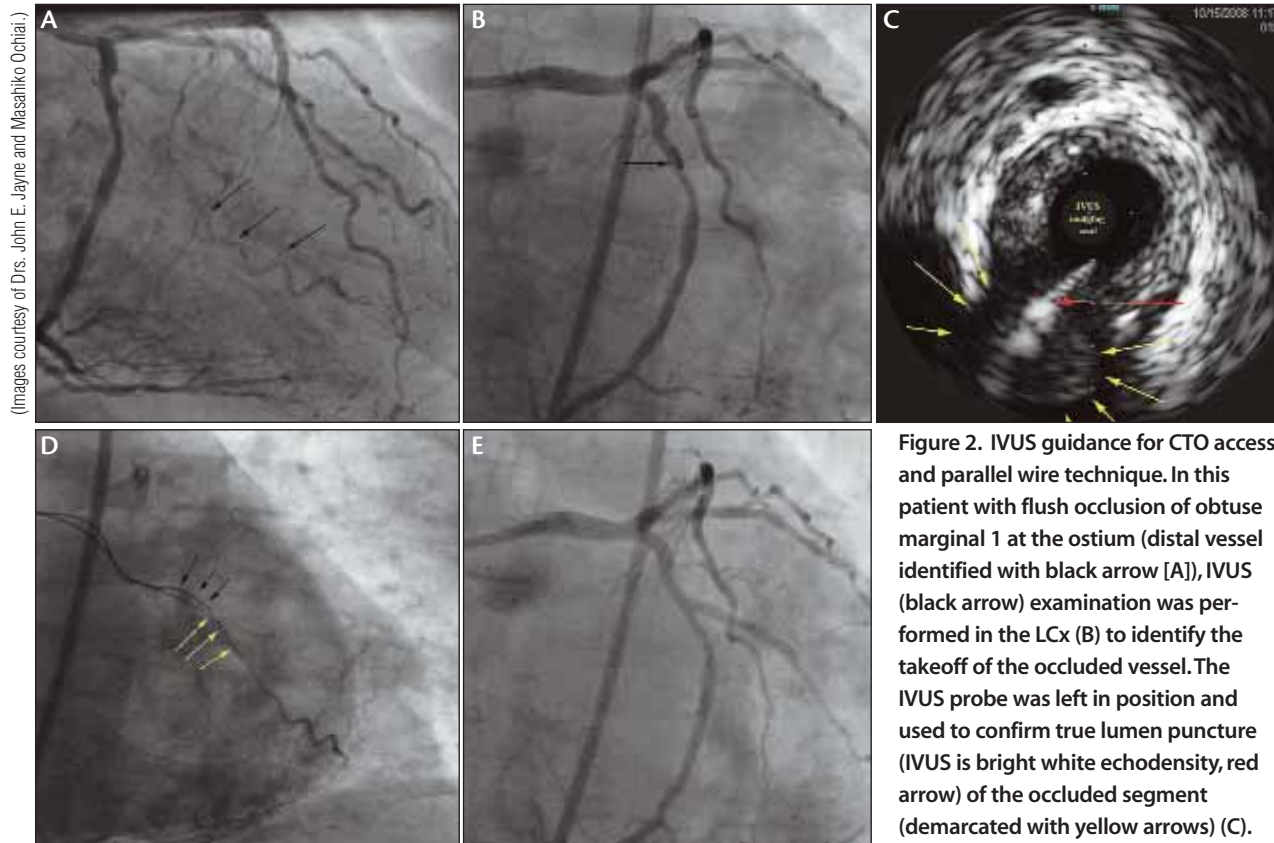


Figure 2. IVUS guidance for CTO access and parallel wire technique. In this patient with flush occlusion of obtuse marginal 1 at the ostium (distal vessel identified with black arrow [A]), IVUS (black arrow) examination was performed in the LCx (B) to identify the takeoff of the occluded vessel. The IVUS probe was left in position and used to confirm true lumen puncture (IVUS is bright white echodensity, red arrow) of the occluded segment (demarcated with yellow arrows) (C). The first wire (black arrow [D]), a 3g

Miracle Bros went offline into the false lumen but was left in place as a marker of the vessel and to improve angulation for subsequent attempt. A second, parallel wire (yellow arrow [D]), in this case, Confianza Pro, was redirected to the true lumen, and the final angiographic result is shown after PCI and DES placement (E).

amounts of contrast) can be achieved (Figure 1). The ultimate goal of this preparation stage is to create an environment that is leveraged for success by maximizing all possible advantages and minimizing uncertainty.

IVUS can add great value in understanding the CTO environment, guiding lesion wiring, and reducing ambiguity. There are three primary methods for current IVUS platforms: (1) identification of the proximal cap location using IVUS in the side branch; (2) real-time or subsequent confirmation of accurate wire penetration into the proximal cap; and (3) IVUS in the false lumen to direct true lumen wiring. When the antegrade approach is performed for a flush occluded vessel at a side branch (Figure 2A), it is generally very helpful to perform IVUS to identify the location and characterize the proximal CTO (Figure 2B and 2C). This can be correlated with angiographic landmarks. Wiring can be attempted with the IVUS in position to verify correct wire placement (Figure 2C), or the IVUS can be withdrawn into the guide and reinserted after wire placement, should it physically interfere with wire manipulation. In addition,

note that IVUS can be beneficial in determining true lumen wire positioning in circumstances when this is not clear by angiography and can help optimize stent deployment.

APPROACHING THE LESION

The strategies of initial antegrade approach may be quite variable and depend on very specific details of lesion and vessel anatomy and architecture. In general, the initial wire attempt uses wire designs and techniques intended to minimize trauma to the artery and within the CTO segment. Support catheters (microcatheters or over-the-wire balloons) offer benefit for multiple wire exchange, which is frequently needed in CTO PCI and to augment or reduce the gram force exerted at the wire tip by adjusting proximity of the support catheter tip to the wire tip. I prefer microcatheters for this purpose because of their tendency to be less stiff and therefore maintain position coaxial to the artery and, because the distal tip marker is useful for showing the position for wire exchanges. However,

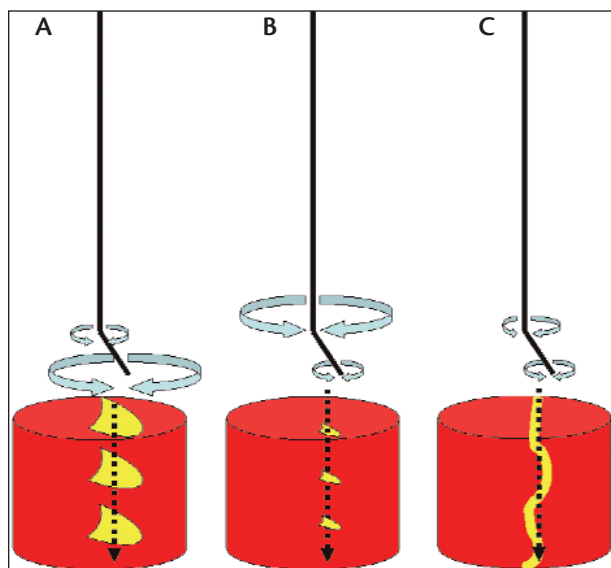


Figure 3. Wire manipulation techniques in CTO PCI. Methods to manipulate wires during CTO PCI include (1) the controlled drill technique (A), in which the wire is pivoted from the bend site (small curved arrows) in a to-and-fro fashion to crush tissue isolated within a quadrant of the CTO; (2) penetration technique (B), in which the wire is advanced along an imaginary vessel path with minimal rotation (when rotation is necessary to reduce friction, it should occur with the wire direction oriented in the intended path and pivoted from the tip [small arrows], with effort to reduce over rotation); and (3) sliding technique (C), in which a polymer-sleeved wire is negotiated with minimal force and rotation to negotiate pre-existing microchannels.

advocates of over-the-wire balloons argue for improved support strength and efficiency for initial lesion dilation after successful wire crossing. Regardless of the support system chosen, it is customary to probe the lesion initially. Traditionally, this has been performed with floppy-tipped, workhorse-style wires, but more recent trends by expert operators include (1) starting with a single-core, CTO wire (eg, 3g Miracle Bros [Abbott Vascular]) for its properties of torque control within the lesion plus a reasonably soft tip, or (2) probing for microchannels (which histologically may be present in half of CTOs) with a tapered, polymer-jacketed wire (Fielder XT, Abbott Vascular). If inability to penetrate the proximal cap or move forward within the lesion occurs, progressively stiffer wires can be used (eg, 4.5-, 6-, or 12-g Miracle Bros to improve crush force and maintain torque control; 9- or 12-g Confianza [Abbott Vascular]; or 9-g Persuader tapered wires [Medtronic, Inc., Santa Rosa, CA]) to improve lesion penetration. In general, wires should have minimal tip bend (15° – 30°)

approximately 1 mm from the tip for optimal performance in the CTO. A secondary bend further back in the wire aids in negotiating vessel tortuosity or awkward approach angles.

Wire manipulation can be divided into three broad approaches, which are best matched with wire design and operator preference:

Controlled Drill

The controlled drill method of wire manipulation is predicated on the supposition that a to-and-fro motion while torquing, being cautious to keep the drilling within a 90° arc, minimizes the likelihood of creating large dissections and can improve torque control and tactile response by reducing stored force. Controlled drill is a very standard technique for CTO PCI and is well suited for single-core wire designs, such as the Miracle Bros series. The pivot point for this method is at the primary bend of the wire (Figure 3A). In concept, the operator is using crush force to grind through a quadrant of the CTO.

Penetration Technique

Fibrotic, calcified, and nontortuous segments are the most well suited for this method. In the penetration technique, the wire is moved forward along the imagined vessel path. The stiff, tapered wire designs of the 9- and 12-g Confianza Pro and 9-g Persuader are best suited for this method. Visual and tactile feedback are reduced (but do exist) with this method and tapered wires and remain valuable observations for the operator. In the penetration method, rotation is often necessary to reduce the frictional coefficient or direct the tip. When the wire fails to progress, manipulation occurs with the pivot point at the wire's tip, with the wire direction oriented in the intended path (Figure 3B). As in controlled drilling, care must be taken not to over rotate the wire and extend dissection.

Sliding Technique

The sliding technique (Figure 3C) is well suited for lesions with known or suspected microchannels, and is best employed with polymer-sleeved wires. In this circumstance, the operator should minimize the amount of manipulation with controlled or penetration drilling techniques and make efforts to direct the wire and allow its lubricity characteristics to follow the vessel path.

It is common for wires to transit from the occluded lumen into the subintimal or subadventitial space. When this occurs, a standard and effective countermeasure is the parallel wire technique (Figure 2D and E and

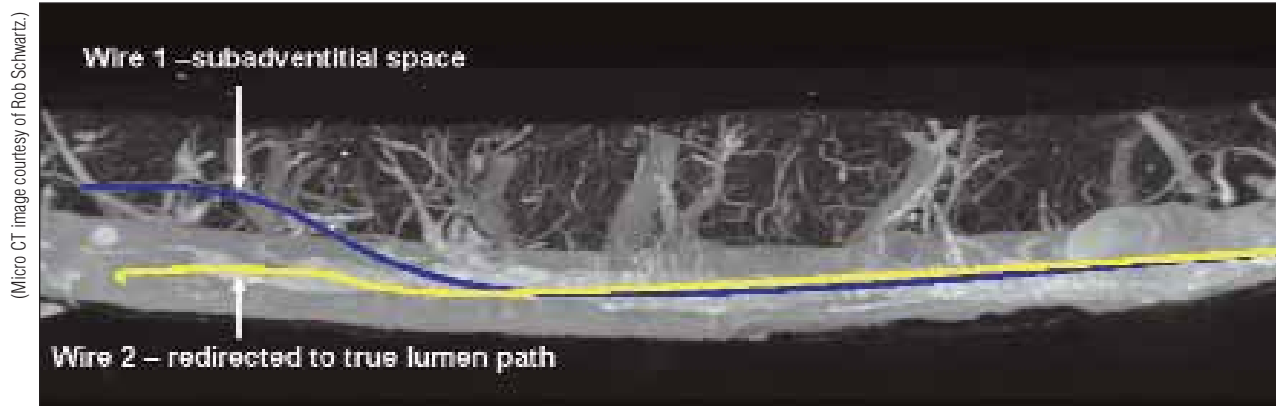


Figure 4. Parallel wire technique. When a guidewire exits the true lumen of an occluded vessel, it may be left in place to minimize further vessel trauma or expand a false channel. This wire serves as a marker and can obstruct entry into the false channel. A second wire, chosen for properties to avoid this same path (eg, greater tip stiffness, penetration properties, etc.) is advanced alongside the first, to the point of the first wire's exit and then redirected along the true, imagined, vessel pathway.

Figure 4). The initial wire is left in place to serve as a visual marker and to obstruct entry into the false lumen. A second wire (with support catheter) can be advanced alongside, or in contact with, the original wire to the point where the initial wire left the occluded true lumen. This point is determined by visual (wire behavior, angiography) and tactile cues. The second wire, chosen for properties to overcome the first wire's failure mode, is advanced along the true occluded lumen's imagined pathway. These properties typically include greater stiffness or transition to a penetration-style wire. Occasionally, polymer-sleeved wires have a role in parallel wiring as well. A variant of the parallel wire technique is seesaw wiring, in which these first and second wires are alternated in the parallel wire approach until distal true lumen wire placement is achieved. The parallel wire technique is a cornerstone of standard antegrade contemporary CTO PCI.

Other approaches have been developed for refractory coronary CTO when the aforementioned methods fail and when the retrograde approach is not an option. The subintimal tracking and re-entry (STAR) technique,² described initially for coronary CTO PCI by Colombo et al, is a method of intentional subadventitial dissection with a polymer-sleeved wire (to reduce friction) with an umbrella handle shape (a very tight curve) on its tip that prevents wire exit and tracks the vessel. This wire can be advanced along the subadventitial space to the distal portion of the vessel, where it may spontaneously re-enter the true lumen at side branches or when the vessel caliber is too small to continue propagating the dissection. It is critical with this technique to maintain a small J loop at the tip of the wire. This technique typically causes extensive dissection that should be repaired

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with stenting. Side branches often become occluded by the enlarged false channel and require the STAR technique to be performed again in order for these occluded side branches to be recanalized. The durability of the PCI result with the STAR technique appears closely coupled with the final number of patent side branches. This technique is reserved for refractory CTOs with strong indications for revascularization and should only be performed by operators experienced in this technique. A variant of this technique, using contrast injection within the CTO, can be performed to help separate the subadventitial layers and facilitate forward wire movement and cross connections between true and false channels.^{3,4} Because of its proclivity to shear side branches, the STAR technique is best suited for conduit-style vessels with minimal branching structure, such as the RCA of obtuse marginal artery branches. This technique should be reserved for more experienced CTO operators.

Another novel concept currently in development (C. Thompson, New Haven, CT and W Lombardi, Bellingham, WA, unpublished data) is the vessel destruction and repair (VDAR) technique. As with the related concept of STAR, VDAR is reserved for refractory CTO in patients with very strong indications and no

alternative for IVUS guidance or retrograde approach. In VDAR, a polymer-jacketed wire is advanced in the sub-adventitial space to a large side branch, with or without knuckling the tip. At this point, a support catheter is advanced to this space, and a penetration wire (9-, 12-g Confianza Pro) is used to attempt pre-side-branch re-entry. Other wires that appear suitable are the 12-g Miracle Bros and Pilot 200 (Abbott Vascular). If this re-entry maneuver is unsuccessful, a stiff gram force, polymer-jacketed wire (Pilot 200) is advanced, without knuckling, to the small terminal branches for distal re-entry, with parallel wire performed as needed. Once true lumen access is achieved and confirmed without ambiguity with angiography or IVUS, PTCA can be performed to fenestrate the vessel and open the true lumen from the distal entry to the proximal segment. Because the false lumen is intentionally maintaining compression at the major side branch points (eg, across the posterior descending artery in RCA interventions, for instance), side branch closure is less common than with the STAR technique and is much easier to reconstruct. In many ways, this technique is more complex than even retrograde procedures and therefore should be reserved for more experienced operators.

COMPLICATION PREVENTION AND MANAGEMENT

It is imperative that the operator and nursing/staff team managing the patient focus on avoiding complications as well as preparing to manage them. Thresholds for patient radiation and contrast exposure should be determined prior to the procedure and constitute a reasonable stopping point if progress is lacking at that point in the PCI procedure. Pericardiocentesis, covered stent grafts, and coils or other embolization materials should be immediately available to manage the rare, but potentially catastrophic bleeding complications. Hemodynamic and pacing support should also be available.

In general, vascular wire exits and dissections within the occluded segment are well tolerated. However, device exits (balloons, stents, atherectomy) from the CTO segment are often not tolerated, so care should be taken to ensure subadventitial positioning within the total occlusion and distal true lumen wire control prior to therapeutic device utilization. In addition, vascular wire exits in distal small branches and dissections that encroach runoff vessels distal to the CTO may not be well tolerated. Distal small vessel perforation can often lead to hemodynamic instability and should be avoided when at all possible. Stiff wires should be exchanged for floppy-tipped, workhorse wires as soon

as possible after distal true lumen access is achieved. Dissections that begin to compromise runoff vessels or important collaterals are often a good reason to stop the procedure and reassess the need for future attempts.

CONCLUSION

Optimal contemporary antegrade CTO PCI in 2009 is predicated on strategy and operator CTO-specific PCI experience. Measures such as bilateral or selective collateral angiography and IVUS are important to optimally understand the CTO environment and to determine safe and effective strategic approaches. The current generation of support catheters and wire platforms adds great value to achieving technical success. The best methods to manipulate these wires include controlled drilling with robust single-core wires, penetration techniques with stiff, tapered wires, and probing/sliding methods with polymer-sleeved wires. The parallel wire technique and seesaw wiring is the first and best initial method to troubleshoot a wire that has left the occluded vessel true lumen. Various wire-based dissection and re-entry techniques exist for a small subset of CTOs refractory to these standard approaches but are best left to operators with CTO-specific PCI experience. CTOs should not be performed ad hoc but rather as planned procedures unless exceptional circumstances are in play. The keys to antegrade CTO PCI success are a thorough and well-prepared strategic plan, intraprocedural adaptation, optimal technique, and a procedural environment leveraged for success. ■

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