Conquering the Last Frontier of Interventional Cardiology

Strategies and tools for facing coronary artery chronic total occlusions.

BY RAJESH M. DAVE, MD, FACC, FSCAI

Recanalization of a coronary artery chronic total occlusion (CTO) improves ventricular function and resolves regional wall motion abnormalities.1,2 A registry analysis of 8,000 consecutive patients after diagnostic coronary angiography identified the presence of at least one CTO in 52% of the patients having significant (≥70% diameter stenosis) coronary artery disease; the presence of the CTO was the strongest predictor against subsequent treatment with conventional percutaneous coronary intervention (PCI).3 Successful coronary CTO intervention could therefore defer a patient from a first bypass procedure or be a welcome alternative to a high-risk second or third bypass procedure. Either scenario captures the essence and importance of understanding how to achieve a successful outcome in this patient subset.

Significant advances in guidewire-crossing, microsupport catheter, and re-entry device technologies and evidence-based clinical equipoise for the use of a drug-eluting stent in the CTO environment have perhaps outdated the reference to the coronary CTO as a “last frontier of PCI.”4-6 Collateral flow or collateralized territory at risk after restoration of flow through the occluded artery, patient comorbidities, and lesion characteristics must be thoroughly considered before proceeding with a CTO intervention. Equally important, operator expertise with the procedure and familiarity with the most appropriate ancillary equipment and techniques are mandatory to optimize the probability for a successful technical outcome of any CTO procedure.

Appropriate lesion and patient selection are critical for achieving an event-free hospitalization and index procedure. A careful review of baseline angiography will determine the suitability of the occluded segment to successful recanalization. Favorable features include a reference vessel diameter of at least 3 mm, absence of heavy calcification, no side branch involvement, and a visible segment of artery distal to the occlusion. Guidewires, support catheters, or crossing devices should be readily available during the procedure. Last, and perhaps of greatest importance, is that adequate time must be allocated to procedure setup, diagnostics, and procedure completion. Coronary CTO lesions can be recanalized, and the purpose of this review is to describe two methods that have been successful in my practice.

**FUNDAMENTAL CTO TECHNIQUE**

Optimal visualization in multiple views coupled with excellent guide catheter support is critical at the start of any procedure. I strongly recommend visualization of the reconstituted collateralized distal segment with simultaneous contralateral injections. The guide
catheter must provide coaxial engagement of the coronary ostium with the XB, VODA, GL, or EBU curves serving left coronary interventions well with the Amplatz (Cook Medical, Bloomington, IN) being a universal guide catheter for access to the right circulation. It is beneficial to use a low-profile support catheter or over-the-wire balloon catheter in conjunction with a good support guidewire to approach the proximal segment of the CTO lesion. Besides providing support, it also allows safe exchange of guidewires without compromising the tip shape of the guidewire. Guidewire placement within the distal true lumen is imperative before balloon angioplasty or atherectomy treatment. Heparin anticoagulation is the preferred option during a CTO procedure to allow for protamine reversal in the event of a significant perforation. A patient presenting with known history for heparin-induced thrombocytopenia may not be an appropriate patient for CTO intervention.

GUIDEWIRE TYPES

Two types of guidewires are useful for crossing a CTO. Hydrophilic straight-tip guidewires can spontaneously gain entry into a CTO and track well through soft plaque. The deficiency of this type of guidewire is that it can easily enter a subintimal plane when it encounters harder fibrocalcific plaque. I most often use a guidewire having a weighted and relatively stiff spring tip and overall design intended specifically for crossing a CTO. CTO-specific guidewires, such as the Asahi Miraclebros and Asahi Confianza (Abbott Vascular, Santa Rosa, CA), have become my guidewires of choice. Both guidewire families are designed to provide increased torque response, tactile feedback during approach and crossing, and excellent steerability—features that are very useful in gaining primary wire placement across a CTO. The trackability and ability to intentionally direct advancement of these two guidewire families is very useful.

BASIC CROSSING STRATEGY

There are two fundamental strategies for primary wire placement: the drilling method and the penetration method. During drilling, a .014-inch guidewire is advanced and retracted with active rotation during advancement. The advancing distance is determined based on the resistance felt as the guidewire is rotated while being pushed into the CTO. The hydrophobic tip is less slippery than a polymer-coated hydrophilic guidewire, and this characteristic aids in gaining CTO cap and core penetration. The resistance feedback is used to differentiate the true lumen from a false lumen. Occasionally, when trying to cross a chronic CTO with a hard proximal cap, multiple advances and retractions are required to gain entry into the body of the CTO. Sometimes the drilling method will fail with creation of a false lumen; this is always a possibility when attempting to reach the distal true lumen.

With the availability of the Confianza family of guidewires, the penetration strategy has become more popular in my practice. These guidewires have a tapered and weighted tip design with a .009-inch nominal tip diameter. The guidewire has substantially greater penetrability and torque transmission than the Miraclebros or other conventional coronary guidewires. The tapered tip and jointless spring coil design allow this wire to be advanced through a CTO in a predetermined path when the location of the distal true lumen is known based on preoperative imagining results or as evidenced by collateralized flow distally. Multidetector coronary CT angiography data can substantially aid this strategy. A penetration strategy is likely to overcome hard tissue.
in CTOs rather than straying into a false lumen. My clinical practice usually combines the two strategies with drilling as the starting method in most cases followed by penetration when needed. One exception is when a calcified CTO is encountered; for this type of lesion, I consider the penetration strategy the gold standard.

It should be emphasized that any CTO guidewire should always be used in conjunction with a microcatheter or over-the-wire balloon. This avoids excessive movement of the guidewire inside the guide catheter and improves torque transmission. This also facilitates guidewire exchange or changing the tip bends without the loss of CTO lumen gained.

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In either strategy, the guidewire should be advanced using both hands with one hand advancing the guidewire while the other hand rotates the wire approximately 90° to affect the drilling action. The direction of the tip should be frequently examined in several views to assess the direction of tip advancement. The force applied to advance the wire should be gentle at the start and increased as needed.

PROXIMAL CAP PENETRATION

A coronary CTO is formed because of thrombus organization after vessel occlusion initially by fresh thrombus. However, this process is not universally concentric but rather frequently involves edges with calcific and fibrous tissue, which are harder to penetrate. The proximal cap is classified as either tapered or abrupt. Generally, a tapered CTO is much easier to penetrate than the abrupt variety because a hard proximal fibrous cap is not formed. When an abrupt CTO is encountered without a well-defined stump, it requires penetration with hard-tip wires, such as the Confianza Pro or Miraclebros 12 g, from the initial start of the procedure.

DISTAL CAP PENETRATION

I have used three techniques to perform coronary CTO procedures: the parallel wire antegrade technique, the retrograde technique, and the intravenous ultrasound-guided subintimal tracking and re-entry (STAR) technique.

Parallel Wire Antegrade Technique

This is the hallmark and gold standard to coronary CTO intervention. The primary guidewire technique allows safe crossing of CTO microchannels or occasionally subintimal tracking and re-entry into the distal true lumen—this is frequently performed using a parallel wire technique. Stiff metal tip or hydrophilic-coated guidewires are utilized in the parallel wire technique. The Miraclebros guidewires with tip weights ranging from 3 to 12 g, Confianza guidewires, hydrophilic-coated Hi-Torque Pilot guidewires (Abbott Vascular), Choice PT guidewires (Boston Scientific Corporation), and several others, including tapered-tip configurations, are all of potential use. There are active guidewires also in use, examples of which are .018-inch Laser Guide Wire (Spectranetics Corporation, Colorado Springs, CO) and the SafeCross (Spectranetics Corporation) total occlusion crossing system. Newer devices, such as the

Figure 2. Case study with the Tornus wire (Abbott Vascular). A proximal RCA CTO with heavy calcification and bridging collaterals, coupled with simultaneous injection from the left coronary artery showing the distal reconstituted vessel (A). Placement of parallel Confianza 12-g wires, with entry into the true lumen (B). Heavy calcification precluded the use of a 1.5-mm balloon, use of a buddy wire, and the Tornus device 2.1 F used for the creation of a channel for final intervention (C). Final angiographic result after placement of a Taxus drug-eluting stent with intravenous ultrasound guidance (D).
Fronrunner XP catheter (Cordis Corporation, Warren, NJ), are also available for use.

The parallel wire technique consists of leaving a non-crossing first guidewire in place and using a slightly stiffer “buddy wire” to gain entry in the true channel with the first guidewire as a guide. The second guidewire is advanced through a support catheter, such as the Transit Exchange catheter (Cordis Corporation) or Quick-Cross catheter (Spectranetics Corporation), positioned close to the proximal fibrous cap while the stiffer wire is gently worked to enter and pass through the CTO in a different track from the primary guidewire. The advantage is that the force applied to the lesion can be increased by leaving the first wire in the first channel. The final phase of the procedure is the crossing of the distal fibrous cap of the occlusion and may benefit from the use of a stiffer guidewire. Having gained entry into the distal true lumen, a soft-tip wire should be exchanged for the stiffer wire using the support catheter for guidewire exchange. Having established guidewire placement across the CTO, predilation is recommended, typically using a balloon catheter sized to the adjacent proximal lumen diameter (Figures 1 and 2).

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In heavily calcified lesions, a frequent problem is the inability to place the predilation balloon within the lesion despite the presence of a .014-inch guidewire. For this situation, I will first try a Tornus support catheter advanced over the .014-inch guidewire with advancement across the proximal cap and through the calcified segment. Other options available today include the use of a 0.7-mm Laser Guide Wire or a Front Runner or SafeCross crossing device (Cordis Corporation). It is important to recognize that in a difficult CTO, entrance of the first wire into a false channel is almost universal, and therefore knowing how to modify the crossing procedure to a parallel wire technique is extremely useful toward achieving primary guidewire placement.

Retrograde Technique

The retrograde technique for treating a CTO is reserved for those procedures in which the antegrade technique has been unsuccessful, provided a guidewire-compatible straight-line collateralized artery has been angiographically identified originating from another major epicardial artery. An exchange-length .014-inch hydrophilic guidewire is placed within the contralateral coronary artery and advanced into the collateral artery serving the myocardial territory distal to the CTO. Once the guidewire is positioned, a small-diameter over-the-wire balloon catheter is advanced, and the guidewire is exchanged for one with a stiffer tip. This frequently requires dilation of the septal collateral with a 1.25-mm balloon at 2 atm. Newer devices, such as septal dilators, are in development. With the second guidewire positioned for advancement into the distal cap of the CTO, the balloon (1.25–1.5 mm) is inflated to support guidewire advancement. If a parallel wire technique was attempted and failed, leaving the primary retrograde wire within the CTO vessel can be used to guide antegrade wire advancement. The ideal indications for the retrograde technique are still being defined, and newer equipment specifically designed for this technique will soon be introduced into the US market.

Ultrasonic-Guided STAR Technique

Intravascular ultrasound can be very useful in certain circumstances. For example, in a CTO at a side branch, placement of an intravascular ultrasound catheter into the side branch will allow visualization of the entry site and primarily identify the demarcation between a true and false channel. However, this requires predilation of the false lumen with a small balloon for placement of the intravenous ultrasound catheter, which inherently carries a risk of perforation. I consider this a technique of last resort.

Rajesh M. Dave, MD, FACC, FSCAI, is Director, Central Pennsylvania Cardiovascular Research Institute, and Chairman, Endovascular Medicine, Pinnacle Health Heart and Vascular Institute at Harrisburg Hospital, in Harrisburg, Pennsylvania. He has disclosed that he receives grant and research funding from Abbott Vascular. Dr. Dave may be reached at (717) 920-4400; rdintervention@yahoo.com.