The Retrograde Technique for Recanalization of Chronic Total Occlusions

A Step-by-Step Approach

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Chronic total occlusion recanalization still represents the final frontier in percutaneous coronary intervention. Retrograde chronic total occlusion recanalization has recently become an essential complement to the classical antegrade approach. In experienced hands, the retrograde technique currently has a high success rate with a low complication profile, despite frequent utilization in the most anatomically and clinically complex patients. Since its initial description, important changes have occurred that make the technique faster and more successful. We propose a step-by-step approach of the technique as practiced at experienced centers in North America. Because the technique can vary substantially, we describe the different alternatives to each step and offer what we perceived to be the most efficient techniques. (J Am Coll Cardiol Intv 2012;5:1–11) © 2012 by the American College of Cardiology Foundation

In addition to angina relief, chronic total occlusion (CTO) recanalization may provide additional benefits, including avoidance of bypass surgery and enhanced survival (1). To achieve such clinical benefits, the procedure has to be technically successful, and complications must be avoided. Historically, success rates have been limited to 60% to 70% with the antegrade approach (1). Knowledge and expertise in the retrograde techniques have become an essential adjunct for CTO operators to improve success. Using collateral channels (CCs) to reach the distal end of the occlusion subsequently allows for the use of combined antegrade and retrograde subintimal tracking techniques to “connect the dots” from both ends of the occluded segment when conventional antegrade wire crossing is ineffective, unsafe, or inefficient.

Retrograde CTO percutaneous coronary intervention (PCI) was first mastered by Japanese operators (2,3), which opened new perspectives through the use of small CCs. The technique has evolved rapidly, resulting in shortened procedural time and reduced radiation, compared with the early days (4). Important modifications of the retrograde technique have occurred since earlier descriptions, notably the advent of the channel dilator (Corsair, Asahi Intecc, Nagoya, Japan) that substantially streamlines the procedure and has modified the crossing techniques (5). The purpose of this review is to summarize and provide a contemporary, updated step-by-step guide for operators wishing to embark on retrograde recanalization of CTO. For the purpose of this review, only supporting equipment available in North America will be discussed.
This paper absolutely cannot replace proper proctorship through live exchanges and in-laboratory work. Therefore, we discourage embarking on these complex procedures without proper training and proctorship. However, we hope that this paper serves to demystify and clarify some of the complex steps of the procedure.

**Step 1: Angiographic Film and CC Analysis**

Careful analysis of the diagnostic films and review of the indications are crucial before considering the technique. Lesion length is important to estimate, although it is much less of a negative predictor of success than in the classic antegrade approach. Even when robust ipsilateral CCs are present, better imaging is obtained with dual injections. Even weak contralateral support can be competitive with the ipsilateral CCs, and therefore optimal angiography is only obtained with complete filling of the distal collateral bed from all feeding sources. Sufficient injection flow and several view angles are crucial for better understanding of collateral sourcing and maximizing visualization. Lower magnification and avoiding panning considerably helps in evaluating CCs, as CC filling will invariably occur in a dissimilar time frame from the epicardial vessels. It is often the circumstance that a single frame or 2 in an entire series of angiograms will relay the appropriate information to determine therapeutic strategy. Other critical information gained from the diagnostic angiograms are the distal vessel size, estimated amount of myocardium jeopardized, lesion calcification, side branches and morphology of the proximal cap and distal end of the CTO, and presence or absence of ambiguity in the course of the vessel within its occluded segment. Frequently, the distal vessel from the CTO is either underfilled or hypoplastic from lack of flow, but will have an apparent large lumen gain acutely post PCI and/or positive remodeling through intermediate follow-up. The distal end of the occlusion, submitted to lower collateral flow pressure, is often more favorable in terms of shape (tapered entry from retrograde direction) and “softer” (more easily penetrated with guidewires) than the proximal cap, submitted to systemic diastolic blood pressure. Therefore, when several classical risk factors for antegrade failure, such as blunt cap, long occlusion, severe calcifications, tortuosity, and side branches at cap level, are present, the retrograde approach becomes beneficial to increase success. Such classical risk factors are not independent predictors of failure in the retrograde era (6). Analysis of the potential donor artery is also important in terms of size and extent of atherosclerosis.

Analysis of all potential CCs is critical. There are 2 types of CCs: septal and epicardial CCs. Septal CCs are the safest and should be the default choice whenever possible. One must pay attention to the course of the CC from its origin to the distal connection. Severe septal tortuosity is a severe limitation to wire advancement, whereas size is less so. It has been learned that straight, faintly visible or even invisible septal CCs can often be crossed, especially with “surfing” with the guidewire, as described later. From the right anterior oblique (RAO) cranial view, the classic septal CC connecting the left anterior descending coronary artery (LAD) to the posterior descending artery (PDA) has a classic b-shape distal turn near its connection (Fig. 1).

**Abbreviations and Acronyms**

- CART = controlled antegrade and retrograde subintimal tracking
- CC = collateral channel
- CTO = chronic total occlusion
- IVUS = intravascular ultrasound
- LAD = left anterior descending coronary artery
- LCX = left circumflex
- PCI = percutaneous coronary intervention
- PDA = posterior descending artery
- PL = posterolateral
- RAO = right anterior oblique
- RCA = right coronary artery

![Figure 1. Favorable LAD to PDA Septal Collateral](image_url)

Before (A) and after (B) wire passage. Please note the b-shape turn of the wire, when looking from the RAO cranial view. LAD = left anterior descending coronary artery; PDA = posterior descending artery; RAO = right anterior oblique.
course should be looked for when advancing the wire. The RAO cranial view may, however, overestimate the turn. A straight RAO or an RAO caudal view is helpful to obtain the perpendicular view of the distal turn. In general, the less tortuous septal CC that seems to connect should be considered as a first candidate.

Epicardial CC assessment includes length, tortuosity, and size. In general and as opposed to septal CCs, the main criteria for epicardial CCs is adequate size and not extent of tortuosity. Epicardial CCs are almost always tortuous; this is not a contraindication, especially in the Corsair era. Epicardial CCs are longer than septal CCs in general, and this needs to be taken into account before selecting the proper guide catheter equipment. As epicardial rupture is more serious than septal rupture, and because epicardial use may be associated with procedural ischemia, these CCs should be used only if no septal CCs are suitable. One exception is the use of epicardial CCs in patients who had previous coronary bypass artery grafts (CABG) surgery; because of the lack of pericardial space and the presence of a very strong and adherent pericardium, epicardial CCs can be used more safely, as perforation is extremely unlikely to cause tamponade in these patients. Traditional epicardial CCs are between the right ventricular branch and LAD, between the distal LAD and PDA, and between diagonal branches and LAD. Posterolateral (PL) CCs, a type of epicardial CC, may be located on the PL left ventricular wall (connection between the distal left circumflex coronary artery and PL branch of the right coronary artery [RCA]).

We use the Werner classification of CC (7). This classification is germane to stratification of retrograde techniques as well as overall evaluation for CTO PCI with prediction for ischemia (and subsequent ischemia reduction) based on CC size; CC0 being a CC with no visible connection to the recipient artery, CC1 being tiny or faint CC connections, and CC2 being small vessel-like connection. CC0 and tortuous CC vessels have been associated with increased failure, although we believe such small CCs (specifically CC0 septal CCs) should not discourage attempts to cross using a gentle “surfing” technique if there is distal filling of the collateral bed. General determinants of successful epicardial CC wiring include epicardial size versus tortuosity (pitch ratio) in which larger, less tortuous CCs are more successful than those that are small with severe tortuosity (Fig. 2). Size appears to be less of a determinant for successful septal CC wiring with the septal surfing (trial and error) technique, where greater relative magnitude of branching becomes more of a limiting issue.

**Step 2: Setting Up the Procedure**

Dual arterial access is essential with the retrograde technique. Arterial access is generally performed using transfemoral or transradial approaches. A combination of 1 radial and 1 femoral approach can be used to mitigate some of the bleeding risk associated with CTO PCI and allow for more options with antegrade 7-F or 8-F catheters, if needed. The bilateral femoral approach has therefore been advocated by the pioneers, especially in the era of septal balloon dilation. Bilateral transradial approach limits the operator to the use of a smaller 6-F to 7-F catheter but is associated with a much reduced risk of bleeding and better patient comfort (8). It is known that larger catheters can provide more passive support. However, retrograde procedures often lead to deep engagement of the retrograde guide after externalization (described
later), which can be potentially catastrophic with large catheters, especially in the donor artery. Hence, the use of a bilateral femoral or radial approach is a matter of operator preference and experience, and acknowledgment of risks/benefits of both approaches is important. Importantly, we discourage the use of 6-F antegrade catheters in the United States as only 7-F–compatible covered stents are available. In Canada, 6-F–compatible covered stents allow a safer use of 6-F antegrade catheters.

Use of short guide catheters, specifically for the retrograde limb, is highly recommended; 90-cm guide catheters (commercially available in 6-, 7-, and 8-F) allow the possibility of externalization of the wire with less concern about equipment length. This is especially crucial if use of an epicardial CC is planned. Regular 100-cm guide catheters can be manually shortened and connected to a 1-F smaller introducer sheath (9). Removing 10 cm is usually sufficient. Shortening catheters manually offers the advantage of using the ideal catheter curve for support after the proper position was confirmed within the patient and reducing inventory needs.

Strategies to reduce bleeding are essential especially because we use unfractionated heparin at higher doses than usual. In this respect, the use of 1 or both radials offers a clear advantage. Because of its reversibility, heparin is the antithrombotic of choice in CTO-PCI. Bivalirudin or glycoprotein IIb/IIIa inhibitors are not recommended, because of concerns in case of perforation. An activated clotting time of 300 to 350 s should be targeted, especially when the retrograde equipment is in place, to reduce the risk of catheter-induced thrombosis. It should be verified every 20 to 30 min.

**Step 3: Retrograde CC Access and Crossing**

The selected CC is first wired proximally with a workhorse wire, shaped to navigate the donor vessel and to access the CC. Currently, the microcatheter of choice is the Corsair catheter (Asahi Intecc). It is an over-the-wire hydrophilic catheter composed of 8 thin wires wound with 2 larger ones that serves as a CC dilator while providing exceptional CC tracking and crossing as well as retrograde guidewire control (Fig. 3). The authors favor the 150-cm version. The maximum outside diameter is 0.93 mm (2.8-F), and its unique tapered-tip entry profile is 0.015 inch. These features make it a “channel dilator,” which has considerably

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**Figure 3. Corsair Catheter**

Reprinted, with permission from Elsevier, from Tsuchikane et al. (5).
simplified CC crossing by virtue of its excellent tip flexibility and lubricity. Currently, the Corsair catheter circumvents septal CCs balloon dilation with a small balloon (1.25 to 1.5 mm) in most cases. Hence, after wire access to the selected CC, the Corsair catheter is positioned at the proximal portion of the CC. Once the position is secured, the workhorse wire is exchanged for a polymer-jacketed wire to cross the CC. Appropriate wires are the nonstented polymer-covered guidewires with small distal tip load. We favor the Fielder FC (Asahi Intecc) or the Pilot 50 (Abbott Vascular, Santa Clara, California), although the tapered-tip Fielder XT (Asahi Intecc) can sometimes help to track very tiny CCs. The distal tip of the wire is shaped with the traditional CTO tip shape consisting of a very distal 1-mm 30 to 45° bend.

After we have positioned the guidewire at the tip of the Corsair, we proceed with CC “surfing” in the cases of septal CCs. This consists of gently advancing the guidewire and observing the path of least resistance within the septal channels. We look for a smooth passage to the distal artery, with the previously described course (Fig. 1). We often do nonselective CC visualization from guide catheter injection. However, poor distal visualization because of the occlusion of the CC with the Corsair is often encountered. If septal surfing fails to access the CTO vessel, we may assess the distal path and microconnections through selective injections from the Corsair catheter positioned in the proximal portion of the septal CC. The downside of selective visualization is the increased risk of septal rupture, which makes the septal CC unusable, and creates a septal hematoma. We thus use selective injection as a last resort after several attempts at surfing have failed. Furthermore, it is safest to inject from the LAD to RCA than the reverse as the CCs near the RCA are much smaller and more prone to rupture. CC rupture is seldom problematic, although it ends the chance of crossing the selected CC. In most instances, a persistent stain is noticed that rarely grows when assessing with nonselective injections. We usually pursue the procedure with alternative CCs. When performing septal surfing, identification of the wrong path is also assessed by the appearance of wire buckling. We then retract and modify slightly the trajectory. On occasion, the wire appears to “flop” freely distally and this usually indicates entry into a cardiac chamber. Wire advancement into the left or right ventricles is common, as natural communications between coronaries and heart cavities exist. Such events are totally benign as long as the Corsair is not advanced.

Alternatively, one can prefer to use, at the very beginning of the retrograde attempt, a microcatheter such as the Terumo FineCross (Terumo, Somerset, New Jersey) or the SuperCross (Vascular Solutions, Minneapolis, Minnesota). Such microcatheter, which has a smaller tip profile on a longer length, allows one to more deeply engage very small septal CCs. Use of the FineCross or SuperCross also avoids the unnecessary use of the more expensive Corsair in case of retrograde failure, and can be used again from the antegrade side. However, if the polymer-jacketed guidewire crosses through the septal CC, the catheter should be exchanged for the Corsair, which is far more performant in crossing the CC.

Once across into the distal recipient artery, the wire classically has a “to-and-fro” movement implying intravascular position. This to-and-fro movement confirms that the wire can move freely within its path from the donor to the recipient vessel, with heart beats. Proper position will then be confirmed by nonselective retrograde guide injection. The wire is then advanced far enough to provide support for the Corsair catheter advancement. This is performed by 5 to 10 alternating clockwise and counterclockwise rotations while providing forward tension. In the presence of very tortuous or severely angulated CCs, the Corsair catheter may become resistant to rotation. Advancement of the Corsair will be more effective with counterclockwise rotations. Exchange for a new Corsair is required if the Corsair cannot be advanced despite several minutes of rotation in both directions. The Corsair is then advanced and positioned near the distal end of the occlusion.

In case of epicardial CC crossing, surfing is not performed as the wire is manipulated to follow the path of the channel. Diverging from the observed path potentially leads to perforation, which is far more problematic than septal ruptures. We usually shape the wire with a small distal bend although a more proximal bend can ease crossing tortuous loops. We thus gently advance the guidewire until any resistance is felt. Advancement of the Corsair is made with the same previously described techniques, although it is helpful to advance the Corsair halfway through the collateral path to provide support for better wire crossing to the distal recipient vessel or to modify the shape of the CC for additional wire manipulation. Although currently unavailable in North America, the Sion guidewire (Asahi Intecc) has been increasingly used by Japanese and European operator with high success and low perforation rates. The epicardial CC often loses temporarily its tortuous shape after crossing with the Corsair, which can lead to ischemia. Therefore, we suggest using epicardial CCs as a last resort and when additional CCs are present to prevent ischemia.

**Step 4: Crossing the CTO**

The objective is to cross retrograde into the proximal true lumen by taking advantage of the softer or more favorable characteristics of the distal end, whenever possible. We tend to limit our choices to a set of 4 guidewires; Fielder XT, Fielder FC (Asahi Intecc) (or Pilot 50), Pilot 200 (Abbott Vascular), and Confianza Pro 12 (Asahi Intecc). Features of those guidewires, with others, are presented in Table 1. A tapered distal cap can be crossed with Fielder XT, Fielder
FC (or Pilot 50), or Pilot 200. Fielder XT and Pilot 200 are felt to be the best suited to progress within the plaque, with or without a knuckle at their tip. However, for firm plaque with an understood CTO trajectory and good target, we prefer the Confianza Pro 12. The Confianza Pro family has the characteristics of hydrophilic coating except for the 1-mm distal tip, which is hydrophobic. The Confianza Pro 12 has a tapered tip of 0.009 inch with 12 g of tip load.

We favor initially the approach of positioning our retrograde wire as far as possible within the occlusion (either within the lumen or the subintimal space) with attempts to cross using a rapid wire escalation strategy. We can provide a landmark for the retrograde wiring using an antegrade wire. We generally do not employ “kissing” or marker wire strategies to meet wires in the lesion with the intent to cross, as the success of these methods is time inefficient. Poor maneuverability of the retrograde wire is one limitation of primary retrograde wire crossing. To overcome this problem, the Corsair catheter should be used as the supporting catheter for the retrograde wire because of its strong backup support. Corsair is frequently advanced into the CTO to improve the wire maneuverability in retrograde vessel tracking. Another important issue is to avoid wire perforation in retrograde vessel tracking.

If the retrograde wire escalation strategy technique fails, or if the CTO lesion length is long or its course poorly understood (also called “vessel ambiguity”), we usually proceed with the “knuckle-wire” technique (Fig. 4). This entails creating a small loop with the retrograde polymer jacketed (Fielder XT or Pilot 200) wire to dissect the subintimal/subadventitial space, and hence prepare an opportunity to connect the proximal lumen with a distal “false lumen” within the CTO segment using reverse controlled antegrade and retrograde subintimal tracking (CART) (10) or standard CART technique (2). The knuckle-wire technique is thus our second approach after unsuccessful pure retrograde crossing and enables a different base of operation for eventual wire crossing. Rotation of a “knuckle-wire” may cause wire knotting, making it impossible to retrieve. Therefore, knuckled wire should be pushed, never rotated.

In many instances, both wires are advanced within the subintimal/subadventitial space but fail to meet in the same plane. The wires are seen as “parallel” to each other in multiple views. We then proceed with the reverse CART technique. The different variations of the CART technique were developed to connect the antegrade and retrograde subintimal/subadventitial or “true lumen” spaces. In the classic CART, a balloon (1.25 to 2.5 mm) is positioned in the CTO and inflated over the retrograde wire into the retrograde subintimal space, parallel to the antegrade wire. The antegrade wire is manipulated to connect with the enlarged retrograde subintimal space to ultimately exit into the distal true lumen. The classic CART is rarely performed in North America nowadays since the introduction of the Corsair catheter. The reverse CART has the same basic concept as CART. A rapid exchange balloon is inflated on the antegrade wire to enlarge the antegrade subintimal/subadventitial space (Fig. 5). If the balloon cannot reach a plane within the vicinity of the retrograde Corsair, a Tornus (Asahi Intecc) catheter can be used to enlarge the track to subsequently deliver the antegrade balloons, for reverse CART. The retrograde wire is then manipulated to enter the enlarged antegrade space. The concept is that 4 fates exist for the wires/catheters in the antegrade and retrograde CTO spaces. 1) Antegrade wire is positioned in a segment that used to be the lumen, as is the retrograde wire.

<table>
<thead>
<tr>
<th>Table 1. Most Commonly Used Guidewires for CTO Recanalization</th>
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<td><strong>Guidewires</strong></td>
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</tr>
<tr>
<td>Collateral surfing</td>
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<tr>
<td>Fielder FC</td>
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<td>CTO crossing</td>
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<td>Pilot 200</td>
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<tr>
<td>Confianza Pro 12</td>
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<tr>
<td>Externalization</td>
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<tr>
<td>Rotablator wire (325 cm)</td>
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<td>ViperWire Advance (330 cm)</td>
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CART = controlled antegrade and retrograde subintimal tracking; CTO = chronic total occlusions; nr = not relevant.
Objective is either to advance the retrograde or the antegrade wire, using the other wire as a landmark (kissing wire). Alternatively, antegrade dilation can be performed to increase the chance of connecting the two wires. If such a strategy fails, intentionally penetrating the subintimal/subadventitial plane either from the retrograde or the antegrade side increases success. 2) Both antegrade and retrograde systems reside within the circumferential subintimal/subadventitial plane, and therefore will easily be connected when the space is enlarged. This is an ideal situation. 3) The retrograde system is in the subintimal/subadventitial plane, and the antegrade one is inside of what used to be the lumen; therefore, a larger layer of tissue resides between the 2 systems. With appropriate antegrade balloon inflation, the CTO tissue and vessel wall can be broken up to the subintimal/subadventitial space, for the retrograde wire to engage the space and then the antegrade true lumen. A stiff wire, such as the Confianza Pro 12, is used to re-enter from the retrograde subintimal/subadventitial space to the true proximal lumen. 4) The antegrade system is in the subintimal/subadventitial space and retrograde is inside of what used to be the lumen. In such a situation, advancing a retrograde knuckled guidewire will likely reach the same subintimal/subadventitial space, which will connect the antegrade and retrograde spaces.
when enlarged with antegrade dilation. Experience has taught us that balloons sized within the presumed or intravascular ultrasound (IVUS)-measured adventitial borders can safely be used to open the space, especially when the antegrade wire is perceived to be surrounded by all the vessel wall layers. The width of the antegrade or retrograde knuckle can help to guide the selection of a properly sized balloon. One problem that is often encountered is the immediate recoil of the subintimal space, despite use of large balloons. To counter this, on occasion, we attempt to aim at the antegrade inflated balloon with the tip of the retrograde wire. Several alternative techniques have also been described. The “Stent reverse CART” technique involves deploying a stent within the antegrade dissected plane to create an open target for retrograde crossing. We prefer the use of the GuideLiner mother-in-child catheter (Vascular Solutions, Minneapolis, Minnesota) inserted into the space to help connect the retrograde wire to the antegrade guide.

Of note, after antegrade dilation, we avoid as much as possible antegrade injections and rely solely on retrograde visualization. The intent is to avoid propagation of hydraulic dissections, which can significantly complicate the procedure. To prevent accident, we usually cover the antegrade manifold or unhook the contrast syringe until stents have been deployed.

The use of IVUS has been advocated (10). We find that the most helpful use of IVUS is in determining the size of the artery, location of the antegrade and retrograde systems in the vessel structure, and distance from the wire to the outside wall when performing reverse CART. This ensures proper expansion of the subintimal space and minimizes risk of perforations. However, we believe that reverse CART can be performed in most instances without IVUS guidance, to reduce procedure cost and expedite the technique, particularly when using knuckle-wire techniques that tend to safely remain within the vessel structure.

**Step 5: Wiring the Antegrade Guide, Snaring, and Externalization**

If the occlusion is crossed antegrade, for example after the “knuckle wire” or a kissing-wire technique, the procedure is performed over the antegrade wire, and the retrograde equipment is removed. Care must be taken to ensure that the distal end of the antegrade wire is in the distal true lumen with contralateral injection. We discourage distal contrast injection through a microcatheter, or an over-the-wire balloon lumen, which can provoke distal dissection. As soon as a microcatheter, an over-the-wire balloon, or an antegrade Tornus catheter has crossed the lesion, the CTO wire should be exchanged for a safer workhorse guidewire. Easy advancement of the workhorse wire into the distal vessels and branches confirms true lumen positioning.

In most instances, it is the retrograde wire that crosses into the proximal true lumen. The goal at this point is to orient the retrograde wire into the antegrade guide. Coaxial alignment of the antegrade guide to the ostial segment of the CTO vessel is helpful for wiring the antegrade guide catheter. When possible, we advance the Corsair through the occlusion. Anchoring the tip of the retrograde wire in the antegrade guide with an antegrade balloon (anchoring technique with a 2.5 mm in a 7- or 8-F guide, 2.0 mm in a 6-F guide) can provide sufficient backup for Corsair advancement. If this fails, the Corsair should be exchanged for a long 1.5- or 1.25-mm over-the-wire balloon, which usually has a smaller crossing profile than the Corsair, to perform retrograde CTO dilation. If this step succeeds, antegrade flow can usually be restored, and a wire can be advance to the distal bed from the antegrade guide. At this point, the procedure is converted to an antegrade fashion, and the retrograde equipment can be removed.

**Externalization**

If the retrograde guidewire and Corsair enter the antegrade guide catheter, externalization should be the next step. The short retrograde wire used to cross the occlusion is removed, and exchanged for a long wire, advanced through the opposite hemostatic valve with the objective of converting the recanalization procedure to an antegrade fashion. Several workhorse wires come in 300 cm, although we prefer using a 300-cm Pilot 200 guidewire, as the plastic jacket eases progression of the wire within the Corsair and out into the antegrade guide. For extra length, the Rotablator floppy wire (Boston Scientific, Natick, Massachusetts) is 325 cm; however, its shaft is only 0.009 inch in diameter, and easily kinkable. The ViperWire Advance guidewire (Cardiovascular Systems Inc., St Paul, Minnesota) has emerged as an ideal guidewire for externalization. It is 335 cm long, the longest of 0.14-inch wires available, and passes very easily through the Corsair to the antegrade hemostatic valve. With septal CCs, as the wire and the Corsair are subjected to the contraction of the septum myocardium, we advance the wire slowly and notice systolic resistance to the advancement of the wire. Use of the ViperWire substantially shortens this step, because its strong shaft eases pushing the wire across all resistances. After significant advancement, one can use fluoroscopy over the opposite access to visualize wire position. We externalize just enough of the wire (10 to 15 cm) to be able to introduce rapid exchange gear over it. Because the distal tip of the wire comes out of the patient’s heart and not the reverse, the gear can be advanced or pulled out despite no proximal control of the wire. As the externalized wire brings tension within the coronaries, extreme care should be taken to avoid deep seating (especially when...
retrograde gear is pulled) and unintentional advancement of the guide catheters, mostly the retrograde one, which can lead to donor artery dissection. Use of 6-F catheters from the retrograde side likely reduces the risk of donor artery dissection. Moreover, care should be taken not to lose the proximal end of the long guidewire into the Corsair, from the retrograde side; it is wise to leave a torquing device on the wire or a clamp to avoid this.

If the retrograde wire is positioned into the aorta, a fast alternative is to exchange the short guidewire for a 300-cm Pilot 200 in order to snare its tip for and snare a long wire. We favor the 3-loop En Snare 18- to 30-mm Endovascular System (Merit Medical Systems, South Jordan, Utah), which works considerably faster than the conventional gooseneck snares. The standard En Snare is 6- and 7-F compatible, as long as its long sheath is not used (Fig. 6). The antegrade guide is pulled back in the aorta above the distal position of the retrograde wire. The wire is first advanced through one of the 3 loops, and then snared and pulled into the guide, preferably on the soft part of the wire. We then gently reposition the antegrade guide at the ostium of the coronary. As the wire is carefully externalized, backward tension is provided on the retrograde guide catheter as this step promotes deep seating of the guide. Once the tip of the wire is out of the opposite connector, its tip is secured and the folded part cut with surgical scissors.

Alternatively, there may be situations where retrograde angioplasty must be performed, especially in the setting of ipsilateral CC crossing when using smaller guiding catheters. This involves removing the Corsair and introducing an over-the-wire or a rapid exchange balloon over the retrograde wire. Because the septal CC has already been dilated by the Corsair, further dilating the channel is usually not required. Once sufficient passage for an antegrade wire has been created by retrograde angioplasty, the procedure is continued in an antegrade fashion.

**Step 6: Opening the Occlusion**

We first withdraw the Corsair to the distal portion of the artery. A rapid exchange balloon is introduced on the distal tip of the retrograde wire, from the antegrade guide. The balloon usually easily crosses the occlusion because the externalized wire provides great support. Care must be taken to never let the tips of the balloon and the Corsair touch each other as they can become entrapped due to dissimilar tip sizes and powerful forces generated working on the same wire. It is also crucial to maintain the Corsair in the CC as long as the retrograde wire is in position. Because the externalized retrograde wire can exert significant shear stress or tension, especially in a septal CC, the Corsair protects the CC and the septum against being transected, as a “cheese cutting” effect.

Once the balloon has opened the occlusion, 2 options are available. One is to continue with ballooning and stenting the vessel over the externalized retrograde wire. This provides excellent support for passage of long stents. Alternatively, an antegrade workhorse wire can be advanced through the newly opened vessel. Once proper wire position is confirmed by contralateral injections, the Corsair and its wire are removed. To do so, we reposition the Corsair forward up to the opposite ostium near the antegrade guide. At this point, we slowly pull the retrograde wire back, remove the wire from the Corsair, followed by pulling out
the Corsair. As with its insertion, we favor alternating clockwise/anticlockwise rotations of the Corsair until it reaches the retrograde guide catheter (Fig. 7).

We have learned not to overtreat distal lesions, particularly small vessels without angiographic atherosclerotic plaque or small dissection. The distal bed disease, which has been chronically underperfused, tends to be overestimated, and the vessel frequently vasodilates and remodels with restoration of antegrade flow. Also, as we position our stents, we use contralateral injections to avoid propagation of antegrade hydraulic dissections.

**Step 7: Final Pictures**

Upon removal of the Corsair, we assess for potential CC damage. Contrast staining in the septum is not infrequent and seldom lead to hemodynamic compromise. In the recent J-CTO registry, the incidence of perforations resulting in cardiac tamponade was only 0.4% (11). Often, distal CCs are less opacified at the end of the procedure; it does not mean dissection or thrombosis but simply less recruitment secondary to restoration of antegrade flow. In addition, we also assess for donor artery patency. Donor artery dissection is very rare and would need to be treated in a standard fashion. The final assessment from the antegrade injections usually shows distal competitive flow. This gradually disappears at follow-up as CCs are shut down.

**Conclusions**

Retrograde recanalization of CTO represents the last frontier in interventional cardiology. We have provided an updated step-by-step approach to demystify the procedure. In a substantial population of patients previously labeled as...
“unrevascularizable,” retrograde recanalization of CTO offers a valuable option. It can now be performed, in experienced hands, with a high degree of success, safety, and efficiency.

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