CHAPTER 9

Retrograde Chronic Total Occlusions

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Introduction

Facility with retrograde chronic total occlusion (CTO) intervention techniques is essential for successful CTO operators. As described in the hybrid algorithm for CTO interventions (**Figure 1**),[1] a retrograde approach may be used as an initial strategy or as a subsequent approach following an antegrade attempt. In general, the distal CTO cap tends to be softer, more clearly defined, and more tapered than the proximal cap, making it easier to enter in many circumstances. At the same time, retrograde CTO PCI is more technically challenging than antegrade PCI and is associated with higher rates of complications in multicenter registry data.[2] According to recent data from the OPEN CTO registry, a retrograde approach was chosen as a first strategy in 31% of cases and a second strategy in 44% of cases, with retrograde approaches serving as the successful strategy 35% of the time.[3]

Step-by-Step Technique

There are four general steps to retrograde CTO PCI:

I) Define a strategy

II) Cross the retrograde collateral

III) Cross the CTO

IV) Treat the lesion

I. FIRST STEP: DEFINE A STRATEGY

As described in the hybrid algorithm,[1] a retrograde approach may be selected either as an initial strategy or because of failure of an antegrade approach. The following scenarios favor a retrograde strategy:

a. Adequate collateral access to the distal CTO cap (e.g. presence of "interventional" collaterals)

b. Difficult access to/engagement of and/or ambiguity of the proximal CTO cap (difficult to engage vessel, such as anomalous origin, proximal calcification or tortuosity, ambiguous proximal cap or flush occlusion)

c. Long occlusion length

d. Reconstitution of the distal CTO at a bifurcation where antegrade dissection reentry into one of the branches would cause loss of the other branch

e. Poor distal target (small or inadequately visualized)

f. Impaired renal function (frequently less contrast is used with a retrograde approach)

Three types of collateral vessels can be used for retrograde CTO PCI: septal collaterals; bypass grafts; and epicardial collaterals. Evaluating the appropriateness of collaterals for CTO PCI depends first on adequate angiographic visualization. Bypass grafts are visualized in the same way they would normally be evaluated. Septal collaterals are often best visualized in the right anterior oblique cranial projection, though modifications - particularly of the degree of cranial-caudal angulation - may be needed to understand the full course of the vessel. Epicardial collaterals involving the lateral wall are best seen in cranial projections.

The adequacy of collateral supply is described according to the Werner scheme most commonly.[4] Werner grade: CCO: No continuous connection; CC1: Threadlike continuous connection; CC2: Side branch-like connection. The Rentrop classification is also used for this purpose. [5]

In general, septal collaterals are preferred for retrograde access to the distal CTO. Risk for tamponade is low in septal collaterals, though tortuosity can increase difficulty relative to bypass grafts. If no septal collaterals, or only small collaterals, are seen on initial angiography, three strategies may increase success. First, selective angiography of the septal perforators via a microcatheter or over the wire balloon may allow visualization of more favorable collaterals. Second, active passing of a wire over the septal origins may allow the wire to select a poorly visualized collateral that connects to the distal CTO. In addition, the process of "septal surfing" can enable the wire to pass to the distal CTO vessel through a septal collateral that might not be seen on angiogram (i.e. invisible collateral). Finally, if there are epicardial collaterals, transient balloon occlusion of these collaterals with concurrent angiography may demonstrate the existence of "recruitable" septal collaterals.

Bypass grafts are also used commonly for retrograde cases when available. Bypass grafts, even recently occluded saphenous vein grafts (SVG), tend to be wired without major difficulty and at low risk for tamponade given pericardial scaring after sternotomy. The risk/benefit tradeoff of instrumentation of a patent left internal mammary arterial graft supplying the left anterior descending artery territory needs to be considered carefully, as injury to the vessel, or temporary changes in conformation reducing flow (pleating), or spasm, can precipitate hemodynamic instability.

Epicardial collateral vessels are typically the access route of last resort. These vessels tend to be small and tortuous, with the highest risk for uncontained perforation resulting in hemodynamic compromise. Further, epicardial collaterals cannot be dilated safely to allow for passage of larger equipment. When using epicardial collaterals, the risk of perforation leading to tamponade is reduced, but not eliminated, in patients with prior sternotomy.

After deciding on a retrograde approach and selecting appropriate collaterals, the next steps are to cross the collateral with the wire and microcatheter and then select the CTO crossing and treatment methods. These steps will be considered in the following sections.

II. SECOND STEP: CROSS THE RETROGRADE COLLATERAL

a. Septal collaterals

Equipment needed:

Workhorse guidewire to deliver the microcatheter to the retrograde collateral

Retrograde crossing wire (e.g. Sion, Fielder FC, Fielder XT-R)

Microcatheter (e.g. Corsair, Turnpike, Turnpike LP, Caravel, Micro 14)

Pre-shaped microcatheter

Access to the origin of the septal collateral should be obtained in the donor vessel via a workhorse wire with a larger curve loaded in a microcatheter appropriate for septal collateral selection .[7] If there is an acute take-off of the septal collateral, an angled microcatheter may facilitate wiring. Once the appropriate microcatheter is advanced to the desired septal artery, there are two general approaches to crossing the vessel with a guidewire, "surfing" and contrast-guided. The "surfing" technique can allow for rapid crossing of the septal collaterals. A hydrophilic wire with a composite core is advanced rapidly into the septal artery without contrast injection and either crosses into the recipient vessel or buckles. If the wire buckles it is withdrawn and another attempt is made.

Contrast-guided crossing involves injection of contrast through the microcatheter into the desired collateral. A 3mL Luer-lock syringe with 100% contrast is attached to the back of the microcatheter. Aspiration is first performed to avoid air embolism. Contrast is then injected into the septal collateral, defining the vessel's course. The microcather should then be flushed with saline prior to wire advancement through the catheter to clear the contrast to avoid sticking of the wire in the catheter. If the initial septal wiring is unsuccessful, the typical technique is to move on to sequential septals until retrograde access is achieved.

Once the guidewire is successfully deployed across the collateral in the distal CTO vessel, the microcatheter, is advanced over the wire, securing position in the target vessel (**Figure 2**). If there is difficulty advancing the microcatheter, make sure the guidewire is placed as far into the distal vessel as possible to provide support. Proximal support can be increased as well by deep-seating the guide or by using a guide extension. Septal collaterals (but not epicardial collaterals) can typically be dilated safely with 1.5 mm balloon or a microcatheter with a smaller outer diameter. Finally, a different collateral may be selected.

Possible complications of septal collateral utilization include vessel dissection, injury to extravascular structures (typically benign staining is observed, but septal hematoma and tamponade have been reported), and guidewire entrapment.

b. Bypass grafts

<u>Equipment needed:</u>

Guidewire to traverse the vein graft (e.g. Sion Blue, Pilot 50, Pilot 200, retrograde crossing guidewire [Sion, Fielder FC, Fielder XT-R])

Microcatheter (e.g. Corsair, Turnpike, Turnpike LP, Caravel, Micro 14)

Pre-shaped microcatheter

Accessing the distal CTO cap via a bypass graft typically does not differ majorly from wiring bypass grafts for other purposes. The graft should be crossed with a workhorse or CTO guidewire with a larger, gentle curve to allow safe traversing of the graft. The wire should be loaded on a microcatheter that will facilitate subsequent crossing of the CTO. An exception to this approach occurs when the bypass graft is anastomosed at an acute angle (**Figure 3**); occasionally, specialized equipment is required to navigate retrograde into the native vessel around this sharp bend. Hydrophilic wires and preshaped

catheters may be considered (magnetically enabled wires may also be considered where available).[6] Once the microcatheter is successfully delivered to the distal CTO cap, the wire can be exchanged for a CTO wire appropriate for the chosen CTO crossing strategy.

Patent or occluded vein or arterial grafts can often be used successfully. If a patent vein graft is used, some operators advocate coiling of the graft after successful CTO PCI to avoid competitive flow across the newly stented lesion.

c. Epicardial collaterals

Equipment needed:

Workhorse guidewire to deliver the microcatheter to the retrograde collateral

Retrograde crossing wire (e.g. Sion, Fielder FC, Fielder XT-R)

Microcatheter (e.g. Corsair, Turnpike, Turnpike LP, Caravel, Micro 14)

As with septal collateral access, the first step is to traverse the native vessel with a workhorse guidewire to the site of the donor epicardial collateral. A CTO microcatheter is then delivered over the wire. It is essential to clearly define the course of the epicardial collateral with adequate contrast filling and orthogonal projections for safe traversing of the collateral with a guidewire.

Wiring of the epicardial collateral requires great care. The guidewire is advanced with contrast guidance; the dominant motion with the guidewire should be rotation as opposed to forward pressure. Once the distal wire is confirmed to be in the true lumen of the target vessel, the CTO microcatheter is advanced over the guidewire.

If difficulty is encountered advancing the microcatheter across the collateral, standard techniques to increase support can be employed, including securing sufficient distal wire position and seating the guide catheter and/or using a guide extension. Epicardial collaterals should not be dilated. The general potential complications of epicardial collateral use are similar to those with septal

collaterals (i.e. perforation and dissection), but the risk of perforation leading to tamponade is much higher.

III. THIRD STEP: CROSS THE CTO

Once guidewire position is obtained at the distal CTO cap, there are three general strategies for crossing the CTO:

a) Retrograde dissection-reentry

b) True lumen to true lumen puncture

c) "Just marker" use of the retrograde guidewire

a. Retrograde dissection-reentry

Retrograde dissection-reentry was the successful CTO strategy in approximately 25% of cases in the OPEN CTO registry.[3] The typical strategy is controlled antegrade and retrograde tracking and dissection (CART), reverse CART, or a variation thereof. To execute standard CART, CTO crossing guidewires from the antegrade and retrograde positions are advanced into parallel subintimal spaces in the CTO (**Figure 4**).[8] A small monorail balloon (approximately 2.0-3.0 mm diameter, non-compliant) is advance over the retrograde wire into the distal CTO subintimal space. The antegrade wire is directed toward the balloon on the retrograde wire. The balloon is then inflated to enlarge the subintimal space. As the balloon is deflated, the antegrade wire is advanced into the subintimal space created by the balloon inflation and delivered out of the CTO into the distal true lumen. The antegrade wire is now positioned in the distal true lumen and antegrade stenting of the CTO can proceed.

To perform reverse CART, antegrade and retrograde guidewires are advanced into overlapping subintimal positions in the CTO just as in the standard CART approach. However, instead of ballooning from the retrograde direction, a 2.0 – 3.5 mm diameter noncompliant monorail balloon is loaded on the

antegrade wire and positioned in the proximal CTO. The balloon is inflated to create a contiguous connection between the antegrade and retrograde subintimal space. As the balloon is deflated, the retrograde wire is advanced and delivered into the proximal vessel true lumen. When using the reverse CART technique, under-sizing of the proximal subintimal balloon is the most common cause of inability to access the proximal vessel lumen with the retrograde wire. Steps to treat the lesion once the CTO has been crossed with a reverse CART technique are described below and outlined in Table 1.

A common question asked has been "Should I *CART or Reverse CART?"* The most common limitation for standard CART techniques is the need to deliver a balloon across the collateral vessel to dilate the distal subintimal space. Because of this potential challenge, reverse CART is often attempted as the first strategy. For patients with long collaterals or other anatomic features increasing the total distance of the retrograde approach, however, available equipment lengths may not allow for externalization of the retrograde wire in a reverse CART technique. Operators typically utilize a 90 cm donor vessel (retrograde) guide to facilitate retrograde microcatheter delivery into the antegrade guide for the reverse CART procedure. If the guide length is limiting, several methods can be used to shorten the guide by cutting out a section and reannealing it with a connecting segment derived from a femoral access sheath.

There are several variations on the CART technique that have been described. One example includes the use of simultaneous balloons. Instead of a single balloon on either the retrograde (CART) or antegrade (reverse CART) guidewire, "confluent balloons" are placed on both guidewires and inflated simultaneously with the goal of creating communicating subintimal spaces.[9] IVUS-guided reverse CART is another example.. In this technique, intravascular ultrasound (IVUS) is used over the antegrade guidewire after balloon inflation to ensure adequate dilatation and to facilitate wiring into the proximal artery.[10]

b. True lumen to true lumen puncture

While true lumen to true lumen puncture with retrograde wire escalation is more intuitive than dissection-reentry techniques, this strategy is employed less frequently and is the successful strategy in only approximately 10% of cases.[3] Because the distal CTO cap is typically softer and more tapered than the proximal cap, it is often easier to enter the CTO from a retrograde approach as compared to antegrade. The microcatheter (or over the wire balloon) is advanced to be near the cap and allow support for cap puncture. The same wire used to cross the collateral can be employed with a CTO bend; alternatively, a hydrophilic, tapered wire with greater pushability may be used. Stiff, penetrating guidewires come with greater risk when used retrograde because a retrograde perforation can be more difficult to control.

d. "Just marker"

Finally, the guidewire positioned at the distal CTO cap can be used simply as a radiographic marker of the distal cap and distal true lumen. The CTO is then crossed into the distal true lumen by antegrade wire escalation or antegrade dissection reentry, using this "stick on the retrograde wire" technique.

IV. STEP FOUR: TREAT THE LESION

The approach to lesion treatment first depends on whether the CTO was ultimately crossed in an antegrade (CART, "just marker") or retrograde (reverse CART, retrograde wire escalation) manner. If the former, then antegrade true lumen to true lumen access has been achieved and intervention can proceed as for typical antegrade approaches. A microcatheter or over the wire balloon is passed across the lesion and the antegrade guidewire used to cross the CTO - typically a stiff, hydrophilic wire - is

exchanged for a safer workhorse guidewire which is less prone to wire perforation or distal vessel dissection. Predilation and stent deployment proceed according to the specific lesion characteristics.

If the CTO was crossed with the retrograde guidewire, retrograde wire externalization needs to be performed before stenting the lesion. Ideally, the retrograde guidewire can be passed into the antegrade guide catheter, either directly or through an antegrade guide extension catheter (i.e. guideliner-assisted reverse CART). Once the retrograde wire is positioned in the antegrade guide, the microcatheter is advanced over the wire in a retrograde fashion into the antegrade guide or guide extension. With the microcatheter inside the antegrade guide, the guidewire used to cross the CTO is removed and exchanged for a long wire (330-350cm) suitable for externalization (e.g. RG3, R350, Viper wire). The Y connector on the proximal end of the antegrade guide is removed to allow atraumatic externalization of the guidewire and the Y connector is then replaced over the guidewire. Once the guidewire is successfully externalized, the distal tip of the retrograde microcatheter is pulled back to the distal true lumen of the target vessel and the retrograde wire is used to deliver antegrade balloons and stents to perform standard intervention. The microcatheter should remain across the collateral in the distal CTO recipient vessel to protect the collateral vessel from wire injury. A hemostat or clamp can be attached to the proximal end of the externalized wire so that the wire is not inadvertently pulled into the body through the retrograde guide and microcatheter.

Two maneuvers may facilitate wire externalization. First, a trapping balloon can be used to anchor the retrograde guidewire in the antegrade guide so that wire position in the guide is not lost as the microcatheter is directed through the CTO and into the antegrade guide. Second, after the microcatheter is delivered into the antegrade guide and the guidewire is retracted, the microcatheter can be flushed with a lubricious fluid such as Rotablator lubricant to facilitate delivery of the retrograde externalization wire.

If the retrograde guidewire cannot be successfully directed into the antegrade guide and externalized directly, the wire is instead advanced into the aorta, where it is snared and pulled carefully into the antegrade guide. Care should be taken to avoid excessive force on the distal guidewire tip with the snare, as the tip can be severed by the snare. Again, after the retrograde wire is externalized, the microcatheter is retracted back distal to the CTO, so as not to interact with the PCI equipment used to treat the lesion while still affording protection of the collateral vessel from the wire. Care should be taken to not allow antegrade balloons/stents to touch the tip of the retrograde microcatheter because it has been reported that the two devices can become stuck to one another making it difficult to separate the devices.

Once PCI is complete, thought needs to be given to safe equipment removal. In particular, there is risk of ostial/proximal vessel injury to either the donor vessel or CTO recipient vessel. First, both guides should be slightly disengaged from the coronary/bypass graft ostia. The externalized wire then needs to be removed safely out the retrograde/donor vessel guide. To achieve this, the externalized wire is pulled back so that the distal tip exits the tip of the antegrade guide and is positioned in the proximal CTO vessel and is left in the proximal vessel. At this point, the retrograde wire traverses the donor vessel, the collateral, and the stented CTO. The microcatheter is retracted back to the donor vessel so that the status of the collateral vessel can be assessed with re-engagement of the guide and contrast injection. If there is good collateral flow with no perforation or dissection, the microcatheter is then carefully advanced across the collateral again to allow safe removal of the wire. It is frequently necessary to re-advance the retrograde microcatheter all the way back to the antegrade guide to prevent damage to the vessel

The wire is pulled back into the donor vessel, followed by the microcatheter. Standard completion selective angiography is then performed.

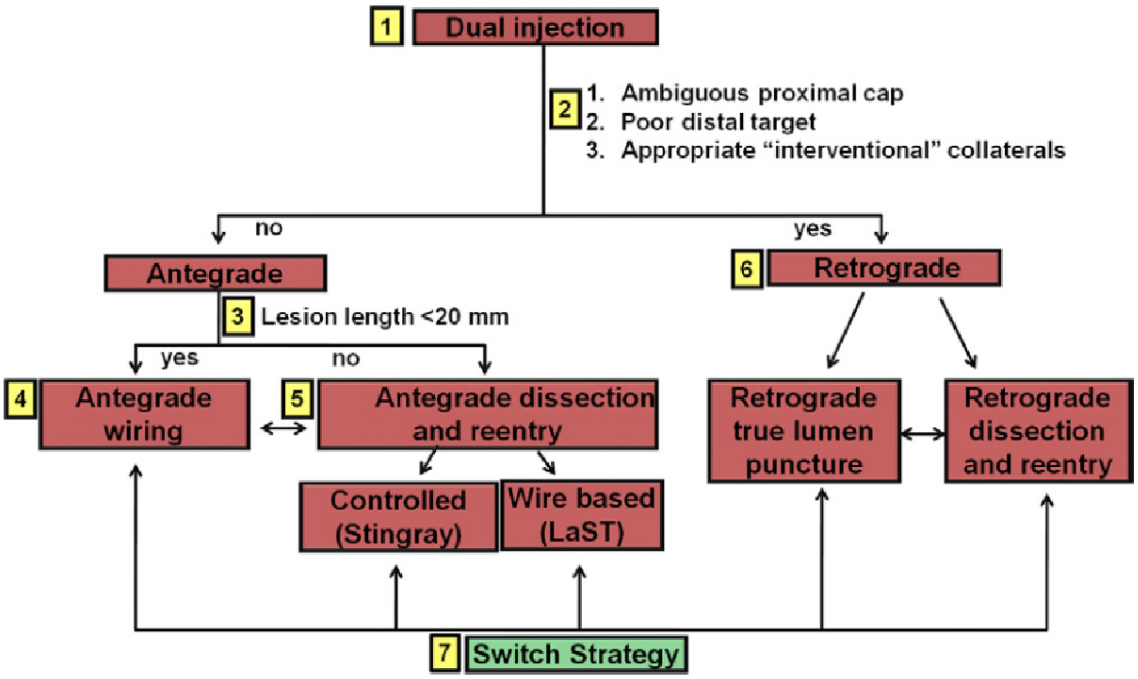
Conclusion

Retrograde techniques are indispensable for successful treatment of CTOs in contemporary practice. While specific equipment, maneuvers, and safety considerations add complexity, these interventions can be completed safely and efficiently by experienced operators. With additive experience in these advanced techniques, risks of procedural complications (e.g. perforation) may be avoided, while maximizing technical success. Importantly, CTO operators should be well-versed in the prompt recognition and management of any potential adverse events (e.g. covered stenting, coil embolization, hemodynamic support). Retrograde PCI approaches and devices continue to evolve, thus allowing successful intervention of even more complex lesions and patients subgroups.

Chapter 9: Retrograde Chronic Total Occlusions

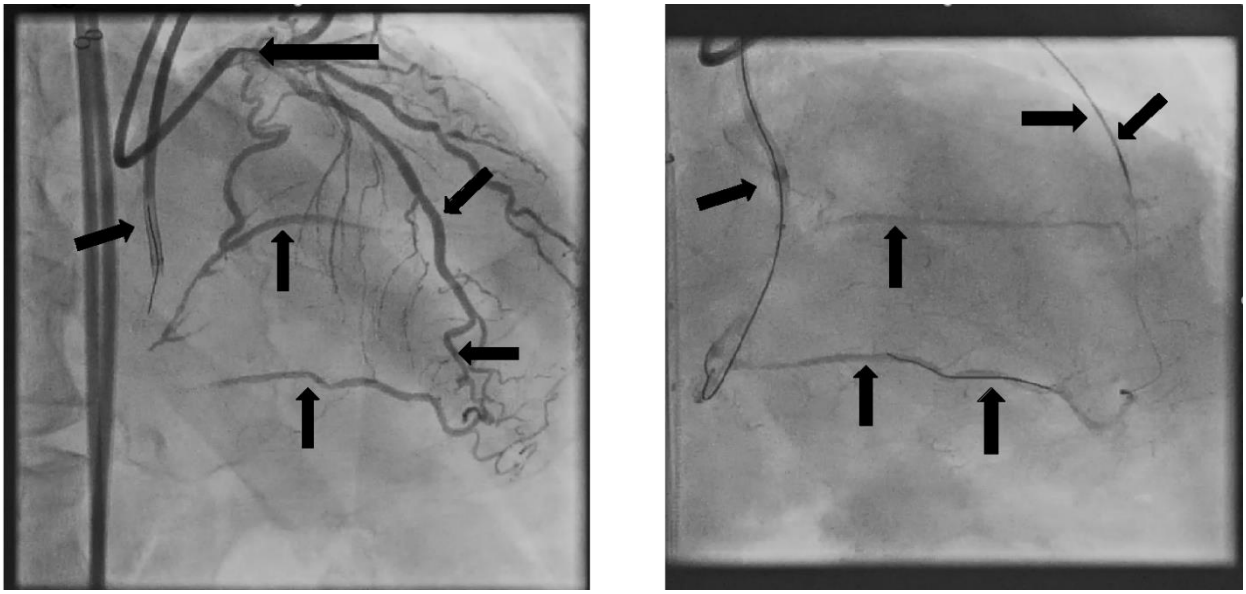
Figures

Figure 1: The hybrid algorithm for chronic total occlusion interventions



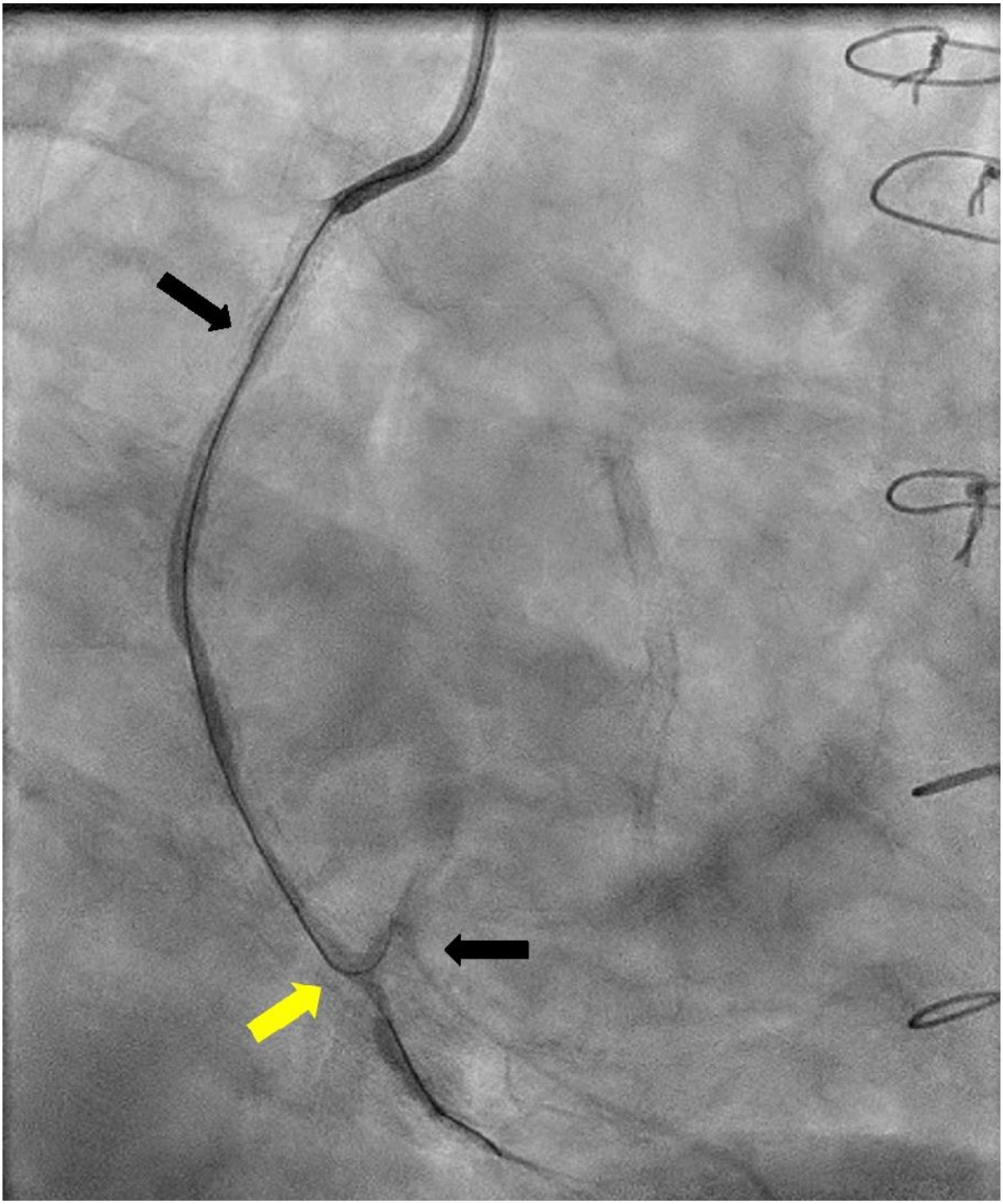
Adapted with permission from Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. J Am Coll Cardiol Intv 2012;5:367-79.

Figure 2: Example of Retrograde wire access from the LAD to the PDA of an RCA CTO



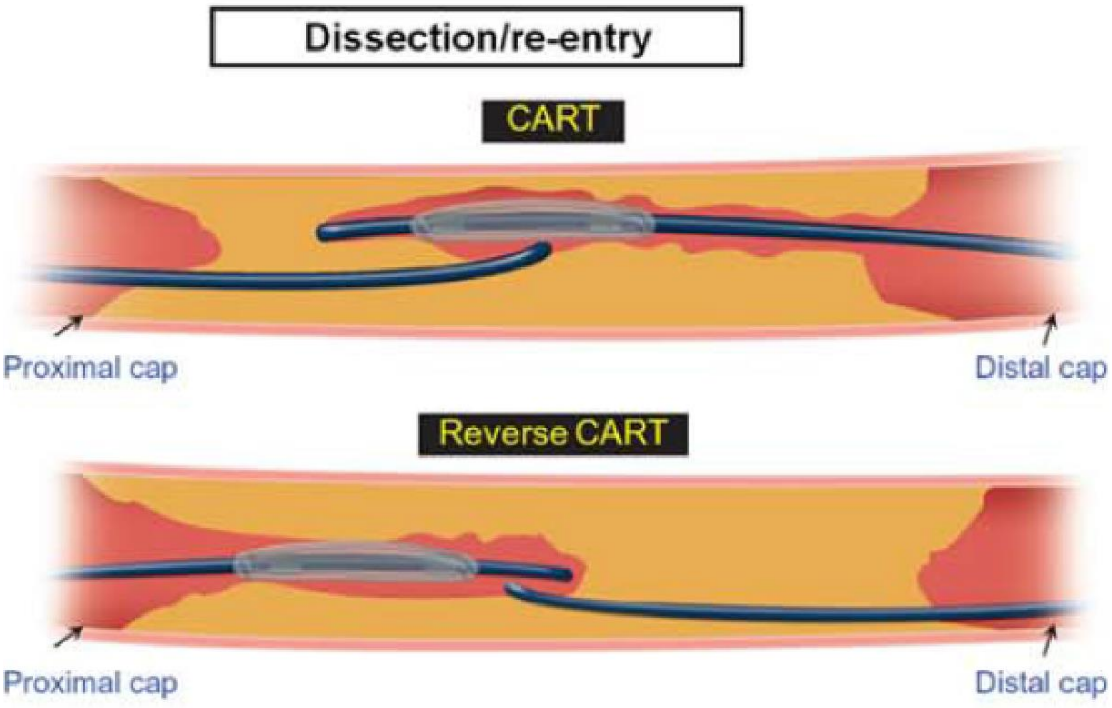
Left panel shows visible LAD to RCA collateral. Right panel shows retrograde Sion wire positioned in the PDA prior to advancement of the Corsair microcatheter.

Figure 3: Example of an acute angle at the graft anastomosis



The saphenous vein graft is anastomosed to the distal right coronary artery in such a manner that the guidewire must make an acute turn (yellow arrow) to reach the CTO in the native vessel.

Figure 4: CART and Reverse CART techniques



Reprinted with permission from Vo M and Brilakis ES. Faster, easier, safer: "guideliner reverse CART" for retrograde chronic total occlusion interventions. Catheterization and cardiovascular interventions 2014;83:933-5.

Tables

Table 1: Reverse CART: step-by-step summary

1. Position a microcatheter at the proximal CTO cap using a guidewire of choice
2. Access the distal CTO cap via the most appropriate collateral

   Graft and septal collateral access > epicardial collateral
3. Position a microcatheter at the distal CTO cap
4. Knuckle subintimal Fielder XT wires from the antegrade and retrograde directions into overlapping positions in the CTO
5. Advance a 2.0-3.5 mm NC balloon over the antegrade wire and inflate (**Figure 3**)
6. Advance the retrograde wire into the newly expanded proximal subintimal space
7. Advance the retrograde wire into the antegrade guide or guide extension
8. Advance the retrograde microcatheter through the CTO and into the antegrade guide or guide extension
9. Exchange for a long (ex. R350) exteriorization guidewire through retrograde microcatheter and externalize out the antegrade guide
10. Perform the PCI via the antegrade guide over the externalized retrograde wire

References:

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