SL Clinical and Experimental Cardiology

SCIENTIFIC LITERATURE

CASE REPORT

Reverse Controlled Antegrade and Retrograde Subintimal Tracking for Chronic Total Occlusion Intervention: My Approach in 2017

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ARTICLE INFO

Received Date: July 20 2017

Accepted Date: October 25, 2017

Published Date: October 31, 2017

KEYWORDS

Chronic total occlusion;

Percutaneous coronary intervention;

Reverse controlled antegrade;

Retrograde subintimal tracking

Citation this article: Dash D. Reverse Controlled Antegrade and Retrograde Subintimal Tracking for Chronic Total Occlusion Intervention: My Approach in 2017. SL Clin Exp Cardiolog. 2017; 1(1):111.

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ABSTRACT

Chronic total occlusion remains one of the most challenging subsets for percutaneous coronary intervention. After initial reports of retrograde cases, important changes have occurred that resulted in faster and more successful procedures. Reverse controlled antegrade and retrograde subintimal tracking is the most commonly used retrograde technique. In this review, the author sheds light on step-by-step approach to this technique, it's standardization and various modifications along with complications.

INTRODUCTION

Despite remarkable progress over the last decades, successful Percutaneous Coronary Intervention (PCI) of Chronic Total Occlusion (CTO) represents the "final frontier" of PCI. CTO PCI still remains technically challenging in spite of development of new devices and a wide range of guidewires [4,5]. Historically the technical success rate has been limited to 65% to 70% with the antegrade approach [1,6]. A higher success rate up to 95% has been achieved with adoption of reverse controlled antegrade and retrograde subintimal tracking. The most common indication of this approach could be subsets of previous antegrade failures. It may be the primary procedure in many situations like ostial occlusions, long occlusions, heavy calcification, occlusions with ambiguous proximal cap, and occlusions with a diffusely diseased distal vessel [7-10].

1. COLATERAL CHANNEL NAVIGATION AND GUIDEWIRE HANDLING

Successful collateral crossing depends on Collateral Channel (CC) selection, guidewire tip curve, and wire handling. The best CC would be clearly visible, less tortuous collaterals by super-selective injection, exemplified by Dr. Werner's CC [11] grade 1 or 2. Acute angulation, branching, cork-screw morphology, and calcification pose major obstacles for wire navigation [7] A hydrophilic non-tapered guidewire with an extremely small (< 1mm) curve is preferred for CC navigation. The Sion guidewire (Asahi Intecc, Aichi, Japan) usually is the first choice for selecting a CC. This can be advanced smoothly and safely because of its coated tip and 0.7-g tip load. The hydrophilic coating and rope coil technology enable good guidewire retention, advanced torque performance and flexible atraumatic tip. The Sion Black guidewire (Asahi Intecc, Aichi, Japan) is a recent addition to the PCI armamentarium that can be advanced more smoothly and, consequently, it has become a useful choice for fine CC. Features of polymer jacket and slip coating with rope coil structure of tip make better sliding in the small CCs. Even fine CCs can be effectively selected by using the Fielder XTR guidewire (Asahi Intecc Aichi, Japan) which has a polymer jacket coating with a 0.010 inch tapered tip. The author prefers to use Suoh 3 guidewire (Asahi Intecc, Aichi, Japan) in curved but nonbranching CCs. It has a light weight of wire tip (0.3 g), resulting in less resistance for bent point CC.

The CC crossing is facilitated via the use of dedicated microcatheters (such as the Corsair, Caravel [Asahi Intecc, Aichi, Japan], and Turnpike [Vascular Solutions, MN, Minnesota], Finecross [Terumo, Japan]). The Corsair (Asahi Intecc, Aichi, Japan) is an Over The Wire (OTW) hybrid catheter composed of 8 thin wires wound with 2 large ones. It has a soft tapered tip with tungsten braiding and a hydrophilic shaft which serves as a CC dilator while providing exceptional CC tracking and crossing as well as retrograde wire control. Gentle rotation of this catheter is required to advance or pull it by either clockwise or counterclockwise rotation. It is performed by 5-10 alternating clockwise and counterclockwise rotations while providing forward tension. Rotation should be limited to 10 times in one direction. Caravel (Asahi Intecc, Aichi, Japan) is a versatile microcatheter with braided shaft providing flexibility and an excellent crossing profile (1.9 Fr) which tracks very well through tiny tortuous septal CC without requiring rotation. This catheter technology has been revolutionary and transformative for safe, effective, and predictable retrograde procedures. If the microcatheter cannot pass the CC along the wire, it can be changed to small diameter monorail balloon with a longer shaft (>145 cm) by using extension guidewire or the counter flush method. The author prefers to use Finecross (Asahi Intecc, Aichi, Japan) for a very tortuous epicardial channel. Turnpike (Vascular Solutions Inc, Minneapolis, MN, USA), are group of OTW tapered tip microcatheters with dual-layer bi-directional coil which provide excellent tracking and advancement in CC. Once workhorse guidewire and microcatheter are advanced into the target CC, the workhorse wire is exchanged for a CC navigating wire with a small distal bend. The crossing technique varies depending on the type of CC used (septal, epicardial, or SVG). Once the microcatheter is inserted into septal CC, there are two techniques for subsequent crossing: "surfing" and "contrast guided." It is advanced rapidly along the path of least resistance (surfing) until it buckles or advances into distal target vessel. The guidewire is quickly redirected to find an alternative CC in case of resistance. Forceful advancement of the guidewire may lead to CC rupture, vessel perforation, and septal hematoma which might be fatal. Septal CCs usually run straight down in their upper half (left anterior descending artery side), then bow towards the apex and turn into the posterior descending artery. Therefore Right Anterior Oblique (RAO) cranial is the best projection for initial wiring, and RAO caudal for entering into the PDA.

In doubtful wire position, selective injection (advancement of micro catheter with pulling the back of the wire) of the contrast (as little as 2 ml) is performed; a wash out of the contrast indicates connection of the CC to the either ventricle. Guidewire advancement into the left or right ventricle is benign as long as the microcatheter is not advanced. When the contrast staying of the contrast in the CC is indicative of focal perforation.

In contrast guided septal crossing technique, cine-angiography is performed while injecting contrast with 3-ml luer-lock syringe. Blood is aspirated before contrast injection not only to avoid air embolization but also to prevent vessel injury if the microcatheter is completely occlusive. The microcatheter is flushed before re-inserting guidewire to minimize subsequent stickiness. Once continuous connection to distal vessel is observed, guidewire crossing is reattempted through that connection. RAO caudal projection is used to evaluate the length and tortuosity of the distal part of septal CC. On occasion, there are sudden rapid and large deviations in guidewire-tip movement indicating entry into a cardiac chamber. Septal hematoma, manifesting as severe chest pain, may lead to a fatal event if not treated adequately, such as by coil embolization of septal CC or creation of a fistula connecting to the ventricle [12].

Eepicardial CC crossing should always be performed using contrast guidance. Surfing is not advisable in view of high risk of perforation. Guidewire should be rotated not pushed in tortuous segments. Divergence from the observed path may lead to perforation which is more problematic than septal rupture. Both arterial grafts and SVGs can be used in retrograde approach with a major challenge of navigating the guidewire through severe angulation at the distal anastomosis.

After the retrograde guidewire position is confirmed, it is advanced as far as possible close to the distal CTO cap to provide sufficient back up for retrograde microcatheter advancement. In case of failure to cross, the microcatheter should be rotated rapidly clockwise or counterclockwise using both hands. Sometimes, the operator may have to dilate septal CC using small (1.20-1.5 mm) balloon at low pressure (2-4 atm) or may replace Corsair or Caravel with Finecross microcatheter. In some cases, a temporary increase in guiding support by deep throating or side branch anchor or a guide catheter extension can facilitate the tracking of the microcatheter.

After a retrograde guidewire has crossed the CC and reached the lumen of the coronary artery distal to the CTO, the following four strategies [13] are available: direct retrograde wiring; the kissing wire technique; the Controlled Antegrade and Retrograde Tracking (CART) technique; and the reverse CART technique.

REVERSE CART

The steps of reverse CART include retrograde dissection creating subintimal space past the distal cap, navigation of retrograde microcatheter over the dissection to near the proximal cap, antegrade dissection with subintimal space to a point distal to the retrograde microcatheter, and deployment of an antegrade balloon in the subintimal space next to the retrograde microcatheter with subsequent connection of both the subintimal space (common space) followed by retrograde wiring from the microcatheter into the proximal true lumen [9].

1. RETROGRADE DISSECTION

A soft tapered or non-tapered polymer jacketed guidewire as described earlier may be used for probing a microchannel, or a knuckle wire may allow access to the subintimal space. If it fails, a stiff tapered guidewire (Conquest Pro 12, Asahi Intec, Japan) may be required. After the distal cap is crossed, and the guidewire is advanced by a short distance of 5-10 mm, the microcatheter should be navigated past the distal cap [9].

2. ANTEGRADE DISSECTION

The proximal cap becomes more obvious after completion of retrograde dissection. At this stage, creation of an antegrade dissection is performed similar to the retrograde technique. The antegrade guidewire along with 15-20 mm long balloon (sized to match the normal artery lumen) is used to create the dissection. Once antegrade dissection is performed, contrast injection through the antegrade guide is avoided to prevent hydraulic dissection and compromise of the distal flow.

3. CREATION OF COMMON SUBINTIMAL SPACE (CSS)

The position of antegrade balloon should be such that the tip of the retrograde microcatheter lies in the mid portion of the antegrade balloon. The balloon and retrograde catheter may appear up to 4-5 mm apart on fluoroscopy. Once antegrade balloon is inflated, the true lumen is moved aside to the point where the two subintimal spaces become the CSS. An undersized balloon may preclude the formation of CSS. There should be no gap between the antegrade balloon and retrogarde microcatheter once CSS is created. A gap indicates the tissue between the two and absence of CSS. In this circumstance, a higher inflation pressure or a larger diameter balloon should be used. After deflation of the balloon the retograde microcatheter could be seen "drooping" into the CSS indicating a continuous pathway from distal true lumen, through the subintimal space, and into the proximal true lumen.

ITERATION OF REVERSE CART

There may be compression or collapse of the subintimal space after antegrade balloon inflation and deflation making wiring the true lumen more difficult even if CSS does exist.9 This difficulty could be overcome by the use of Intravascular Ultrasound (IVUS), mother and child catheter [Guideliner (Vascular Solution, Minnepolis, MN, USA) Guidezilla (Boston Scientific, USA) or Guidion (IMDS, Netherlands)], and stent reverse CART techniques. Sometimes, it takes a longer time for successful connection even under IVUS guidance because the retrograde dissection by wiring disturbs the further direction control. The concept of contemporary reverse CART has been introduced to facilitate the procedure with innovation of Gaia (Asahi Intec, Japan) series of guidewires [9].

1. IVUS-GUIDED REVERSE CART

IVUS is useful in estimating optimal size of antegrade balloon matching the vessel size, which can cause medial disruption. The risk of perforation is negligible under IVUS guidance. More importantly, the formation of medial disruption and CSS could be checked by IVUS after antegrade balloon inflation. Redilatation with a bigger balloon is indicated if there is recoil of CSS. IVUS also provides direct visualization of the position of the retrograde guidewire in the subintimal space. The retrograde wire could be negotiated into the proximal true lumen under IVUS guidance [7-9,14-16].

2. STENT REVERSE CART

This technique entails deployment of a stent from the antegrade true lumen into the subintimal space created by antegrade balloon inflation. This forms an open target for retrograde guidewire crossing. Repeated attempts are hampered with this technique [7-9,11].

3. MOTHER-CHILD REVERSE CART

An alternative method is to use a guide-extension device such as Guideliner (Vascular Solutions, Minneapolis, MN, USA), Guidezilla (Boston Scientific, USA) or Guidion (IMDS, Netherlands) into antegradely created space to help connect the retrograde guidewire to the antegrade guide (Child-in-Mother reverse CART). Once it is placed into the subintimal space, it provides a continuous conduit to the antegrade guide. So creation of new dissection plane or wiring into side branches may not be required. Unlike a stent, the guide extension catheter may be removed or repositioned once the connection between the antegrade and retrograde true lumen is not successful [7-9,12].

4. CONTEMPORARY REVERSE CART

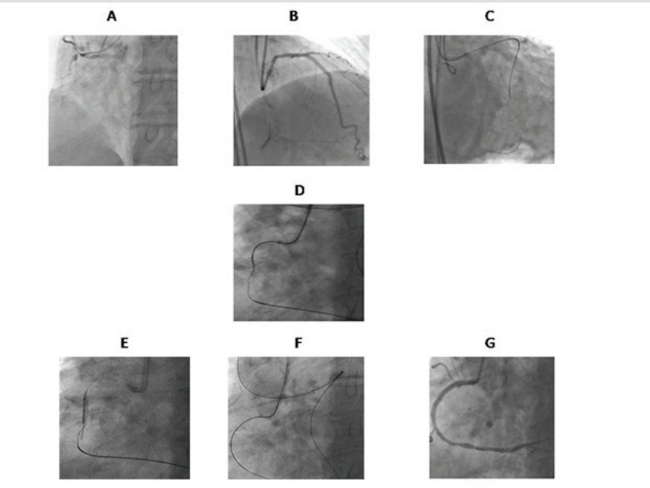

Figure 1:

A. Coronary angiogram revealing total occlusion of proximal right coronary artery (RCA).

B. Werner's collateral channel grade 2 from left anterior descending artery (LAD) to RCA.

C. Retrograde navigation of guidewire though septal collateral using microcatheter.

D. Antegrade navigation of guidewire in RCA with microcatheter support.

E. Antegrade 3 x 18 mm balloon dilatation.

F. Advancement of retrograde guidewire with microcatheter into antegrade guide.

G. Final result following predilatation with 3 x 20 mm balloon and deployment.

In classical reverse CART, the connection is established at the position of overlapped bilateral guidewires. With larger antegrade balloon, once the retrograde dissection is created by wiring, the further retrograde direction control with various guidewires becomes very difficult even under IVUS guidance. The author prefers contemporary reverse CART technique in which antegrade preparation is initiated before retrograde wiring [9]. When antegrade and retrograde wires come together in CTO vessel, a smaller balloon (2.0 mm) is advanced antegradely and inflated close to distal end of CTO. The shoulder of inflated balloon is being penetrated by the Gaia series of guidewires. With quick deflation of antegrade balloon, the Gaia guidewires penetrate the membrane between the different spaces known as contemporary reverse CART. These guidewires enable the precise intentional retrograde wire control (Figure 1). In case of failure, retrograde wire is still controllable because of smaller dissection plane created by smaller antegrade balloon. This minimizes the length of subintimal stenting which might impact the outcome of CTO PCI. Hence, long-term clinical and angiographic follow-up of patients undergoing contemporary reverse CART is needed to assess the long-term safety and efficacy of this novel technique [9].

5. CONFLUENT BALLOON REVERSE CART

In this variation, both antegrade and retrograde balloons are inflated simultaneously in a kissing fashion to cause the subintimal space to become confluent, allowing retrograde guidewire navigation [7].

6. PUNCTURED ANTEGRADE BALLOON REVERSE CART

In this technique, devised by Wu et al [17], the antegrade balloon is kept inflated during retrograde crossing attempts and is punctured by the retrograde guidewire, which is then advanced while the punctured antegrade balloon is retracted under fluoroscopy

EXTERNALIZATION

The crossing wire is exchanged for an externalization wire after a microcatheter is delivered into the antegrade guide. This step is only applicable to cases in which the CTO is crossed in retrograde direction (retrograde true lumen puncture and reverse CART). The externalization of the retrograde guidewire must be carried out with utmost care. The retrograde guide catheter may be deep throated; this needs to be avoided to prevent ostial damage. While advancing the stiffer shaft of the retrograde guidewire into the CC, the collateral needs to be protected by the presence of the microcatheter.

Several workhorse guidewires come in ≥ 300 cm (300-cm Pilot 200 wire, Abbott Vascular, USA; 325 cm Rota floppy, Boston Scientific, USA; 335 cm Viper, CSI, St Paul, Minnesota; 330cm RG3) for externalization [7]. The Viper wire is extraordinarily stiff, and is often difficult to pass through very tortuous CCs. The shaft of the Rota floppy wire is only 0.009" in diameter, and is easily kinkable. It should be used as a last resort if no other long wires are available. RG3 is 0.010" tiny wire emerging as the most ideal guidewire for externalization. With loop wire condition, the tip of the delivery device comes to inner curve of the coronary artery which provides the strongest support for the devices. Two options are available for wire externalization depending on whether the retrograde wire enters the antegrade guide or not.

1. EXTERNALIZATION WHEN RETROGRADE WIRE ENTERS ANTEGRADE GUIDE CATHETER

Wiring the antegrade guide is simpler and preferable and may be facilitated by guide catheter extension (such as Guideliner, Guidezilla or Guidion) into antegrade vessel. Once retrograde guidewire enters the antegrade guide, a trapping balloon is inflated within the antegrade guide next to the wire to facilitate negotiation of the retrograde microcatheter into the antegrade guide. The retrograde guidewire is removed while the retrograde microcatheter remains within the antegrade guide catheter.

The wire to be externalized is inserted through the microcatheter. Once the externalized wire approaches the antegrade guiding hub, the operator needs to detach the copilot, place a finger over the hub of antegrade guide until the retrograde wire is felt tapping on the finger. Retrograde wire is pushed 5 to 7 cm out of the guide, once the tap is felt. Then a wire introducer is placed into antegrade copilot and the externalized soft tip of the wire is threaded. Introducer and copilot over the wire are slided and reconnected without flushing. Flushing after reverse CART can result in hydraulic dissection. The retrograde guidewire is pushed until 20-30 cm of the wire have exited through the Y-connector. If the externalized wire is damaged, it may be cut off to facilitate loading of balloons or stents [7,18,19].

2. SNARING THE RETROGRADE WIRE

Despite coaxial antegrade guide, retrograde navigation of wire into guide fails in conditions such as aorto-ostial lesions or extremely tortuous vessels, or whenever there is poor retrograde wire control. Difficulty in wiring the antegrade guide can be overcome by snaring. The 3-snare system, referred to as tulip snare (EN Snare; Merit Medical Systems, South Jordan, USA), is the most useful snaring system for externalization of wire during retrograde procedure. The larger the snare the better it is. An 18X30 mm EN Snare, which is 6 French compatible, is preferred [7,18]. The snare is pulled back into snare introducer, once it is removed from the package. The guide catheter is used for snare delivery instead of the snare delivery catheter. The snare is introduced into antegrade guide by inserting the introducer through the Y-connector (Co-pilot is preferred). The snare is advanced out of antegrade guide and opened. Then it snares the externalized guidewire brought into the aorta by the microcatheter. If retrograde microcatheter fails to reach into the aorta, a standard length wire may need to be snared to avoid fracture or unraveling of the distal part of the wire. [35]. PCI can be performed using rapid exchange equipment after successful externalization of retrograde guidewire. The tip of the antegrade equipments (balloon/catheters) should never be allowed to meet with the tip of the retrograde equipment to avoid interlocking and entrapment.

EXTERNALIZED WIRE REMOVAL

After the completion of PCI, the retrograde microcatheter is readvanced into the antegrade guide, unless resistance is encountered. It must protect the CC until the soft wire tip is back in the CC. Both antegrade and retrograde guiding catheters are disengaged from the coronary ostium and pulled back 3 to 4 cm into the aorta to avoid ostial dissection because of externalized wire retraction (antegrade guide is disengaged by pushing the externalized wire and the retrograde guide by fixing the microcatheter using it as rail for guide retraction) After establishing guiding catheter control, the externalized wire is withdrawn gradually synchronized with the heart beat taking care not to kink it. Then the retrograde microcatheter is withdrawn into the donor vessel leaving the retrograde wire in the CC. The contrast is injected via retrograde guide to ensure that no injury of the CC (perforation or rupture) has occurred. If CC injury is detected, the microcatheter is re-advanced over the retrograde guidewire to cover the CC perforation and possibly deploy coils. If no CC injury exits, the guidewire is removed after re-advancing microcatheter to minimize the risk of injury, especially in tortuous epicardial CCs [7,18,19].

COMPLICATIONS

There is an augmented risk of donor artery injury owing to spasm, dissection or thrombus formation. Equipment withdrawal or externalization of snared wire may cause deep throating of the artery leading to dissection. Given the typical longer duration of CTO procedures, and having microcatheters in the vessel, CTO PCIs are more susceptible to donor artery thrombosis. Back bleeding and good flushing should be allowed after removal of any equipment. ACT should be monitored at least every 30 minutes to maintain it in between 300-350 seconds. Stenting of donor artery should be done in case of dissection. Aspiration thrombectomy and additional heparin as required might be needed for donor vessel thrombosis.

Complications exclusive to the retrograde approach are guidewire and balloon kinking or entrapment into CC, dissection, perforation and hematoma formation. Many CC ruptures are benign and do not require further treatment apart from abandoning that CC and trying for another. The use of dedicated microcatheters (such as the Corsair, Caravel [Asahi Intecc, Aichi, Japan], and Turnpike [Vascular Solutions, MN, Minnesota], Finecross [Terumo, Japan]) is safer than a balloon and rarely causes CC dissection or perforation even with excessive tortuosity. While advancing the microcatheter, if septal wire shows excessive kinking, the wire needs to be withdrawn to prevent vessel perforation. Septal perforations usually do not lead to adverse consequences, although septal hematomas [20] and even cardiac tamponade [21] have been reported. In one case report, septal hematoma manifesting as an echo-free space, caused asymptomatic bigemini and severe chest pain, and resolved spontaneousl [22]. Perforation into cardiac chamber usually does not result in complications; however balloon dilataion or advancement of additional device should be avoided [23].

Epicardial CC perforation can rapidly lead to cardiac tamponade and may be difficult to control. This CC should never be dilated to minimize the risk of perforation. Epicardial collateral wiring is safer in patients with prior CABG or other surgery requiring pericardial entry, as bleeding may be contained within pericardial space. However, some case reports have demonstrated that there is potential for the development of loculated effusions that may compress the cardiac chambers, or the development of intramural hematoma with avulsion of the epicardial arteries as a consequence of vessel perforation in post-CABG patients [24].

These CC perforations are prevented by meticulous wire manipulation ensuring position of wire prior to advancement of microcatheter, cautious injection of contrast through its tip ensuring that back bleeding is possible prior to injection of contrast, withdrawing epicardial collateral wire after ascertaining no perforation at the end of procedure, avoiding surfing the epicardial CC. Negative pressure from the wedging microcatheter might sometimes be sufficient to seal the ruptures. Advancing microcatheter and coiling from both sides that feed the CC might to be required to address perforations [23,25]. It is advisable to perform dual contrast injection from both sides to confirm that there is no bleeding from the antegrade or retrograde side. With contemporary techniques and devices, the risk of complications is reasonably low with retrograde approach, as has been demonstrated in the meta-analysis of El Sabbagh et al [26]. In general, complications are more frequent with the retrograde approach than the antegrade one. Lo et al [27] reported a myocardial injury rate of 13.8% with the retrograde approach versus 6.7% with the antegrade approach. The Euro CTO Club [28] reported complications of the retrograde approach in 8.6% of patients, including channel perforation and hematoma (6.9%). A Japan retrograde PCI registry study [29] demonstrated that the rates of major collateral injury and perforation were similar after successful and unsuccessful intervention for CTO, but there was a significantly higher rate of minor collateral injury after unsuccessful intervention (17.0 vs 7.5%).

CONCLUSION

With growing expertise and procedural volume, the numbers of CTO procedures and the success rate have dramatically increased over the years and more cases are attempted with a reverse CART technique. It is expected that there will be further improvements in the performance of imaging systems, guidewires, and catheter devices. It will also be necessary to develop new preoperative CTO imaging diagnosis systems and guidewire autonavigation devices that can be employed to assess the nature of plaques in detail, as well as devices for CTO PCI.

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