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Retrograde approach for percutaneous treatment of chronic total occlusions of coronary arteries

Técnica retrógrada para tratamento percutâneo das oclusões coronárias crônicas

João Eduardo Tinoco de Paula[1ID], Breno de Alencar Araripe Falcão[2], Antonio Carlos Botelho da Silva[3]

[1] *Interventional Cardiology Department, Hospital Rio Doce, Linhares, ES, Brazil.*

[2] *Interventional Cardiology Department, Hospital Messejana, Fortaleza, CE, Brazil.*

[3] *Head of the Interventional Cardiology Department, Hospital São José do Avaí, Itaperuna, RJ, Brazil.*

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ABSTRACT – Coronary artery chronic total occlusions are diagnosed in about 20% of coronary angiograms, nevertheless, percutaneous recanalization of these lesions is under attempted. Theses patients usually have incomplete percutaneous revascularization or are referred for coronary artery bypass surgery. Current improvements in the interventional armamentarium along with innovative approaches led to a marked increase in recanalization success rates, even in the most complex anatomic scenarios. Retrograde approach techniques are considered an essential part of the skillset for chronic total occlusion dedicated operators, and is probably the most difficult step to master. Refinements in the retrograde technique were paramount to achieve the safety and efficacy current standards. The authors propose a step-by-step guide for operators wanting to embrace this strategy.

Keywords: Coronary occlusion; Coronary artery disease; Percutaneous coronary intervention; Strategies

RESUMO – As oclusões coronárias crônicas são diagnosticadas em cerca de 20% das coronariografias, mas a recanalização percutânea dessas lesões é subindicada. Esses pacientes são usualmente tratados com revascularização percutânea incompleta ou referenciados para cirurgia de revascularização miocárdica. O constante avanço nos dispositivos de intervenção, associado a técnicas inovadoras, propiciou importante incremento nas taxas de sucesso de recanalização, mesmo nos cenários anatômicos mais complexos. As técnicas de abordagem retrógada são consideradas parte do conjunto de habilidades essenciais para um operador dedicado a oclusões coronárias crônicas e provavelmente a etapa mais difícil do treinamento. Refinamentos da técnica retrógrada foram essenciais para alcançar os padrões de sucesso e segurança atuais. Os autores propõem um guia passo a passo para os operadores interessados em adotar essa estratégia.

Descritores: Oclusão coronária; Doença da artéria coronária; Intervenção coronária percutânea; Estratégias

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Corresponding author:
João Eduardo Tinoco de Paula
Hospital Rio Doce
Avenida João Felipe Calmon, 1.285 – Centro
Zip code: 29900-010 – Linhares, ES, Brazil
E-mail: joaoeduardotp@yahoo.com.br

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BACKGROUND

Chronic total occlusions (CTO) of coronary arteries are frequently seen in patients undergoing coronary angiography, with a prevalence of 20% to 50%.[1-3] However, the presence of well-developed collaterals does not prevent myocardial ischemia at the area distal to the occlusion.[2] Successful percutaneous CTO recanalization may reduce angina symptoms, and improve quality of life and left ventricular systolic function.[2,4-8]

The selection process for the initial and subsequent percutaneous crossing strategies depends on the lesion characteristics and the local equipment availability, along with the operator expertise. Currently, there are various algorithms that can help select the best crossing strategy, such as the hybrid,[9] Asia Pacific,[10] and EUROCTO[11] algorithms. As initial strategy, the antegrade approach, particularly antegrade wire escalation, is preferred to retrograde crossing, given the higher risk of complications with the retrograde approach,[12] and the need for antegrade lesion preparation, even when the retrograde approach is eventually required.[4,6]

Usually, antegrade wire escalation is used in cases with non-ambiguous proximal cap, good distal landing zone and short lesions (<20mm); cases with ambiguous proximal cap and or long lesion length are explored with antegrade dissection techniques.[6,13]

Providing that there are coronary collaterals deemed negotiable for crossing (so-called interventional collaterals), a retrograde approach is more desirable in ostial CTO or with an ambiguous proximal cap as well as in CTO with long and tortuous lesions, CTO with diseased landing zone or with distal bifurcated caps.[6] In addition, a retrograde approach is preferable in previous failed antegrade attempts with extensive dissection. Lastly, an initial retrograde strategy might also be handy in patients with interventional collaterals and renal impairment, in whom a retrograde approach may help spare contrast volume. Although retrograde collateral wiring can be challenging, distal caps are typically softer and more tapered than proximal ones.

In this article, we will review the preoperative planning as well as the intraoperative steps required for successful CTO recanalization using a retrograde approach.

PREOPERATIVE PLANNING

Currently, CTO revascularization should be considered in patients with angina or dyspnea despite optimal medical therapy or with a large area of documented ischemia in the territory of the occluded vessel.[5]

In patients with clinical indication for CTO revascularization, meticulous evaluation of coronary angiogram remains cornerstone to guarantee success and to define the appropriate strategy.[6]

The use of scoring models can help gauge procedural difficulty and the probability of success, which can guide clinical decision making as well as better case selection, according to operators' experience.

The Japan CTO score (J-CTO), a multicenter CTO registry in Japan, is the first and the most widely used score (Table 1).[14] Several factors may predict failure including a prior failure attempt, the presence of heavy calcification, bending ≥45° within the occluded segment, blunt proximal stump and an occlusion length >20mm. The J-CTO stratifies as simple, intermediate, complex, and very complex (J-CTO scores of zero, 1, 2, and ≥3, respectively). The J-CTO score has been validated with CTO cohorts outside Japan, providing prognostic information at 1-year follow-up.[15] Experienced CTO operators may be able to tackle even the toughest cases, while less experienced operators should select simpler easier cases (J-CTO score zero or 1).

Newer CTO scores emphasizes focus on the percutaneous coronary intervention (PCI).[16] The clinical and lesion-related (CL) score[17] is primarily focused on antegrade procedures, and hence, it would be more useful for antegrade-only operators. On the other hand, the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO) score,[18] the ORA (ostial location, Rentrop grade <2, age ≥75 years) score[19] and the Castle (EUROCTO club)[20] may be more suitable for predicting recanalization success in retrograde or hybrid procedures. Additionally, the PROGRESS-CTO complication score assesses the preoperative risk of complications using three variables (age ≥65 years, lesion length >23mm, and use of the retrograde approach).[21]

DYNAMICS OF THE PROCEDURE

Only approximately 50% to 60% of CTO are successfully crossed with the initial strategy, thus, it is essential to

Table 1. Clinical-angiographic chronic total occlusions risk scores

Variables	Japan CTO	CL	ORA	PROGRESS CTO	EUROCTO (Castle)
Age ≥70 years			1x		1x
Prior CABG					
Prior MI		1,5x			
Occlusion duration*					
Prior attempt	1x				
Ostial location			1x		
Blunt stump	1x	1x		1x	1x
Severe tortuosity	1x	1x		1x†	1x
Length >20mm	1x	1,5x			1x
Severe calcification	1x	2x			
Extent of calcification					1x‡
Circumflex		1x		1x	
Absence of interventional collaterals			2x§	1x	

* More than 12 months; †moderate/severe; ‡ more than 50% of segment; § collateral class less than 2.

CL: related to the clinical characteristics and lesion; ORA: ostial location, collateral filling of Rentrop <2, and age >75; CABG: coronary artery bypass surgery; MI: myocardial infarction.

remain flexible during the case. If the first crossing strategy fails, either incorporating small changes (like altering the guidewire tip angulation or changing guidewire) or switching strategies (such as converting from an antegrade to a retrograde approach) have to be done in a timely fashion to avoid patient and/or operator fatigue, as well as excessive radiation or contrast exposure. Also, a CTO-PCI attempt may need to be stopped in the event of a serious complication, presence of high radiation exposure (usually >5Gy air kerma dose) or large contrast volume use.

CTO procedures are to be performed within dedicated programs that stimulate constant training and meticulous monitoring of outcomes.[22] Inevitably, higher CTO-PCI volumes are linked with higher success rates.[23,24]

PROCEDURE

Periprocedurally, an initial bolus of intravenous unfractionated heparin (100IU/kg) is generally administered, checking the activated clotting time every 30 minutes. Additional bolus of unfractionated heparin is given to maintain an activated clotting time >350 seconds. Upstream use of low molecular weight heparin, glycoprotein IIb/IIIa inhibitor therapy or bivalirudin is generally not recommended.

As for any CTO procedure, it is mandatory to ensure an optimal guide catheter support, with a large lumen size to allow devices in parallel, as well as two arterial sheaths for contralateral injections. Dual injection is mandatory in the vast majority of cases, providing better visualization and grasp of CTO characteristics than single injection (Figure 1). In addition, strong collateral visualization may improve procedural safety, by depicting guidewire location during crossing attempts. CTO PCI with a single guide can be performed in selected cases, with absent collateral circulation or only ipsilateral collateralization.

Usually, 6 to 8F guide catheter size is appropriate for the target vessel (antegrade route), and 7F is most frequently used. For contralateral or retrograde route, 6 or 7F are often used but we strongly recommend 7F use to enable some maneuvers to enhance support, such as trapping or anchoring. For the left coronary artery, extra backup guide

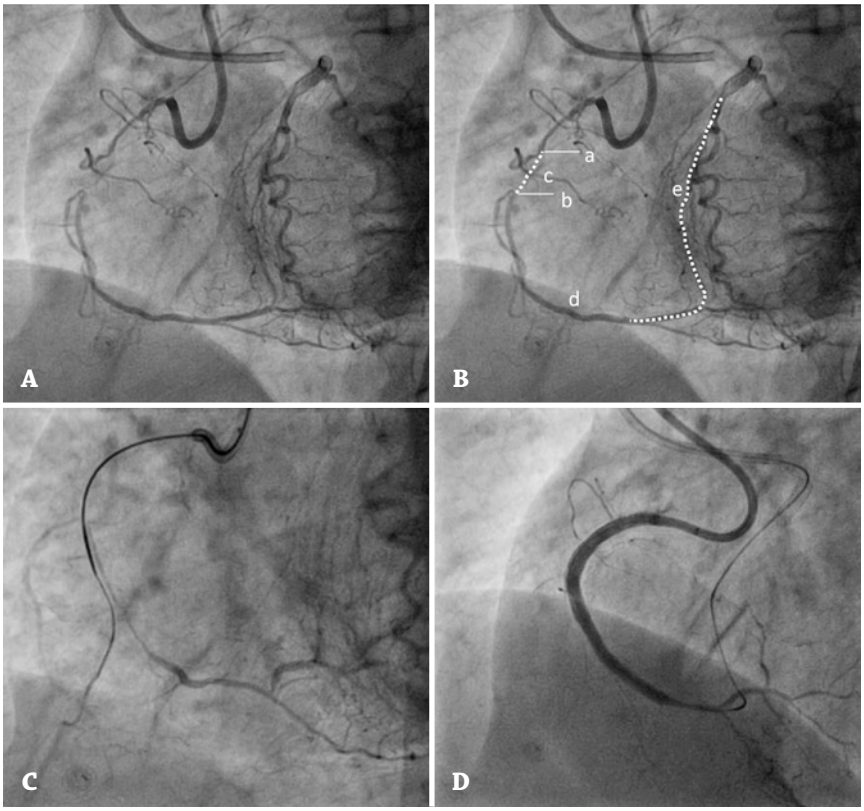

Figure 1. Dual injection and selection of recanalization strategy. In this example of right coronary artery chronic total occlusion recanalization, dual injection allowed identification of crucial parameters to procedure planning. (A and B) The proximal portion of the vessel is diffusely diseased with some ambiguity of the proximal cap (a) related to a marginal branch. Chronic total occlusion length is fairly short around 20mm (c) and the distal cap (b) is bifurcated, with one branch being small and less relevant. Distal landing zone (d) is large enough and mildly atheromatous. "Interventional" septal collaterals (e) are clearly identified even in this left anterior oblique projection. Antegrade wire escalation and antegrade dissection-reentry were sequentially tried first but failed (C), and a retrograde approach (reverse controlled anterior and retrograde tracking - CART) through a septal collateral finally succeed (D).

(EBU) is most appropriate; while, Judkins right or Amplatzer® left 1 or 2 are most often used for the right coronary artery (RCA). Access can be either femoral, radial (or ulnar) artery, or a combination of both.

In addition to the standard equipment needed for the antegrade approach, the retrograde technique requires specialized devices: short guides, specialized microcatheters (150 to 155cm long), and long guidewires for externalization, such as the R350 and RG3 wires.

SPECIALIZED EQUIPMENT

The use of a shorter antegrade guide catheter (90cm) is preferable for retrograde cases. Since such catheters are not available in Brazil, a standard guide catheter can be customized manually.

Microcatheters

There are several long (150cm) microcatheters for the retrograde approach (Table 2). Larger microcatheters, such as the Corsair and Turnpike® may facilitate collateral crossing, causing collateral dilation at the same time, and providing strong support to help penetrate into the distal cap. However, it may be challenging to deliver through small and tortuous collaterals. Conversely, lower profile microcatheters, such as the Caravel, Turnpike® LP, Finecross®, and Micro 14, may be easier to deliver but provide less support.

Externalization guidewires

These 330 to 350cm long wires are dedicated for externalization. They are thinner than standard guidewires, and have largely hydrophilic coating on their shaft. Ideally, these guidewires should be used for externalization whenever possible. The tip of this wire should remain straight to ease loading of antegrade equipment following externalization. If there are not available, a RotaWire™ (330cm long) or ViperWire Advance® (325cm), can be used but cautiously, since they may kink. A standard length (300cm) guidewire can often be used for externalization, especially if short guide catheters or guide catheter extensions are being used. Nevertheless, externalization of standard guidewires is more difficult and riskier. Lubricating the microcatheter with Rotaglide™ may facilitate externalization of such wires.

Collateral crossing guidewires

The use of composite core soft guidewires (such as the Fielder Fc, and Samurai RC) is recommended for septal crossing. The Sion and Suoh 03 are the most often used worldwide, but these wires are currently not available in Brazil. In this setting, it is best to make a short and shallow bend at the guidewire tip.

STEPS OF THE RETROGRADE PROCEDURE

Step 1 – selection of the retrograde route

Depending on the patient scenario, various routes can be taken, including collateral circulation (either septal or epicardial) (Figure 2), a saphenous vein graft or an internal mammary graft. Owing to the enhanced risk of myocardial ischemia and/or tamponade risk, it is best to avoid internal mammary artery grafts and epicardial collaterals

Table 2. Overview of microcatheters used in chronic total occlusions interventions

Manufacturer	Catheter	Length (cm)	Distal shaft outer diameter (F)
Asahi Breweries	Tornus	135	2.1 and 2.6
	Corsair e Corsair Pro	135 and 150	2.6
	Caravel	135 and 150	1.9
Boston Scientific	Renegade™ 18*	105, 115 and 135	2.5
IMDS	NHancer Pro X	135 and 155	2.3
Roxwood (atual BTG)	Micro Cross® 14 and Micro Cross® 14ES	155	1.6
Terumo	Finecross®	130 and 150	1.8
Teleflex	Venture®	145 (rapid exchange) and 140 (over-the-wire)	2.2
	SuperCross™	130 and 150 Preformed tip angle (45°, 90° or 120°)	2.1
	Turnpike®	135 and 150	2.6
	Turnpike LP	135 and 150	2.2
	Turnpike® Spiral	135 and 150	3.1
	Turnpike Gold®	135	3.2
Acrostak	M-CATH	135	2.25
Merit Medical	SwiftNINJA	125	2.4

Asahi Intecc, Aichi, Japan; Boston Scientific Corp., Marlborough, MA, USA; IMDS, International Material Data System, Roden, Netherlands; BTG, Bothell, WA, USA; Terumo Corp., Tokyo, Japan; Teleflex/Vascular Solutions, Minneapolis, MN, USA; Acrostak, Genève, Suice; Merit Medical, Galway, Ireland.

* Available in Brazil.

(especially if very tortuous), and stick to septal collaterals or saphenous vein grafts, unless there is ample CTO expertise.

Preferably, the shorter collateral is first attempted, because it provides stronger support and bears a greater chance to reach the target lesion. But, if a septal collateral enters the vessel close to the distal cap, there may not be enough space to advance a wire and a microcatheter into the distal true lumen. In such cases, it is best to choose a collateral that enters the target vessel more distally. Collaterals characteristics are by far the best predictors of crossing failure, chiefly a corkscrew morphology and >90° angle with the recipient vessel may be tough to wire,[25,26] whereas straight, large collaterals (CC1 or CC2 by the Werner classification)[27] are the easiest to wire (Figure 3). Often invisible collaterals (CC 0 by the Werner classification)[27] can be successfully crossed, using the surfing technique.[28] Tip injection of the septal perforator branches (through a microcatheter) may allow visualization of previously invisible collaterals.[28]

It is generally easier to advance a wire through a septal collateral from the left anterior descending artery (LAD) to the RCA than the other way round, because the RCA ends of septal collaterals usually have more acute kinks at their origins, and more tortuosity in their lower courses.

Bypass grafts are easier to negotiate, but are present in less than 20% of CTO cases. Due to prior cardiac surgery, coronary anatomy can be distorted, requiring a sharp turn to access retrogradely the distal cap.

Step 2 – crossing septal collateral

A workhorse wire is advanced into the septal collateral and exchanged for a high-torque wire with a low tip load, usually a Fielder FC or a Samurai RC, while outside Brazil the Sion family of wires is more often used for traversing collaterals. These wires are shaped with a very small bend at the tip, which helps negotiating tortuosity and deflecting away from small side branches.

Contrast-guided septal crossing technique is recommended during an operator learning curve, usually in the presence of visible collaterals, whereas experience operators may also opt for surfing in the setting of tiny or invisible collaterals.[28]

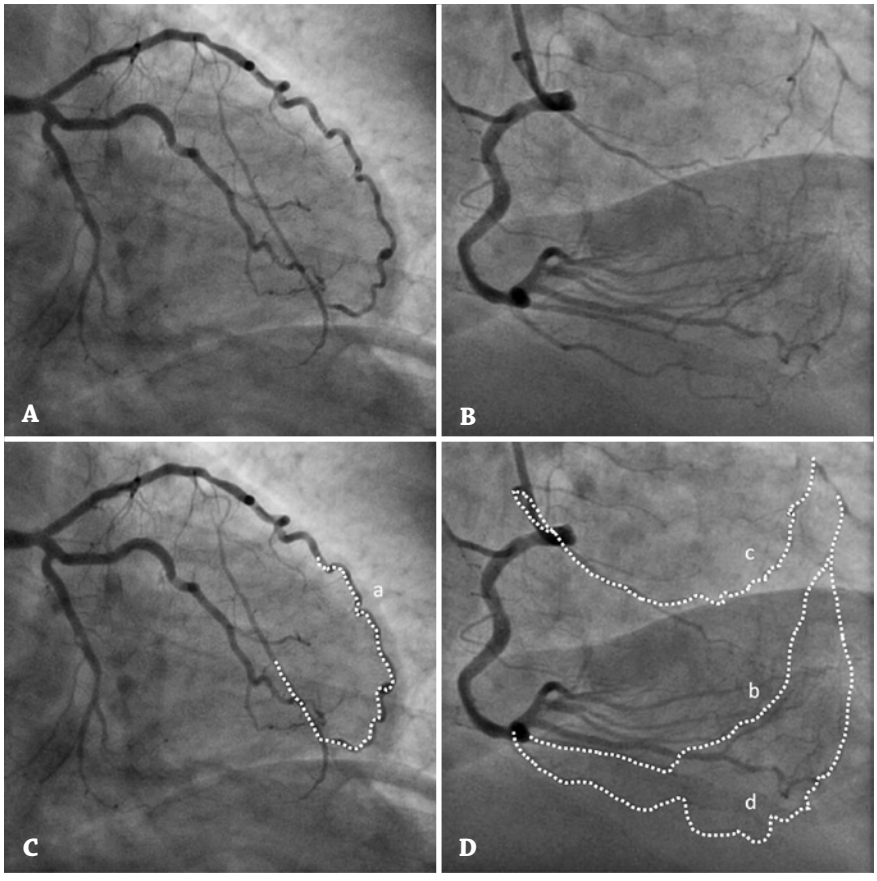

Figure 2. Collateral channel evaluation. (A) Left coronary angiogram (anteroposterior caudal view) showing an ipsilateral epicardial collateral from the first diagonal branch to the distal left anterior descending artery (a). (B) Right coronary angiogram (same patient) showing septal collaterals to the left anterior descending artery coming from the posterior descending artery (b), in addition to contralateral epicardial collaterals, coming from the conus branch (c) and the right marginal branch (d).

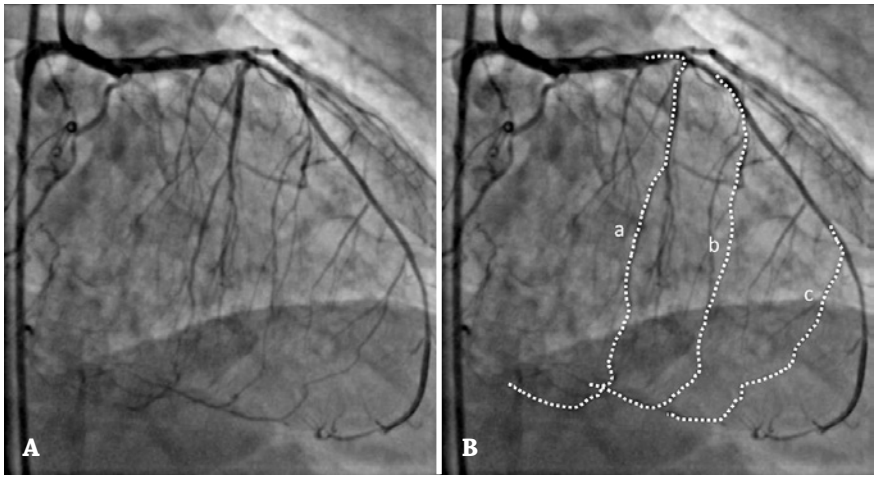

Figure 3. Evaluation of potential interventional septal collaterals on a patient with right coronary artery chronic total occlusion. There are three visible collaterals: a large proximal one (a) with a straight course at the proximal portion, but with an acute angulation at the exit from de donor artery. In this channel, there is tortuosity distally, which could challenge crossing to the distal landing zone. Channels (b) and (c) are thinner than the proximal one (a), but with an obtuse (favorable) angulation both at the exit of the donor vessel and at the entry to the distal landing zone. Of note, channel (b) seems to be less tortuous and requires a shorter distance path. Thus, operators usually attempt crossing this collateral first.

For contrast-guidance, it is best to use a small (3mL) but resistant syringe with 100% contrast. The operator should first aspirate until blood enters the syringe. If there is no blood return, the operator should back out the microcatheter (just for a short distance) until blood can be aspirated. These maneuvers aim to prevent air embolism and limit vessel dissection. A static coronary angiography (to avoid pain) with gentle 3mL injections is done at right anterior oblique (RAO) caudal view to measure the length and assess the tortuosity of the distal part of the septal collateral. In case of poor guidewire progress, consider using left anterior oblique (LAO) view. Once a septal connection is observed to the distal vessel, the microcatheter is flushed (to prevent stickiness) and the guidewire is reinserted and further advanced.

Surfing should only be done in septal collaterals, owing to the high risk for perforation of epicardial collaterals. The wire is quickly advanced and pulled back at the presence of resistance and redirected into a different channel. It is important not to push hard and stop immediately when you sense resistance, to avoid collateral injury. During surfing, the chances for successful wiring are typically higher in proximal, non-tortuous septal collaterals.

After reaching the distal part of the collateral, we perform contrast angiogram through the retrograde microcatheter, in two orthogonal projections, to confirm guidewire location, which could be either the distal true lumen, the septum (no crossing achieved) or a ventricular cavity (suspect if the wire starts making large back and forth movements). The presence of septal staining is a benign finding in the vast majority of cases.

Regardless of the crossing technique utilized, once we confirm that retrograde guidewire has reached the distal true lumen, the guidewire is progressed towards the distal CTO cap (or deeply in another distal branch) to obtain enough support to allow for microcatheter progression.

The microcatheter is typically advanced by rapid device clockwise and counterclockwise rotation (for Corsair and Turnpike®), using both hands. It is vital not to rotate more than ten turns in one direction before releasing, to prevent damage to the microcatheter. If this maneuver failed, the operator should increase the retrograde guide catheter support, either actively or by using additional extra support wires, the side branch anchor technique, or a guide catheter extension (GuideLiner or Guidezilla™). Sometimes, retrograde guidewire can be anchored by a balloon advanced through the antegrade guidewire. If still unsuccessful, the operator may try a different microcatheter with a lower profile (Caravel, Turnpike® LP, Finecross®, and Micro 14), a shorter microcatheter (135cm long) with better torque transmission. Also, a new microcatheter should also be tried, since the previous can get sticky after prolonged use. If prior maneuvers have failed, dilatation of the septal collateral with a small (1.0 to 1.5mm) balloon at low pressure (2 to 4atm) may do the trick. As one would expect, this can never be attempted in epicardial collaterals.

Once the retrograde microcatheter has reached the distal cap, there are three ways to cross the lesion: (1) retrograde crossing distal true lumen to proximal cap (retrograde true lumen puncture or "true-to-true"); (2) antegrade crossing of the CTO (using the kissing wire or the "just-marker" technique); and (3) retrograde dissection/reentry techniques (the controlled anterior and retrograde tracking or CART) is the most commonly used technique).[29]

In the retrograde true-lumen technique, CTO is crossed either with the same guidewire (as the distal CTO cap may be softer and more tapered than the proximal cap) or with a stiffer guidewire. Optimal support and the use of a stiffer, tapered tip, and/or polymer-jacketed wire are essential for success, nonetheless, operators should use guidewires with high-penetrating characteristics, because an epicardial retrograde perforation can have catastrophic consequences.

If both wires reached the subintimal space, two techniques can allow reentrying into the true lumen: (a) inflating a balloon over the retrograde guidewire, followed by advancement of the antegrade guidewire into the distal true lumen (CART); and (b) inflating a balloon over the antegrade guidewire, followed by advancement of the retrograde guidewire into the proximal true lumen (reverse CART).[29]

Antegrade or standard CART technique has been largely substituted by the reverse CART technique,[29] and is used whenever the latter cannot be performed, when the retrograde equipment is not long enough to reach the antegrade guiding catheter, or the antegrade equipment (microcatheter/balloon) cannot be reached to the site of wire overlap.

Thus, reverse CART remains the most frequently retrograde technique used worldwide. Most commonly, failure to connect both guidewires is frequently due to the use of small balloons.

A guide catheter extension can be used antegrade to form a larger target for the retrograde wire (GuideLiner-reverse CART technique).[30] This step may ease entry into the guide catheter (Figure 4). This technique is vital for LAD ostium and circumflex ostium CTO, to minimize the risk for left main coronary artery dissection during retrograde crossing attempts.

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None.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

CONTRIBUTION OF AUTHORS

Conception and design of the study: JETP, BAF and ACBS; data collection: JETP, BAF and ACBS; data interpretation: JETP and ACBS; text writing: JETP, BAF and ACBS; approval of the final version to be published: JETP, BAF and ACBS.

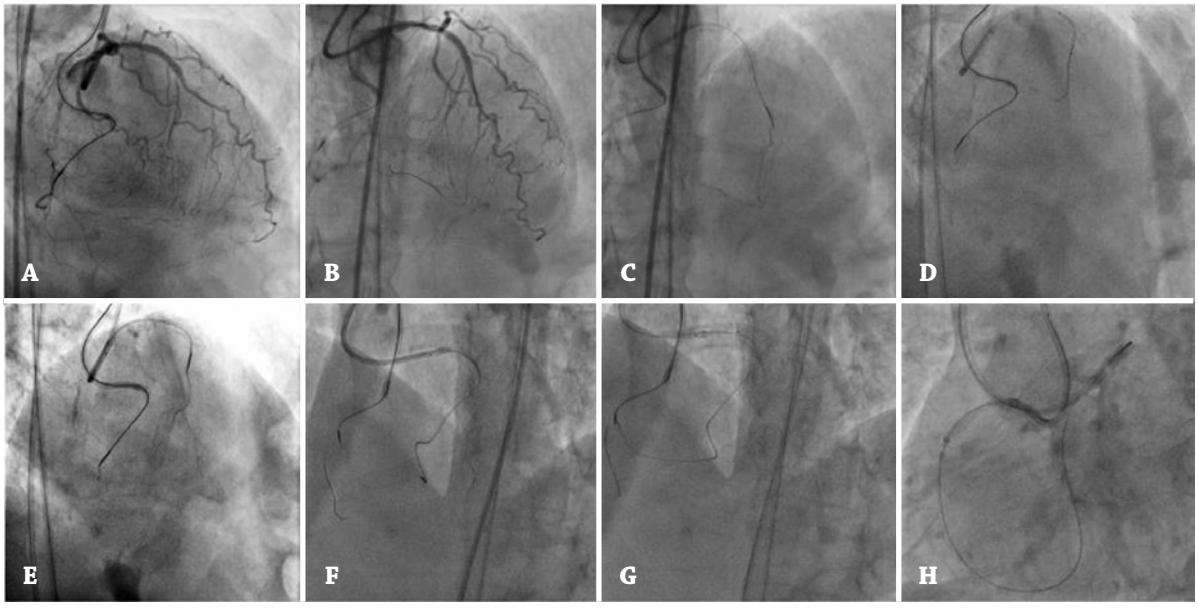

Figure 4. Case illustrating septal collateral crossing. (A) Left coronary angiogram in right anterior oblique view with low magnification and no panning. There are three septal collaterals (S1, S2 and S3 from proximal to distal), all classified as CC2. They appear tortuous and with obtuse angles at entry and exit points. S1 and S2 ostium are jailed by a proximal left anterior descending artery stent. (B) S3 was initially selected for "surfing". (C) After 5 minutes of failed S3 surfing, a tip injection did not show a path. (D) S1 was selected and opening the stent struts with a balloon dilatation for S1 access was performed. (E) After a short try of S1 surfing, S1 tip injection showed the right path. (F) A guidewire (Fielder FC) crossed S1 and was positioned distally in a right marginal branch, while the microcatheter (Turnpike® standard) could not cross the channel. (G) The standard microcatheter was replaced for a low-profile one (Turnpike® LP) which easily crossed S1. (H) GuideLiner-assisted reverse controlled anterior and retrograde tracking was performed for retrograde recanalization.

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