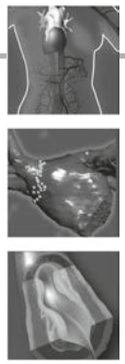

Illustration of the 'hybrid' approach to chronic total occlusion crossing

The 'hybrid' approach to coronary chronic total occlusions advocates using all feasible crossing techniques in a manner that maximizes both efficacy and efficiency. We describe a case of right chronic total occlusion in which several crossing strategies (the 'hybrid' approach) were sequentially utilized during the same procedure, leading to successful recanalization.

KEYWORDS: chronic total occlusion ■ percutaneous coronary intervention ■ technique

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The main mode of failure of coronary chronic total occlusions (CTOs) percutaneous coronary intervention (PCI) is failure to cross [1]. Several techniques can be used for CTO crossing and can be broadly categorized to antegrade wire escalation, antegrade dissection re-entry [2–4] and retrograde [5,6] strategies. Selection of the optimal approach depends on anatomy; for example, long lesions with ambiguous proximal cap and diffusely diseased distal target vessel may be best initially approached using the retrograde approach, provided that appropriate collaterals exist. However, which approach will eventually be successful is variable and may often only be determined by repeated 'trial and error' – the so-called 'hybrid' approach [7]. The 'hybrid' approach to CTO crossing has recently been proposed as the approach that focuses on opening an occluded vessel using all feasible techniques and placing emphasis on procedural success, efficiency and aiming to recanalize the CTO in the shortest time, using the least amount of radiation, contrast and equipment. In other words, the 'hybrid' approach advocates a rapid switch between available crossing strategies until a strategy succeeds.

We describe a CTO case that was successfully recanalized using the 'hybrid' approach.

Case report

A 57-year-old man presented with severe exertional stable angina in spite of optimal medical therapy. Nuclear stress testing revealed a large inferior reversible perfusion defect. Diagnostic coronary angiography demonstrated a proximal right coronary artery (RCA) CTO (Figure 1A). The right posterior descending artery and the distal RCA were filling retrogradely via collaterals from the left anterior descending artery (Figure 1B).

The patient elected to proceed with percutaneous coronary intervention of the RCA CTO. Dual femoral arterial access was obtained with two 45-cm long 8 French sheaths, and unfractionated heparin was administered for anticoagulation. Dual injection revealed a long segment of occlusion (Figure 1B). The procedural milestones are highlighted in Table 1. An initial crossing attempt was made antegradely using a Fielder XT wire (Asahi Intecc, Nagoya, Japan) through a FineCross™ microcatheter (Terumo, NJ, USA) without success. Use of a stiffer guidewire was not attempted because the likelihood of successful antegrade crossing was considered to be low. We subsequently attempted retrograde crossing using a Fielder FC guidewire (Asahi Intecc) through a Corsair microcatheter (Asahi Intecc), however the wire could not cross into the posterior descending artery (Figure 1C). Repeat antegrade crossing attempts using a Confianza Pro 12 guidewire (Asahi Intecc) failed (the guidewire exited the vessel structure, Figure 1D). A second retrograde attempt through an epicardial collateral from the obtuse marginal branch also failed to cross (Figure 1E). A CrossBoss™ catheter (Bridgepoint Medical, MN, USA) successfully crossed the proximal cap subintimally (Figure 1F), but could not be advanced to the distal part of the vessel, in spite of the use of a knuckle wire to redirect the catheter, as the knuckle wire repeatedly entered an acute marginal branch. Finally, a third retrograde attempt through the first septal collateral branch was successful in crossing into the distal true lumen (Figure 1G). The Corsair catheter was advanced using counterclockwise rotation through the septal collateral into the distal RCA (Figure 1H). A Pilot 200 guidewire (Abbott Vascular, CA, USA) was advanced

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Figure 1. Application of the 'hybrid' approach in a right coronary artery chronic total occlusion intervention. (A) Coronary angiography demonstrating a chronic total occlusion of the proximal right coronary artery (arrow). **(B)** Dual coronary injection demonstrating filling of the right posterior descending artery and the distal right coronary artery by collaterals from the left anterior descending artery and the circumflex. **(C)** Unsuccessful retrograde septal collateral crossing attempt. **(D)** Unsuccessful antegrade crossing attempt using a Confianza Pro 12 wire (Asahi Intecc, Nagoya, Japan). **(E)** Unsuccessful retrograde crossing attempt via an epicardial collateral from the obtuse marginal to the right posterior descending artery. **(F)** Unsuccessful attempt for antegrade crossing using the CrossBoss™ catheter (Bridgepoint Medical, MN, USA). **(G & H)** A Corsair catheter (arrow; Asahi Intecc) was advanced via a septal collateral into the distal right coronary artery. A Pilot 200 guidewire (Abott Vascular, CA, USA) was advanced via the Corsair catheter subintimally into the proximal right coronary artery, **(I)** adjacent to an antegradely placed balloon (arrow), followed by **(J)** successful externalization of the retrograde guidewire. **(K)** Final angiographic result showing successful recanalization of the right coronary artery.

subintimally into the proximal RCA, where a reverse controlled antegrade and retrograde tracking and dissection technique was used for successful crossing into the proximal RCA, as confirmed by intravascular ultrasonography (Figure 1I). The Pilot 200 wire was snared and exchanged for a ViperWire Advance™ (CSI, MN, USA) that was successfully externalized (Figure 1J). After balloon predilation and implantation of three everolimus-eluting stents,

an excellent final angiographic result with TIMI 3 flow was obtained (Figure 1K). The total dose of unfractionated heparin administered was 14,000 units, the total air kerma radiation dose was 5.9 Gy, and 520 ml of contrast was used.

Following the procedure, the patient developed a left femoral artery pseudoaneurysm that was successfully treated with thrombin injection. He had complete angina resolution.

Discussion

Our case highlights the importance of flexibility and persistence during CTO PCI: multiple strategy changes (the 'hybrid' approach) may be required for a successful final outcome.

Traditionally, once a crossing strategy is selected for CTO PCI, it is pursued at length, and another strategy is usually not attempted during the same procedure [8]. In case of procedural failure, the patient returns for a repeat attempt at a later time. There are many reasons for not attempting multiple strategies during the same procedure: avoidance of excessive contrast administration or radiation exposure; lack of equipment or expertise in using alternative techniques, such as retrograde or dissection/re-entry strategies; and limited time availability of the cardiac catheterization suite due to other scheduled cases.

The 'hybrid' approach has emerged through the experiences of North American operators in an effort to improve the success rates and optimize use of equipment and resources during CTO PCI [7]. The basic premise of the 'hybrid' approach is that no single procedural crossing strategy should be pursued to exhaustion, but should be abandoned in favor of an alternative strategy if it is not successful during a reasonable amount of time. What is considered a reasonable amount of time varies based on operator experience and whether or not progress is achieved using the initial strategy.

All major CTO crossing strategies were used in the present case. Antegrade wire escalation was attempted initially using a Fielder XT, followed by a Confianza Pro 12 guidewire (Asahi Intecc). Fielder XT is currently commonly used as the initial wire for antegrade crossing, given its soft tapered tip and polymer jacket construction. The Confianza Pro 12 is a stiff (12 g), tapered tip, penetrating guidewire that crossed the proximal cap, but did not advance within the lumen or subintimal space in our case. A rapid escalation strategy is currently preferred by North American CTO operators: if the Fielder XT guidewire fails to cross, then a moderately high gram-force (4–6 g), polymer jacket, nontapered guidewire, such as the Pilot 200 guidewire (Abbott Vascular) is used if the course of the vessel is not well understood, whereas a stiff high-gram force guidewire with a tapered 0.009-inch nonjacketed tip, such as the Confianza Pro 12 wire, is preferred when the vessel pathway and location of the target coronary segment are well understood [7].

Dissection/re-entry strategies involve use of a 'knuckle' guidewire or the Bridgepoint Medical CTO system [3]. In our case, dissection re-entry was attempted using a CrossBoss catheter that actually crossed the proximal cap into the subintimal space (Figure 1F). The CrossBoss has

Table 1. Outline of the procedural strategies utilized in the described case.

Stage	Procedure time (since case start)	Fluoroscopy time (since case start), min	Air kerma radiation dose in Gray (since case start)	Description
1	5 min	4	0.094	Antegrade wiring
2	19 min (24 min)	8 (12)	0.527 (1.467)	Retrograde second septal
3	10 min (34 min)	5 (17)	0.368 (1.835)	Antegrade Confianza Pro 12
4	19 min (53 min)	5 (22)	0.32 (2.155)	Retrograde epicardial
5	18 min (71 min)	8 (30)	0.629 (2.784)	Antegrade CrossBoss™-knuckle
6	14 min (85 min)	8 (38)	0.611 (3.395)	Retrograde collateral crossing
	26 min (111 min)	20 (58)	1.15 (4.545)	Crossing into aorta
	14 min (125 min)	9 (67)	0.351 (4.896)	Snaring plus externalizing wire
	50 min (175 min)	13 (80)	1.101 (5.97)	Stenting completed

a 1-mm blunt round tip that advances with rapid rotation using the 'fast spin' technique. However, we were unable to advance the CrossBoss catheter more distally in spite of using a knuckle wire to redirect it, as the knuckle wire entered an acute marginal branch, requiring use of alternative strategies.

Three retrograde attempts were performed in our case, using both a 'surfing' and a contrast-guided approach to crossing septal collaterals [5]. Epicardial collateral crossing was also attempted, after other procedural strategies had failed, as epicardial collateral perforation would carry high risk for tamponade, especially in patients who have not had prior cardiac surgery, as was the case with our patient. An initial attempt to cross the second septal collateral was unsuccessful, whereas a subsequent attempt to cross the first septal collateral succeeded, highlighting the difficulties in selecting the optimum septal collateral vessel (there was no continuous connection of septal collaterals with the right posterior descending artery in our case) and the optimum length of crossing attempts. After collateral vessel crossing into the distal RCA true lumen, the Corsair catheter was advanced into the distal RCA to support retrograde CTO crossing attempts. The Corsair catheter is the most commonly used catheter for retrograde CTO PCI, as it is easier to advance through collaterals and also dilates them, obviating the need for additional septal collateral balloon dilation [9]. The reverse controlled antegrade and retrograde tracking and dissection technique is the most commonly used technique for retrograde crossing, and was successfully used in our case [10]. After reverse controlled antegrade and retrograde tracking and dissection technique, it is simplest to advance the retrograde guidewire into the antegrade guide catheter followed by externalization; however, sometimes the retrograde wire advances into the aorta requiring snaring to enter the antegrade guide catheter, as in our case [5]. Keeping a high activated clotting time (>350 s) is important during retrograde CTO PCI to minimize the risk for thrombotic compications, such as donor vessel thrombosis [5,11].

The fluoroscopy time used in this case was 80 min, which is higher than the mean fluoroscopy time in contemporary CTO crossing series (42–45 min) [12,13], reflecting the higher technical difficulty of crossing the lesion in this patient. However, in spite of the high fluoroscopy time, the total air kerma radiation dose was acceptable at 5.970 Gy.

In summary, our case illustrates that CTO PCI interventions may require the use of multiple crossing strategy changes during the same procedure, as dictated by procedural progress and as advocated in the 'hybrid' approach to CTO PCI.

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Executive summary

- The 'hybrid' approach to chronic total occlusions involves rapid switch between available crossing strategies until a strategy succeeds.
- Familiarity with the various contemporary chronic total occlusion techniques (antegrade wire escalation, retrograde and dissection/re-entry) is important for implementation of the 'hybrid' approach.
- Close monitoring of radiation and contrast exposure allows optimization of the crossing strategy and minimization of the risk during chronic total occlusion interventions.

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