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CASE REPORT

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The "double stingray technique" for recanalizing chronic total occlusions with bifurcation at the distal cap

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Abstract
Antegrade dissection re-entry is often discouraged for chronic total occlusions (CTOs) with a bifurcation at the distal cap due to risk of side branch occlusion that can lead to periprocedural myocardial infarction and incomplete revascularization. Antegrade dissection re-entry, however, is often needed, especially in complex cases. We present the novel "double Stingray technique" for CTOs involving bifurcations, in which the Stingray system is used twice for re-entry into both vessel branches, followed by two-stent bifurcation stenting to maintain the patency of both branches.

KEYWORDS
CAD - coronary artery disease, complex PCI, CTO, CTO-percutaneous coronary intervention

1 | INTRODUCTION

Chronic total occlusions (CTOs) involve a bifurcation in 26.5%-33.0% of cases [1,2]. CTO percutaneous coronary intervention (PCI) can often lead to occlusion or failure to recanalize the side branches, leading to higher rates of periprocedural myocardial infarction [3,4] and possibly higher restenosis rates. Antegrade dissection and re-entry (ADR) is an important CTO crossing technique, especially for more complex CTOs [5–7]. ADR can, however, lead to side branch occlusion, hence presence of a bifurcation at the proximal or distal cap is considered a relative contraindication for use of this technique. We describe two CTO cases, one with bifurcation at the proximal cap and one with bifurcation at the distal cap, that were successfully recanalized using the "double Stingray" technique, i.e., re-entry in both branches using the Stingray system.

2 | CASE 1

A 64-year-old man with Canadian Cardiovascular Society (CCS) class IV angina was referred for right coronary artery (RCA) CTO PCI for symptom relief. Dual angiography (using a bifemoral approach with two 8 French 45 cm-long sheaths) revealed a blunt proximal cap, mid RCA filling via ipsilateral collaterals and a second CTO in the distal RCA (Figure 1, Panel A). The lesion length was approximately 60 mm with a bifurcation at the distal cap. The right posterior descending artery (PDA) was filling via septal collaterals as well as a large apical epicardial collateral.

Anticoagulation was achieved with unfractionated heparin. Antegrade wire escalation was attempted with several guidewires including Fielder XT, Gaia 2nd (Asahi Intecc, Nagoya, Japan) and Pilot 200 (Abbott Vascular, Santa Clara, California) advanced through a Corsair microcatheter (Asahi Intecc), without success. Attempts for retrograde crossing through two septal and the apical epicardial collateral were also unsuccessful, despite using several guidewires (Sion and Fielder FC, Asahi Intecc) through a Corsair microcatheter (Figure 1, Panel B and C). Repeat antegrade crossing attempts through a CenterCross support catheter (Roxwood Medical, Redwood City, California) using a Pilot 200 guidewire resulted in subintimal guidewire entry. The Pilot 200 guidewire was exchanged for a Fielder XT guidewire that was knuckled and advanced subintimally to the distal cap (Figure 1, Panel D). Given that both distal branches were large, we decided to perform re-entry into both braches. After multiple 1.5 mm balloon inflations over the Fielder XT wire, a Stingray balloon (Boston Scientific, Natick, Massachusetts) was advanced to the right posterolateral vessel (PLV). Re-entry was attempted using the Stingray balloon initially at the bifurcation of the PDA and PLV using the "double blind stick and swap" technique [8], however, contralateral injection from two orthogonal projection did not confirm distal true lumen wire position. As a result, a more distal location

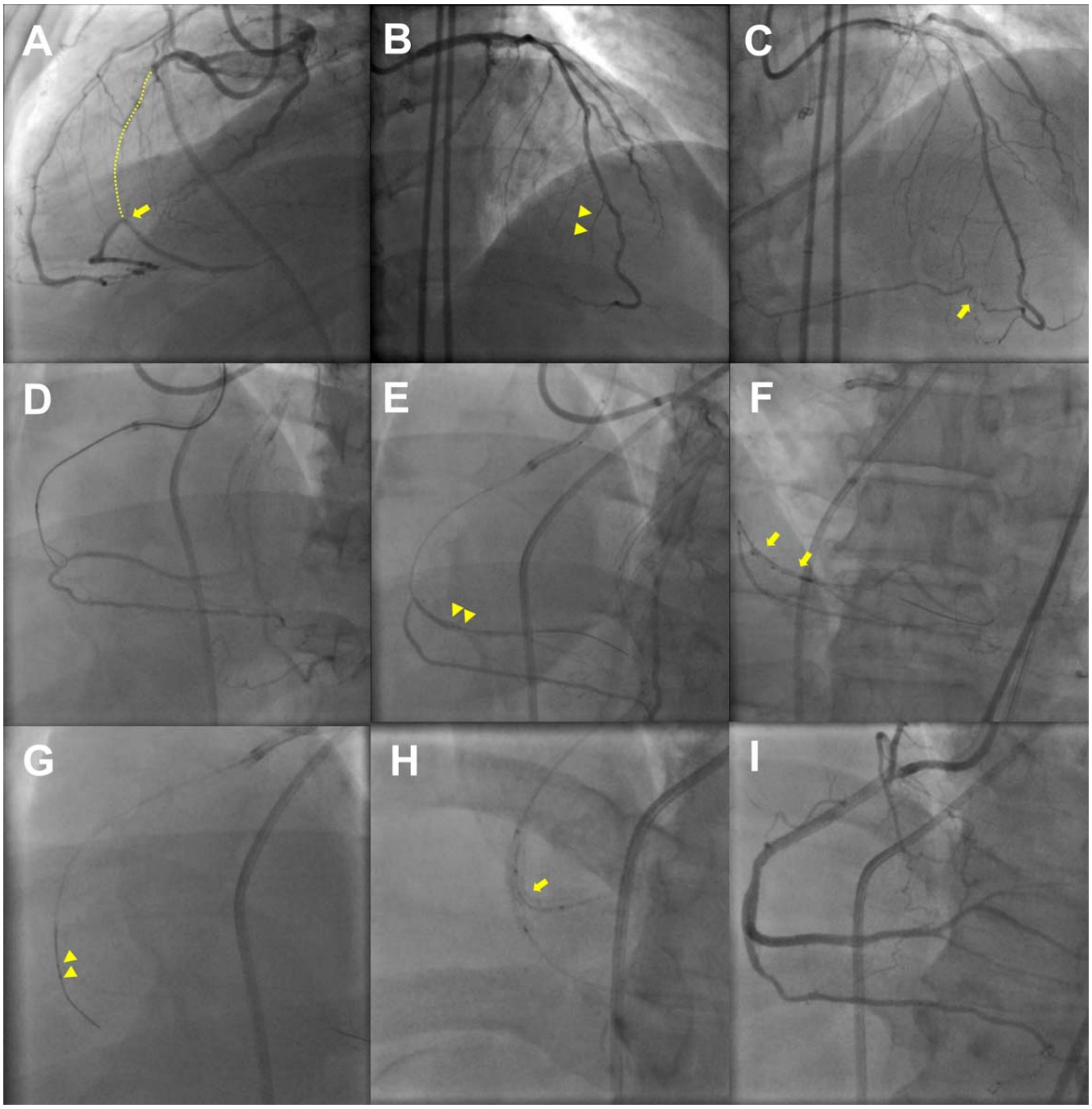

FIGURE 1 Successful recanalization of a right coronary artery CTO with bifurcation at the distal cap. Panel A: Diagnostic angiography showing a mid RCA CTO with ambiguous proximal cap and a bifurcation at the distal cap (arrow). Panel B-C: Failed retrograde crossing attempts via septal (arrowheads, panel B) and epicardial (arrow, panel C) collaterals. Panel D: Antegrade crossing with a knuckled Fielder XT guidewire. Panel E: Reentry into the right posterolateral vessel using the Stingray balloon (arrowheads) and the double blind stick and swap technique. Panel F: Confirmation of distal true lumen guidewire position using intravascular ultrasound (arrows). Panel G: Successful reentry into the right posterior descending artery using the Stingray system (arrowheads) and the stick and swap technique. Panel H: Kissing balloon inflation (arrow) after stenting of the right posterolateral and right posterior descending artery. Panel I: Final angiography showed TIMI 3 flow in both distal branches [Color figure can be viewed at wileyonlinelibrary.com]

were selected for reattempting re-entry ("bobsled" technique [9]) once again using the "double blind stick and swap" technique. Successful reentry into the PLV distal true lumen was finally achieved, as confirmed by intravascular ultrasound (IVUS) (Figure 1, Panels E, F).

Attempts to wire the PDA using a Twin-Pass Torque dual lumen microcatheter (Teleflex, Plymouth, Minnesota) and a Pilot 200 guidewire failed. We advanced a knuckled Fielder XT guidewire to the proximal segment of the PDA, followed by successful re-entry using the Stingray balloon and the "double blind stick and swap" technique (Figure 1, Panel G). The guidewire Pilot 200 was exchanged for a regular workhorse wire using a Corsair microcatheter. Because of subintimal dissection in both branches, an upfront two-stent bifurcation stenting technique was planned, after both vessels were predilated with a 2.0 × 20 mm and a 3.0 × 28 mm balloon. We implanted 4 drug eluting stents (DES) using the double kissing crush (DK-crush) [10] technique (Figure 1, Panel H), followed by proximal optimization technique (POT), with an excellent final result (Figure 1, Panel I). The patient had an uneventful recovery and complete angina resolution.

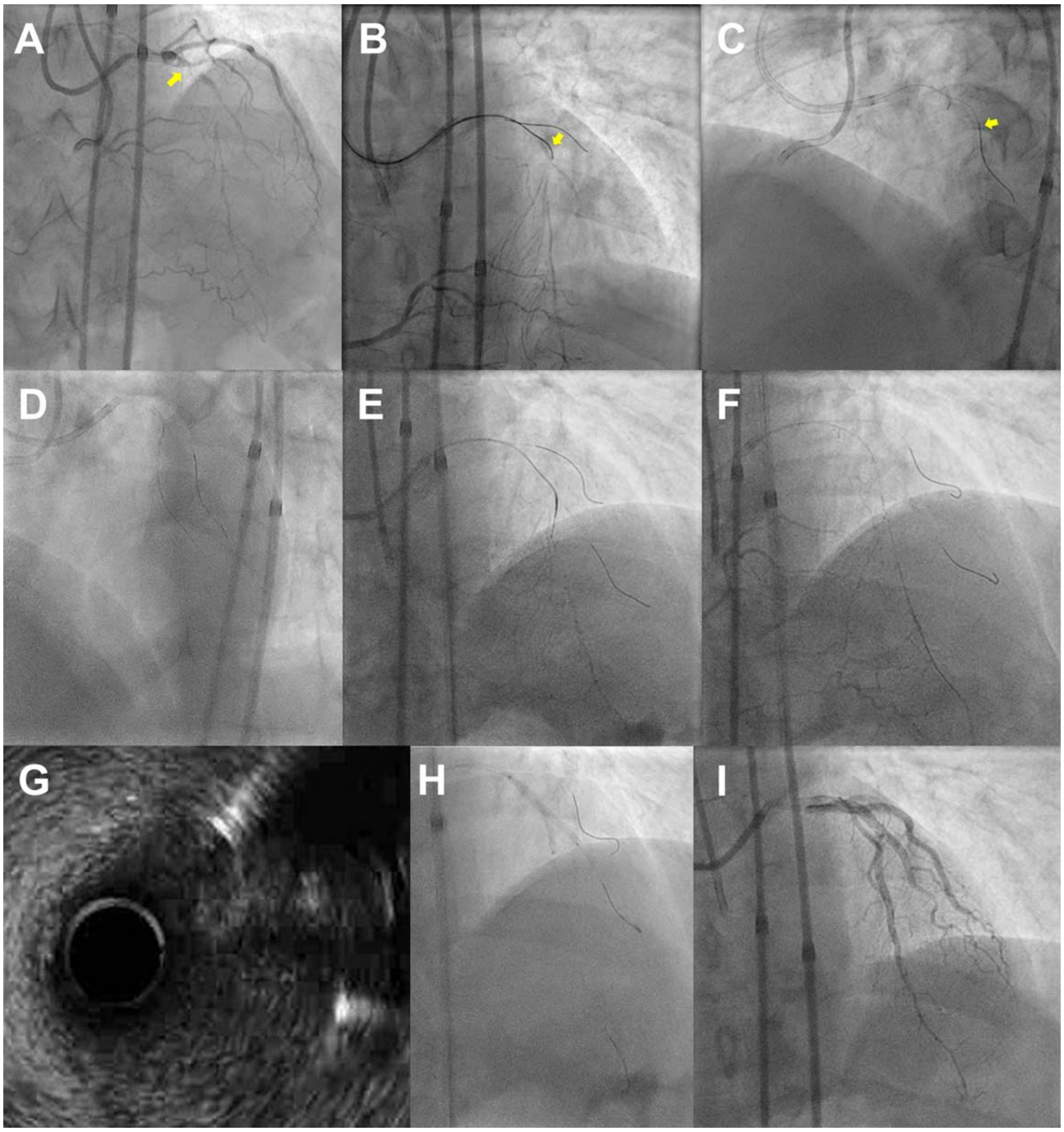

FIGURE 2 Mid left anterior descending artery CTO PCI with bifurcation at the proximal cap. Panel A: Mid left anterior descending artery chronic total occlusion with a blunt, ambiguous proximal cap (arrow). Panel B: Subintimal crossing into the diagonal branch using a Pilot 200 guidewire (arrow). Panel C: Positioning of the Stingray balloon in the diagonal branch (arrow). Panel D: Reentry into the diagonal branch using the stick and swap technique. Panel E: Subintimal crossing into the LAD using a Pilot 200 guidewire. Panel F: Confirmation for true lumen distal LAD wire position with retrograde injection. Panel G: IVUS in the mid-LAD demonstrating the guidewires in the same subintimal space. The IVUS is in the subintimal space as evidence by the lack of the appropriate vessel layers. The true lumen can be seen between the 2 to 3 o' clock position. The diagonal and LAD guidewires were at the 1 o'clock and 4 o' clock position, respectively. Panel H: Kissing balloon inflations of the LAD and diagonal branch. Panel I: Successful recanalization of both the LAD and the diagonal [Color figure can be viewed at wileyonlinelibrary.com]

3 | CASE 2

A 47-year-old man with a history of hypertension, hyperlipidemia and a strong family history of coronary artery disease presented with a two-day history of worsening angina. He had 2-millimeter ST depressions in the inferior EKG leads and a slight troponin elevation. A transthoracic echocardiogram demonstrated mild inferior wall hypokinesis, but otherwise normal left ventricular wall motion. The patient underwent coronary angiography and was found to have a 90% mid-RCA lesion and a left anterior descending artery (LAD) CTO. He underwent successful PCI of the mid-RCA and was referred for LAD CTO PCI.

The patient underwent LAD CTO PCI using bifemoral access with two 8 French guide catheters. Anticoagulation was achieved with unfractionated heparin. The left coronary artery was engaged with an EBU 3.5 guide catheter and the RCA was engaged with an AL1 guide catheter. Dual injection demonstrated two occlusions in the LAD (one occlusion in the mid-LAD and a second occlusion in the distal-LAD) (Figure 2, Panel A). Because of a blunt ambiguous proximal cap, a primary retrograde approach was utilized. Despite several attempts by various skilled CTO PCI operators, the retrograde collaterals could not be crossed. As a result, the decision was made to switch to an antegrade approach.

A Pilot 200 guidewire (Abbott Vascular, Santa Clara, California) supported by a Corsair microcatheter (Asahi Intecc, Nagoya, Japan) was used in hopes of crossing the CTO. The wire entered the subintimal space and tracked into the first diagonal (Figure 2, Panel B). A Stingray balloon (Figure 2, Panel C) was used for re-entry into the distal true lumen using the stick with a Stingray wire and swap for a Pilot 200 wire technique (Figure 2, Panel D). The Pilot 200 was exchanged for a standard workhorse wire using a Corsair microcatheter. The Pilot 200 guidewire was then used to wire the main body of the LAD. However, it also entered the subintimal space after penetration of the proximal cap (Figure 2, Panel E), but it tracked into the distal LAD. Once again, the Stingray re-entry system was used to reenter into the true lumen of the LAD (Figure 2, Panel F), as confirmed by contralateral injection. Kissing balloon inflations were performed in the LAD and diagonal bifurcation (Figure 2, Panel H). Both the LAD and diagonal were then evaluated by IVUS, which demonstrated that both guidewires were in the true lumen proximally and distally. It also demonstrated that the guidewires were in the same subintimal space in the area immediately proximal to the diagonal (Figure 2, Panel G). Based on the guidewires' location, bifurcation stenting using a T-stenting technique was performed (Figure 2, Panel I), restoring TIMI 3 flow in both the LAD and diagonal. The patient was discharged the following day without any complications.

4 | DISCUSSION

To the best of our knowledge, this is the first description of using the Stingray system twice for re-entering into both branches of a bifurcation at the proximal or distal cap of a CTO. Recanalizing both branches of a CTO is important for minimizing the risk for perirprocedural myocardial infraction and the risk for in-stent restenosis.

Several studies have assessed the prevalence and outcomes of bifurcated CTO PCI. In an analysis of 391 CTO PCIs in 373 patients Ojeda et al. reported involvement of a bifurcation in 33% ($n = 105$) with successful recanalization in 81%. As compared with nonbifurcated CTOs, PCI of bifurcated CTOs was associated with higher rates of periprocedural MI (32% vs. 5%, $P < .01$), but similarly low MACE rate at 12-month follow-up (7.7% vs. 9.5%, $P =$ nonsignificant) [2]. Baseline side branch wiring (OR 0.01, 95% CI 0.01-0.09, $P < .01$) and avoidance of side branch involvement in case of subintimal crossing (OR 0.10, 95% CI 0.02-0.49, $P < .01$) were associated with technical success. Galassi et al. reported involvement of a bifurcation in 26.5% of 922 CTO target lesions in 905 patients. Technical and procedural success rates were lower in bifurcated CTOs (87.3% vs. 92.5%, $P = .04$; and 84% vs. 89.4%, $P = .038$), whereas the risk of perforation (4.9% vs. 1.7%, $P < .001$) and tamponade (2.4% vs. 0.4%, $P < .001$) were higher, especially if the bifurcation was located distal to the CTO [1]. Similarly, Nguyen-Trong et al. reported that side branch occlusion was more frequent with use of dissection reentry (both antegrade and retrograde) techniques, stenting over the side branch, and dissection during antegrade wire escalation and were associated with higher incidence of periprocedural MI (32% vs. 12%, $P = .03$). However, the incidence of MACE was similar during a median follow up of 11.3 months [11].

Preserving the patency of both CTO branches in bifurcated CTO PCI can be achieved using retrograde or antegrade techniques. The retrograde approach has been successfully used for restoring flow into the side branch after antegrade CTO crossing into the main vessel [12,13]. However, the retrograde approach is not always feasible, since some patients may not have interventional collaterals; even among patients with appropriate collateral vessels crossing fails in approximately 20%. Moreover, the retrograde approach carries higher risk for complications as compared with antegrade crossing [14,15]. Therefore, antegrade crossing of bifurcated CTOs is highly desirable.

True-to-true lumen antegrade crossing offer the highest likelihood for maintaining patency of both branches in bifurcated CTOs and should be attempted as first line approach, however, this may not feasible in some cases (e.g., patients without "interventional" collaterals, or multiple failed retrograde and antegrade approaches). The "double Stingray" technique offers a solution in such cases, by allowing re-entry into both branches. It does, however, have limitations. First, it may lead to large subintimal hematoma compressing the distal true lumen and hindering re-entry in one or both distal vessels, potentially leading to side branch loss. The risk for subintimal hematoma could be minimized by avoiding any antegrade injection after subintimal wire entry and by minimizing wire manipulations distal to the distal cap. In case of subintimal hematoma formation, decompression of the subintimal space (STRAW technique [9]) by aspiration can be attempted with the Stingray balloon itself, or through a guide catheter extension. Second, it requires subintimal entry in both branches, which may not always be feasible, for example in cases where the guidewire preferentially enters one vessels or in cases of extreme angulation and severely diseased distal vessels. Third, it almost always requires use of a two stent bifurcation technique, such as DK crush, which can be more complex to perform than provisional stenting and requires longer fluoroscopy time and contrast volume and potentially predisposes to higher risk for stent thrombosis and/or restenosis. Fourth, it requires extensive experience in the use of the Stingray system and the various re-entry maneuvers, such as the bobsled, the stick and swap, and the double blind stick and swap techniques. Fifth, use of IVUS is strongly recommended in both branches to ensure that the guidewires are localized in the same subintimal vessel layer, as well as confirm distal true lumen wire positions. Kissing balloon inflations are important prior to stenting to fenestrate the intimal flaps created by the dissection re-entry to avoid possible intimal flap shift and side branch loss.

5 | CONCLUSION

The double Stingray technique can allow successful crossing and recanalization of both branches of bifurcated CTOs, minimizing the risk for periprocedural myocardial infarction and maximizing the likelihood of achieving long-term patency in both involved vessels.

AUTHOR CONTRIBUTIONS

Peter Tajti: Nothing to disclose.

Darshan Doshi: Nothing to disclose.

Dimitri Karmpaliotis: Speaker honoraria from Boston Scientific, Abbott Vascular.

Emmanouil S. Brilakis: Consulting/speaker honoraria from Abbott Vascular, Amgen, Asahi, Boston Scientific, Cardinal Health, CSI, Elsevier, GE Healthcare, and Medicure; research support from Boston Scientific, InfraRedx and Osprey; spouse was employee of Medtronic.

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