Subadventitial Advancement of a Mother-and-Child Catheter to Allow Successful Recanalization of a Complex In-Stent Chronic Total Occlusion: Testing the Resistance of the Adventitia

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ABSTRACT: In-stent chronic total occlusion (CTO) represents a challenging lesion subset for percutaneous coronary intervention (PCI), and although a true-to-true lumen crossing is the first-line strategy, a subadventitial approach may become necessary. Here we describe a case of successful in-stent right coronary artery CTO-PCI performed with subadventitial crossing, crushing of the occluded stents, and advancement of a mother-and-child catheter to the distal right coronary artery through the subadventitial space to allow stent delivery. The use of intracoronary imaging in this setting proved crucial to confirm adequate apposition of the newly implanted stents and optimal crushing of the occluded stents.

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KEY WORDS: chronic total occlusion, in-stent restenosis, subadventitial

Chronic total occlusions (CTOs) represent one of the most challenging lesion subsets for percutaneous coronary intervention (PCI), and those secondary to in-stent restenosis have historically been associated with higher failure rates.[1,2] True-to-true lumen crossing, achieved by either a wire-based approach or by means of the CrossBoss catheter (Boston Scientific), is the optimal strategy to recanalize in-stent CTOs.[3] However, this is sometimes impossible to achieve, and alternative crossing strategies need to be pursued.

Subadventitial crossing followed by external crushing of the occluded stent has been anecdotally reported as a feasible strategy to overcome "uncrossable" in-stent CTOs.[4,5] However, in such cases, the occluded stents were rather short, which allowed stent delivery with conventional techniques.

Herein, we describe a case of successful recanalization of a CTO due to a long occlusive restenosis in two overlapping stents in the mid-to-distal right coronary artery (RCA). Since true-to-true crossing could not be achieved, subadventitial crossing with subsequent stent crushing was performed. However, the extensive length of the crushed stent segments prevented advancement of new stents into the distal true lumen. Therefore, a mother-and-child catheter was successfully advanced through the subadventitial channel to allow stent delivery. Invasive imaging confirmed optimal apposition of the newly implanted stents and adequate crushing of the occluded stents.

Case Presentation

A 54-year-old man was admitted for a third attempt at RCA-CTO recanalization. He was known to have hypertension, dyslipidemia, smoking habit, and significant coronary artery disease (CAD), having undergone multiple PCIs to the three coronary arteries. In particular, he had received multiple bare-metal stents in his RCA, which were found to be occluded 10 years earlier. The patient remained symptomatic despite optimal medical therapy and myocardial perfusion imaging demonstrated inducible ischemia in the inferior wall. Two unsuccessful PCIs of the RCA-CTO were performed through both antegrade and retrograde approaches.

The occlusion extended from the ostium to both the posterolateral (PL) branch and posterior descending artery (PDA), and presented proximal cap ambiguity, multiple focal areas of calcification, and a short island of patent vessel (visualized through an ipsilateral epicardial collateral from the proximal RCA; Mashayekhi type B[6]) just proximal to two overlapping occluded stents in the mid-to-distal RCA (Figures 1A and 1B). The Japanese-CTO score was 5.

In previously failed CTO-PCIs, antegrade true-to-true crossing was attempted with multiple guidewires of different tip shape, which consistently tracked outside the occluded stents in the mid RCA (Figure 1C) due to gross stent undersizing (Figure 2). A retrograde approach was performed via ipsilateral epicardial collaterals from the proximal to the mid RCA in an attempt to recanalize the proximal segment of the occlusion and therefore to facilitate a staged attempt at revascularization of the more distal part of the CTO. However, vessel calcification and the steep angle between the landing of the epicardial collateral and the occluded vessel prevented retrograde microcatheter advancement and wire externalization (Figure 1D). Therefore, antegrade balloon angioplasty of the occluded proximal RCA was performed (investment procedure; Figures 1E and 1F).

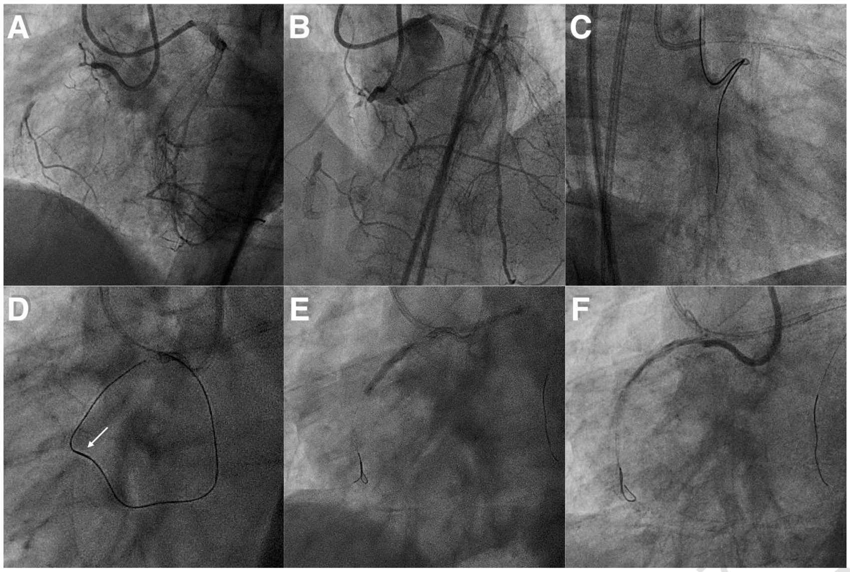

FIGURE 1. First procedure: right coronary artery (RCA) in-stent chronic total occlusion. (A) The occlusion is very long, with proximal cap ambiguity, multiple focal areas of calcification, and a short island of patent vessel just proximal to two overlapping occluded stents in the mid-to-distal RCA. (B) Ipsilateral epicardial collaterals (from the proximal to the mid RCA), as well as contralateral septal (from the left anterior descending to the acute marginal) and epicardial (from the circumflex to the posterolateral) channels are visualized. (C) Antegrade true-to-true crossing fails, with wires tracking outside the occluded stents in the mid RCA. (D) The retrograde approach through an epicardial ipsilateral collateral also fails due to impossibility in overcoming the steep angle, as indicated by the arrow. (E) Balloon predilation in the subadventitial space is performed (investment procedure). (F) Final result.

For the current procedure, dual access was secured via left radial artery and right femoral artery with 7 Fr sheaths. Baseline angiography showed similar findings as prior to the previous attempt (Figure 3A). The retrograde approach was attempted with a Turnpike LP microcatheter (Vascular Solutions) and a Sion wire (Asahi Intecc) via epicardial collaterals from the circumflex, to no avail due to their extreme tortuosity (Figures 3B and 3C).

An antegrade approach was therefore undertaken with the CrossBoss catheter, which tracked outside the stents in the mid RCA due to the aforementioned stent-vessel size mismatch (Figure 3D). CrossBoss wire-redirection was similarly unsuccessful.

Subsequently, a knuckle wire was created with a Fielder FC (Asahi Intecc). Due to difficulty in advancing the knuckled wire through the subadventitial space in the crushed stent area, the Turnpike LP itself was knuckled and successfully advanced to the distal RCA (Figure 3E). The subintimal tracking and re-entry (STAR) technique was performed and the wire crossed into the PL branch (Figure 3F). Extensive lesion predilation was then achieved using a 2.5 x 20 mm non-compliant (NC) balloon and a 2.5 x 30 mm semicompliant balloon, with subsequent crushing of the occluded stents (Figure 4A). However, it was not possible to pass a new stent to the distal RCA through the subadventitial space. A 7 Fr GuideLiner mother-and-child catheter (Vascular Solutions) was therefore advanced through the channel created in the subadventitial space, outside the occluded/crushed stents, using the stepwise repeated distal balloon anchoring technique[7] (Figure 4B; Videos 1 and 2), with subsequent implantation of five overlapping drug-eluting stents (3.0 x 38 mm, 3.5 x 38 mm, 4.0 x 38 mm, 4.0 x 38 mm, and 5.0 x 12 mm) from the PL branch to the ostial RCA. High-pressure postdilation was carried out using 3.5 mm, 4.0 mm, 4.5 mm, and 5.0 mm NC balloons from the distal to the proximal segments. Excellent angiographic result was obtained (Figures 4C and 4D), and both intravascular ultrasound (IVUS) and optical coherence tomography confirmed optimal crushing of the occluded stents and expansion of the newly implanted stents (Figure 5).

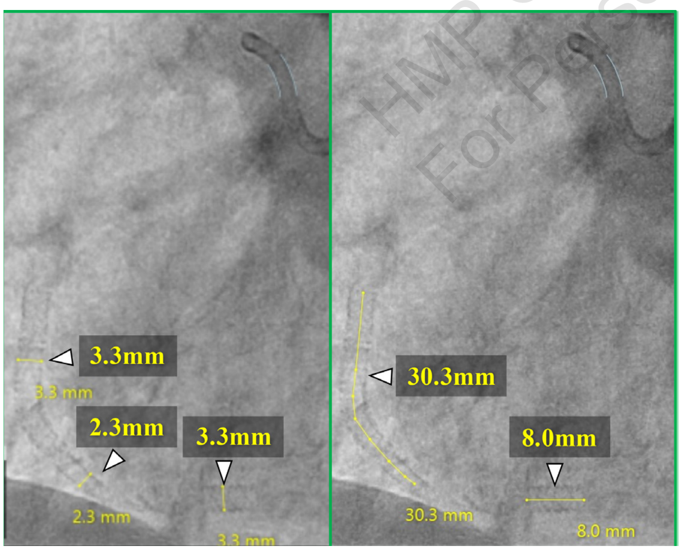

FIGURE 2. Quantitative coronary analysis of the occluded stents with relative measurements. Two overlapping stents for a total length of 30 mm are visualized in the mid-to-distal right coronary artery, with evidence of gross stent undersizing at the level of the distal part of the overlapping segment.

The patient was discharged the following day on long-term dual-antiplatelet therapy and was asymptomatic at subsequent follow-up exam.

Discussion

CTO due to in-stent occlusive restenosis represents a particularly challenging lesion subset and can be secondary to neointima formation, neoatherosclerosis, adverse reaction to polymer, or stent thrombosis, fracture, malapposition, or under-expansion.[3,8] Despite potential advantages deriving from the use of previously implanted stents as a roadmap[9] to guide through the occluded vessel, in-stent CTO-PCI has traditionally been associated with lower success rates when compared with PCI for *de novo* CTOs.[1,2] Inability to wire the occlusion is the most frequent mechanism of failure of both in-stent and native coronary artery CTO-PCI; however, balloon-uncrossable and balloon-unexpandable lesions are more frequent with in-stent CTO[1] due to the resistance offered by stent struts in close proximity to the guidewire.[9] Nevertheless, as a result of technical developments (lower-profile microcatheters and balloons, steerable wires, CrossBoss) and the introduction of the hybrid algorithm,[10] procedural success rates of in-stent CTO-PCIs have recently become comparable to those for *de novo* CTOs.[3,11]

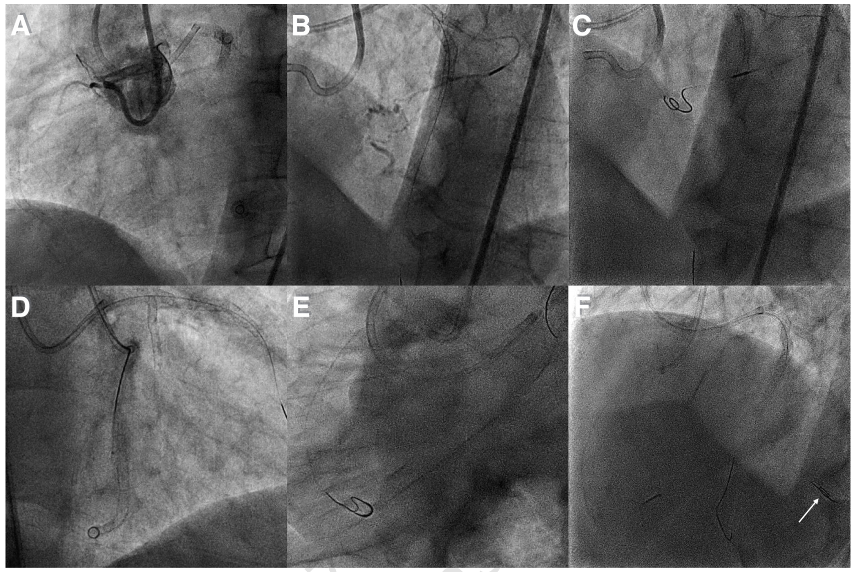

FIGURE 3. Second procedure. (A) Baseline angiography is unchanged from the initial attempt. (B) Tortuous epicardial collaterals from the circumflex are accessed (C) with a Turnpike LP microcatheter and a Sion wire, to no avail due to extreme tortuosity. (D) The CrossBoss tracks outside the occluded stents. (E) The Turnpike LP and a Fielder FC wire are knuckled in the subadventitial space and (F) advanced, reaching the true lumen in the posterolateral branch (arrow).

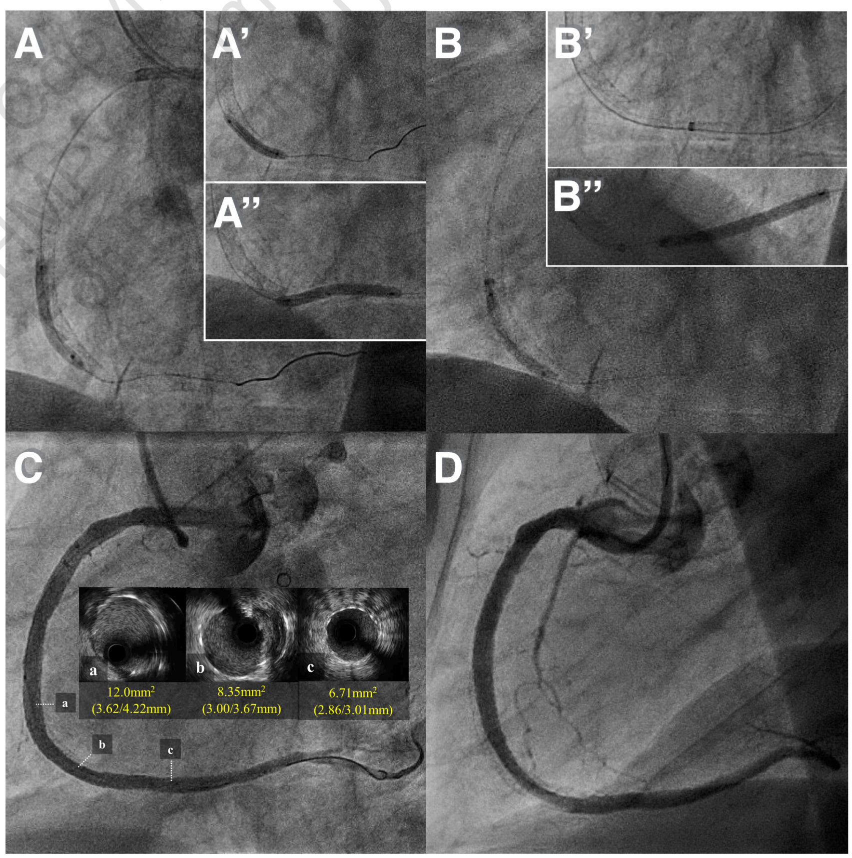

FIGURE 4. (A) Subadventitial crushing of the occluded stents is performed with 2.5 mm balloons. (B) A 7 Fr GuideLiner is advanced to the distal right coronary artery (RCA) through the subadventitial space using the stepwise repeated distal balloon anchoring technique.[7] Five drug-eluting stents were implanted from the posterolateral branch to the RCA ostium, with optimal angiographic result confirmed with intravascular ultrasound imaging (C and D). Note the much larger final lumen diameter (C) compared with the baseline situation shown in Figure 2.

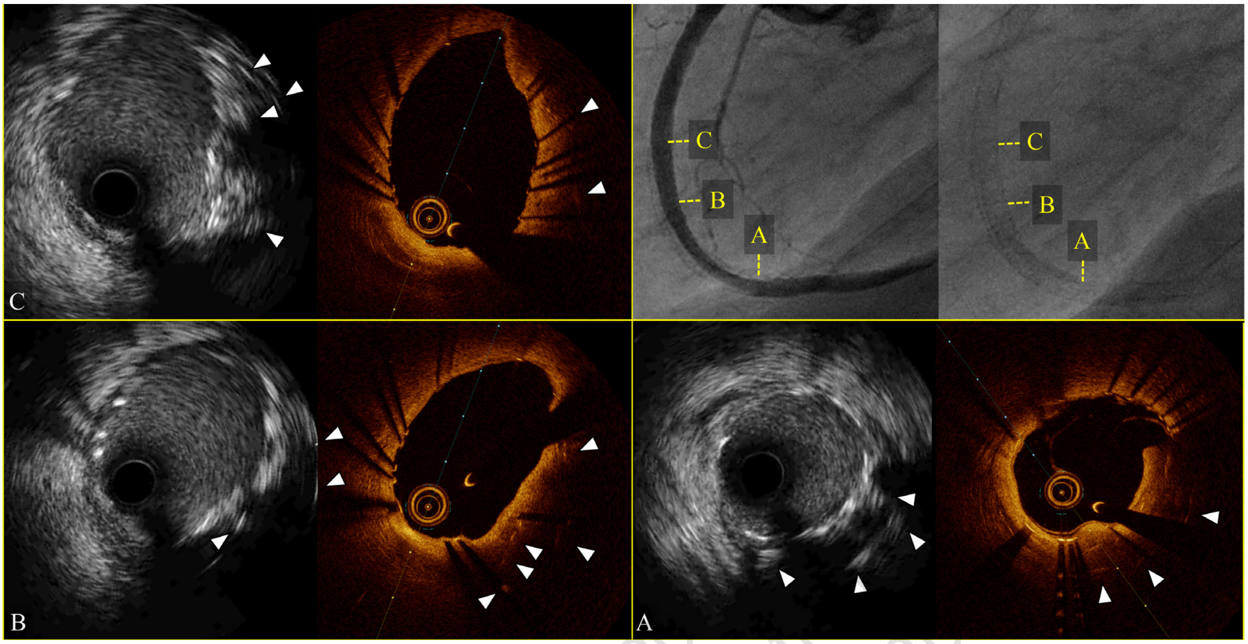

FIGURE 5. Intravascular ultrasound and optical coherence tomography showing adequate crushing of the occluded stents and optimal expansion and apposition of the newly implanted stents. Arrowheads indicate crushed stent struts.

In particular, the use of the CrossBoss, an over-the-wire catheter with a blunt, atraumatic 3 Fr tip, offers the opportunity of a quick, safe, within-stent, true-to-true crossing, utilizing the "fast-spin" technique.[9] However, in the current case, we could not manage to engage the CrossBoss into the occluded stent, likely due to the lower resistance of the subadventitial space compared with the intraplaque plane, as well as the gross stent under-sizing. Wire redirection was also unsuccessful.

Alternative techniques, including antegrade-wire escalation and the retrograde approach through ipsilateral and contralateral epicardial collaterals, were attempted to no avail. Subadventitial crossing with subsequent crushing, which has previously been shown feasible both antegradely[5] and retrogradely,[4] appeared the only remaining option to recanalize such a complex occlusion in a severely symptomatic patient. An important point of concern is represented by the possibility of vessel perforation/laceration from predilation underneath the thin adventitial layer and against the resistant metallic stent. For this reason, some operators advocate against performing aggressive stent sizing and postdilation, which could, however, lead to subsequent new episodes of in-stent restenosis.

Crucially, experimental evidence indicates that the adventitia possesses very high tensile strength compared with inner layers,[12] thus allowing aggressive manipulation (including rotational atherectomy[13]) and safe CTO recanalization, as long as advancement of wires and other devices takes place through a plane that is longitudinal to the vessel main axis.[14]

In the current case, a large-bore device – a 7 Fr GuideLiner – was advanced through a long subadventitial channel from the mid to the distal RCA. To the best of our knowledge, this is the first description of this technique. This maneuver became necessary because stent delivery to the distal vessel was impossible, despite extensive crushing of the occluded stents. Fully expanded balloons in this setting (Figure 4A) indicated that the underlying mechanism was subadventitial space recoil. Therefore, utilization of a device able to prevent collapse of the subadventitial space, such as a mother-and-child catheter, appeared the best choice. Advancing the GuideLiner with the stepwise repeated distal-balloon anchoring technique[7] (Figure 4B) was crucial to the delivery of long stents to the distal vessel, thus avoiding friction and interference by the distorted struts of the long, crushed, occluded stents. This novel utilization of a mother-and-child catheter through a long subadventitial channel following external crushing of occluded stents confirms the high tensile strength of the adventitia.[12]

Another important element in the safe and successful performance of such an aggressive intervention is represented by the use of intravascular imaging to confirm optimal apposition of the newly implanted stents and adequate crushing of the occluded stents. There is solid evidence indicating that compared to angiography guidance alone, IVUS-guided CTO-PCI is associated with better mid-term outcomes, including lower incidence of myocardial infarction and target-vessel revascularization.[15] In the setting of in-stent CTO treated with subadventitial crushing of a long segment of occluded stents, the indication for invasive imaging appears even more compelling. However, specific outcome data are lacking due to the very low frequency of such procedures, and evidence derives from anecdotal case reports.[4,5]

Conclusion

We report a challenging case of successful in-stent CTO recanalization achieved with an unconventional approach represented by the combination of subadventitial crushing of occluded stents and the innovative use of a mother-and-child catheter through the subadventitial space and alongside the crushed stents. Invasive imaging confirmed optimal apposition of the newly implanted stents. Clearly, the techniques described in this article should be considered by operators with advanced skills tackling complex cases, and when conventional techniques and maneuvers have proved unsuccessful.

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