Check for updates

Received: 12 November 2022 | Revised: 3 January 2023 | Accepted: 11 January 2023

DOI: 10.1002/ccd.30565

ORIGINAL ARTICLE - CLINICAL SCIENCE

WILEY

Role of the retrograde Carlino technique for chronic total occlusion percutaneous coronary intervention

Lorenzo Azzalini MD, PhD, MSc[1] | Nicolas Boudou MD[2] | Alexandre Avran MD[3] | Jesse Kane MD[1] | William L. Lombardi MD[1] | Kathleen E. Kearney MD[1] | Mauro Carlino MD[4]

[1]Department of Medicine, Division of Cardiology, University of Washington, Seattle, Washington, USA

[2]Clinique Saint Augustin, Bordeaux, France

[3]Hôpital de Valenciennes, Valenciennes, France

[4]Cardio-Thoracic-Vascular Department, Interventional Cardiology Unit, San Raffaele Hospital, Milan, Italy

Correspondence
Lorenzo Azzalini, MD, PhD, MSc, Department of Medicine, Division of Cardiology, University of Washington, 1959 NE Pacific St, Box 356422, Seattle, WA 98195, USA.
Email: azzalini@uw.edu

Abstract

Background: There is scarce data on the outcomes of the Carlino technique for chronic total occlusion (CTO) percutaneous coronary intervention (PCI). We aimed to investigate the indications and outcomes of the Carlino technique as performed in the context of the retrograde approach.

Methods: We pooled CTO PCI cases where a retrograde Carlino technique was performed from high-volume operators at four centers. The Carlino technique was characterized according to its indication (achieving plaque/cap modification, clarifying microcatheter location within the vessel, resolving distal cap ambiguity) and was considered successful when it led to the desired outcome.

Results: A total of 43 patients were included. Occlusion complexity was very high (mean J-CTO score 3.3 ± 0.8). The two most common indications were understanding the anatomy of the occlusion and clarifying gear location (37.2%) and impenetrable distal cap (34.9%). The Carlino technique was successful in 88.4% of cases. Overall technical and procedural success was 86.0%. The most common successful crossing technique was reverse controlled antegrade and retrograde subintimal tracking (70.3%). No complications were attributed to the Carlino technique.

Conclusions: We observed a high success rate of the retrograde Carlino technique, as well as overall technical and procedural success rates. No Carlino technique-related complications were observed. Additional data from larger registries are warranted to further confirm the safety and efficacy of this technique.

KEYWORDS

Carlino technique, chronic total occlusion, percutaneous coronary intervention, retrograde approach

1 | INTRODUCTION

After its introduction in 2005, the retrograde approach has promoted a remarkable increase in success rates of chronic total occlusion (CTO) percutaneous coronary intervention (PCI), allowing recanalization of complex occlusions with proximal cap ambiguity, extensive calcification, tortuosity, and/or length, or presence of a bifurcation at the distal cap.[1–4]

However, fibrocalcified and tortuous occlusions still represent a challenge for the operator, even if the retrograde approach is utilized.

 © 2023 Wiley Periodicals LLC.

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

In particular, impenetrable or ambiguous distal caps, fibrocalcified segments within the occlusion, ambiguity of vessel course, and presence of side branches within the occlusion, all hamper safe and effective navigation of the retrograde equipment.[5]

Several possible solutions exist for these challenges (e.g., knuckle wire technique to navigate tortuous occlusions, balloon-assisted microdissection for impenetrable cap[5]). The Carlino technique[6,7] consists in the gentle injection of a small volume of contrast media through a microcatheter advanced into the occlusion, with the goal of either modifying plaque compliance (if the microcatheter is located intraplaque) or providing topographic information with regard to microcatheter position (in the main segment of the occluded vessel vs. a side branch) if the latter is in the extraplaque space.[8] While the Carlino technique is routinely utilized by hybrid operators,[9–12] the outcomes of such an approach have been characterized mainly in the setting of the antegrade approach.[13]

The aim of this study is to characterize the practice patterns, applications, and outcomes of the Carlino technique during the retrograde approach for CTO PCI.

2 | METHODS

2.1 | Patient population

This retrospective multicenter registry included patients treated with the Carlino technique as performed via a microcatheter advanced retrogradely into the occlusion after collateral crossing. Subjects treated at four dedicated CTO programs in Italy, France and the United States between March 2014 and October 2022 were included. All procedures were indicated to treat angina, ischemia or both, and were performed electively (ad hoc PCI was discouraged).[1] Baseline, procedural, and hospitalization data were recorded. The study received local institutional review board approval.

2.2 | Definitions

CTO was defined as a 100% stenosis with Thrombolysis In Myocardial Infarction (TIMI) 0 flow for >3 months.[14]

Successful Carlino technique was defined as a meaningful change in distal cap/plaque compliance that allowed retrograde gear advancement, or in case the operators were able to obtain topographic information that allowed them to solve doubts with regard to vessel course or distal cap ambiguity.

Technical success was defined as achievement of TIMI grade 2 or 3 antegrade flow in all ≥2.5-mm distal branches with <30% residual stenosis of the target CTO lesion.[14] Procedural success was defined as technical success plus the absence of an in-hospital major adverse cardiovascular event (death, myocardial infarction, or clinically driven target-vessel revascularization).[14]

2.3 | Carlino technique

The Carlino technique has been previously described in detail.[6,8] Briefly, a small (<0.5 ml) volume of contrast is gently injected through a microcatheter advanced into the occlusion. In case of intraplaque location of the microcatheter (*intraplaque application*; Figure 1), contrast injection will distribute along loose tissue planes within the occlusion and will modify plaque compliance by softening it, with the goal of making subsequent gear advancement easier. In this scenario, the aim of the technique is to get a vague localized blush of contrast with a "patchy" distribution inside the occluded segment: this patchy distribution of the contrast likely reflects the recruitment of the soft portion of the occlusive plaque. If the microcatheter is located in the extraplaque space (*extraplaque application*; Figure 2), two possible angiographic images can be identified. A "storm-cloud" appearance is indicative of transient increase of wall permeability in a small vascular structure (typically, a small side branch). A "tubular" staining mirrors the accumulation of contrast along subintimal planes in a larger vessel (typically, the main course of the occluded vessel). In the contemporary Carlino technique only small amounts of contrast are gently injected, so the operator should immediately stop injecting when such pattern appears, to avoid creating extensive dissection planes. Operators can therefore judge where their gear is located and redirect (storm-cloud dissection) or continue advancing (tubular dissection) it. Finally, if the microcatheter is located at the distal cap (*cap application*; Figure 3), the Carlino technique will allow a precise characterization of features that might not be noticed upon simple dual angiography from the guide catheters: for example, presence of tiny side branches, a tapered stump, or a microchannel.

There are no differences in the technical aspects of the maneuver according to its "direction" (retrograde vs. antegrade).

2.4 | Statistical analysis

Continuous variables are presented as mean ± standard deviation. Categorical variables are presented as frequency (percentages). Statistical analysis was performed using SPSS 24 (IBM Corp).

3 | RESULTS

A total of 43 patients who were treated with the Carlino technique in the context of the retrograde approach were included (Table 1). Mean age was 67.0 ± 9.2 years and 86% of patients were male. The most frequent target vessel was the right coronary artery (RCA; 76.7%). Occlusion complexity was very high (mean J-CTO score 3.3 ± 0.8). In slightly over half of the study population, the retrograde approach was utilized as a first-line strategy. In 58.1% of cases, additional maneuvers were attempted before utilizing the Carlino technique: these included a retrograde knuckle wire approach (44%), use of an antegrade guide catheter extension to try to advance the

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

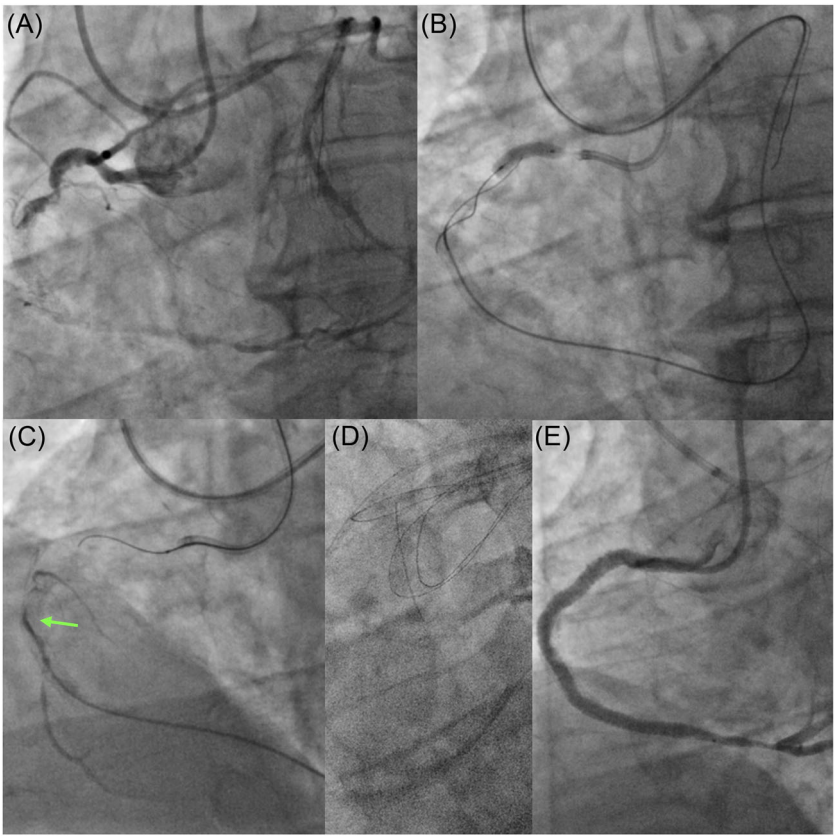

FIGURE 1 Retrograde Carlino technique: plaque modification. (A) Right coronary artery CTO with extensive calcification and tortuosity. (B) After retrograde crossing, the microcatheter cannot advance past a focal spot of calcification in the mid vessel. (C) A Carlino technique is performed (arrow), which shows clear intraplaque location, as demonstrated by contrast recruitment of multiple side branches. (D) This was sufficient to allow microcatheter advancement in the proximal vessel, and direct wiring of the right coronary artery ostium into the aorta, with subsequent snaring of an externalization wire. (E) Final result after stenting. CTO, chronic total occlusion. [Color figure can be viewed at wileyonlinelibrary.com]

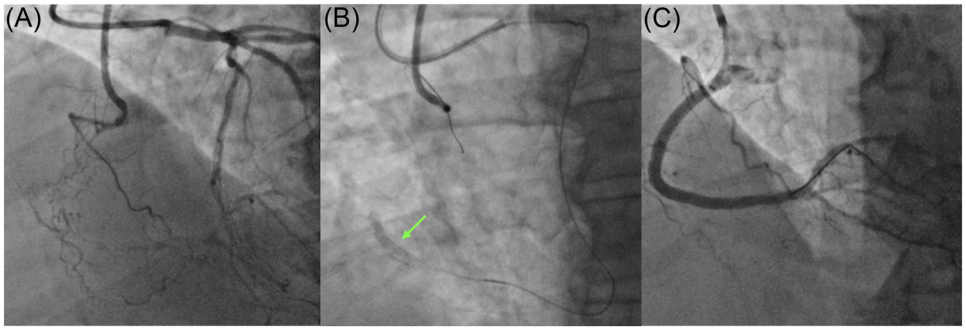

FIGURE 2 Retrograde Carlino technique: tubular dissection. (A) Long right coronary artery CTO with proximal cap ambiguity and calcification. (B) After retrograde crossing, the operator was not sure of the wire/microcatheter location. A Carlino technique showed a reassuring pattern of tubular dissection (arrow), indicating gear location in the expected course of the main vessel (right coronary artery). (C) Final result after occlusion crossing and stenting. CTO, chronic total occlusion. [Color figure can be viewed at wileyonlinelibrary.com]

base of operations closer to the retrograde system (7%), retrograde wiring (2%), and snaring the retrograde wire after it crossed into the aorta to support retrograde microcatheter advancement (2%).

Figure 4 shows the indications of the retrograde Carlino technique in our cohort. The two most common indications were understanding the anatomy of the occlusion and clarifying gear location (37.2%) and impenetrable distal cap (34.9%). Other indications included: plaque modification within the occlusion (14.0%), a combination of understanding the anatomy and plaque modification (9.3%), and distal cap ambiguity (4.7%).

The Carlino technique was successful in 88.4% of cases. Overall technical and procedural success was 86.0%. The most common successful crossing technique was reverse controlled antegrade and retrograde subintimal tracking (reverse CART; 70.3%), followed by retrograde wiring (24.3%), CART (2.7%), and kissing wires (2.7%).

Complications were observed in two cases: coronary air embolism in the donor vessel in one, and guide catheter-induced dissection on the target vessel in another; both were managed successfully and all patients were discharged after uneventful hospital stay. No complications were attributed to the Carlino technique.

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

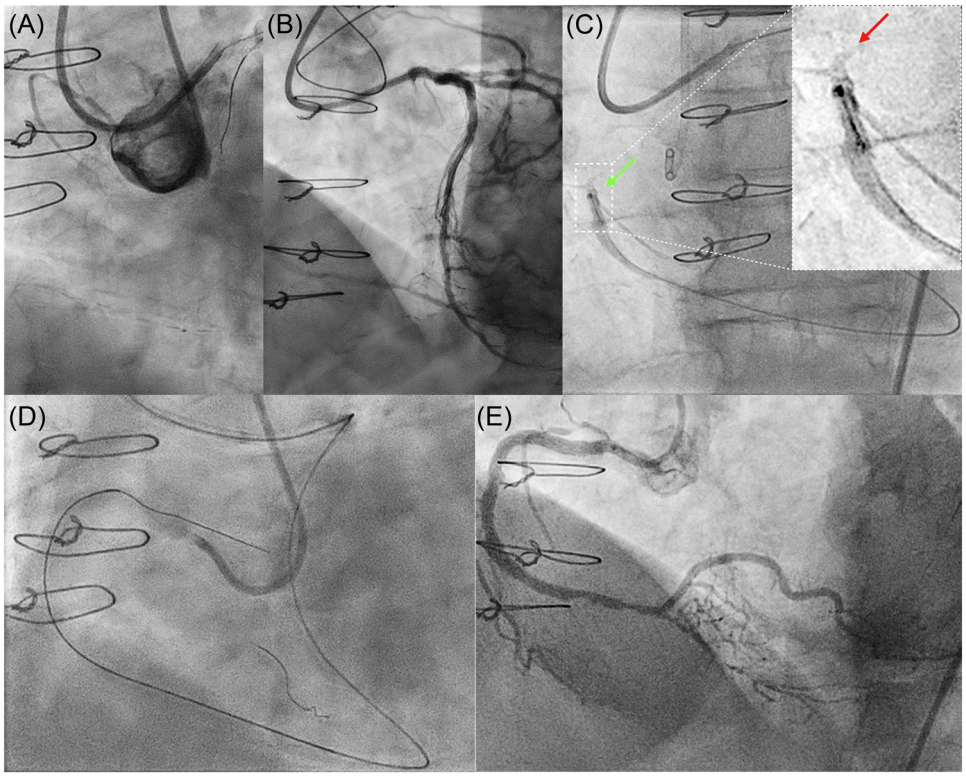

FIGURE 3 Retrograde Carlino technique: resolving distal cap ambiguity. (A) Flush ostial right coronary artery CTO, (B) which extends until the mid vessel. (C) After retrograde crossing, a Carlino technique is performed at the distal cap (green arrow), which shows a tapered cap (red arrow in the inset). (D) Accordingly, a retrograde wiring strategy was chosen by operator, who used a highly torqueable wire to puncture into the aorta. (E) Final result after stenting. CTO, chronic total occlusion. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Patient characteristics and procedural data

Variable		*N* (%) or mean ± SD
Age		67.0 ± 9.2
Men		86.0%
Target CTO vessel	Right coronary artery	33 (76.7%)
	Circumflex	5 (11.6%)
	Left anterior descending	5 (11.6%)
J-CTO score		3.3 ± 0.8
Retrograde approach as first-line strategy/ bailout of failed antegrade		55.8%/44.2%
Additional maneuvers attempted before retrograde Carlino		25 (58.1%)

Abbreviation: CTO, chronic total occlusion.

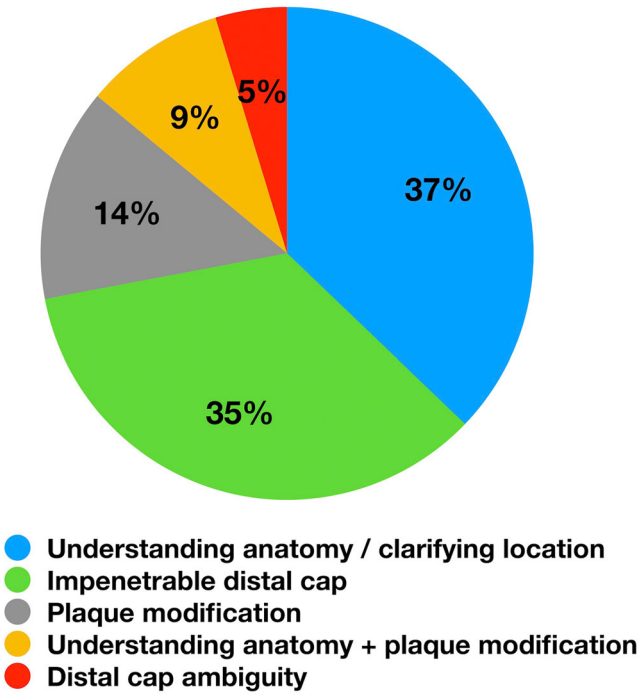

FIGURE 4 Indications of the retrograde Carlino technique in our cohort. [Color figure can be viewed at wileyonlinelibrary.com]

4 | DISCUSSION

For the first time, our study reports on the role and outcomes of the Carlino technique to facilitate retrograde CTO recanalization. We found that hybrid operators utilized the Carlino technique in very complex occlusions tackled with the retrograde approach (mean

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

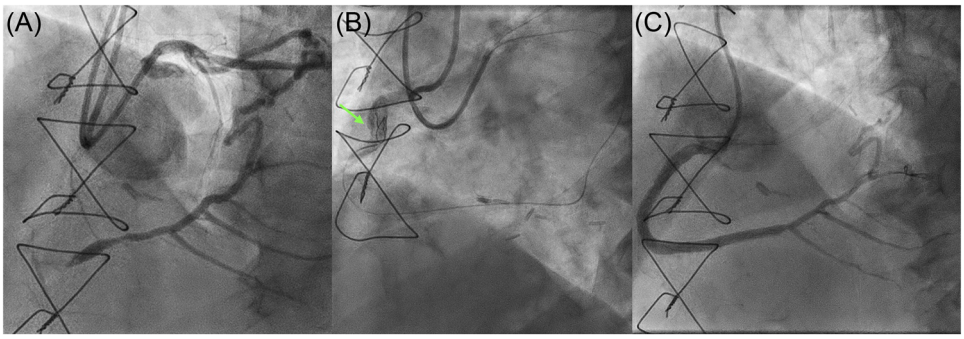

FIGURE 5 The temporal nature of contrast staining caused by the Carlino technique. (A) Flush ostial right coronary artery CTO with ambiguous course. (B) The operator performs a retrograde Carlino technique (arrow) to clarify gear location within the vessel as well as to promote microcatheter advancement along a calcified segment of the vessel. This causes a large tubular dissection, (C) which however has completely disappeared after stenting, 30 min later. CTO, chronic total occlusion. [Color figure can be viewed at wileyonlinelibrary.com]

J-CTO score 3.3 ± 0.8), mainly with the goal of understanding the anatomy of the occlusion and clarifying gear location or to deal with an impenetrable distal cap. Importantly, the Carlino technique was successful in achieving the desired objective in the vast majority of cases (88.4%), which in turn promoted a high procedural success rate (86.0%) despite the high baseline complexity of these occlusions. Of note, no complication was ascribed to the Carlino technique, and this could be related to improved understanding of gear location within the occluded segment and to the fact that high-tipload guidewires (which are more likely to exit the vessel architecture) can usually be avoided after performing the Carlino technique, as navigation within the occlusion can subsequently be performed with polymer-jacketed wires in most cases.

There have been some misconceptions about the Carlino technique, which is considered by some operators an exclusively subintimal or extraplaque facilitating technique.[6,8] While this classification correctly applies for the *extraplaque application* of the technique (see Section 2), it must be underscored that if the microcatheter is located intraplaque (*intraplaque application*), plaque modification will take place, possibly favoring a retrograde wiring approach ("true-to-true" recanalization). In fact, one quarter of successful cases in our series were recanalized with such a crossing strategy. Although short extraplaque tracks can be observed in over a quarter of cases when an intentional true-to-true lumen wiring approach is performed,[15] our data supports the role of the Carlino technique to facilitate intraplaque wiring through fibrocalcified segments of the occlusion.

Operators that are less facile with extraplaque/subintimal techniques [16,17] are often concerned b the angiographic images produced by the *extraplaque applications* of the Carlino technique, wrongly referring to them as perforations. Instead, such pattern can be attributed to a transient increase in vessel wall permeability, allowing the contrast to stain the adventitia (without breaching into the pericardial space). Characteristically, such images persist for some time (usually <30 min), which is not what is observed in case of a perforation, where contrast extravasation quickly washes out. Moreover, these "adventitial tattoos" quickly disappear after stenting (Figure 5). To date, the authors are not aware of a single perforation attributable to the Carlino technique (either antegrade or retrograde), which is now also supported by these registry data.

In light of the data contained in this multicenter experience, the authors recommend that the Carlino technique can be considered during retrograde CTO PCI, either as first line strategy (e.g., to better characterize an ambiguous distal cap or to modify an impenetrable distal cap) or as a bailout following other maneuvers (e.g., retrograde wiring or knuckle wire approach) with the goal of clarifying gear location within the vessel or modifying the plaque.

Our study has some limitations. First, its retrospective design makes it susceptible to the usual bias ascribed to observational studies. Second, as our institutional databases did not keep systematic track of all CTO crossing maneuvers performed during the cases, it is possible that some cases where the retrograde Carlino technique was actually used were not included in our study. Third, all participating centers and operators are experienced in the treatment of CTOs, performing between 100 and 400 cases/year. Therefore, our results might not be applicable to lower volume practices. Finally, the Carlino technique appears to suit the hybrid algorithm[4,18] particularly well, as hybrid operators are facile with quick switches from intraplaque to extraplaque techniques. Therefore, its role and uptake among operators adhering to different crossing algorithms is minimal.

5 | CONCLUSIONS

The Carlino technique is a valuable and safe tool to facilitate crossing of complex occlusions recanalized with the retrograde approach. In this multicenter registry, we observed a high success rate for this maneuver, as well as overall technical and procedural success rates. Importantly, no complications were attributed to the Carlino technique. Additional data from larger international registries are warranted to further confirm the safety and efficacy of this technique.

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

CONFLICTS OF INTEREST

Dr. Azzalini received consulting fees from Teleflex, Abiomed, GE Healthcare, Asahi Intecc, Philips, Abbott Vascular, and Cardiovascular Systems, Inc. Dr. Boudou received proctoring fees from Boston Scientific, Asahi Intecc, and Terumo. Dr. Avran received proctoring fees from Boston Scientific, Biotronik, Asahi Intecc, Abbott Vascular, Medtronic, Terumo, and Orbus Neich. Dr. Lombardi received consulting fees from Asahi Intecc, Abiomed, Boston Scientific, Medtronic, Siemens, and Teleflex; receives royalties from Asahi Intecc; and his spouse is a Philips employee. Dr. Kearney received consulting fees from Abiomed, Abbott Vascular, Boston Scientific, Medtronic, Teleflex, and Cardiovascular Systems, Inc. The remaining authors declare no conflict of interest.

ORCID

Mauro Carlino http://orcid.org/0000-0003-2326-4749

REFERENCES

1. Azzalini L, Vo M, Dens J, Agostoni P. Myths to debunk to improve management, referral, and outcomes in patients with chronic total occlusion of an epicardial coronary artery. *Am J Cardiol*. 2015;116(11):1774-1780.
2. Xenogiannis I, Gkargkoulas F, Karmpaliotis D, et al. Temporal trends in chronic total occlusion percutaneous coronary interventions: insights from the PROGRESS-CTO Registry. *J Invasive Cardiol*. 2020;32(4):153-160.
3. Wu EB, Brilakis ES, Mashayekhi K, et al. Global chronic total occlusion crossing algorithm. *JACC*. 2021;78(8):840-53.
4. Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. *JACC: Cardiovasc Interv*. 2012;5(4):367-379.
5. Riley RF, Walsh SJ, Kirtane AJ, et al. Algorithmic solutions to common problems encountered during chronic total occlusion angioplasty: the algorithms within the algorithm. *Catheter Cardiovasc Interv*. 2019;93(2):286-297.
6. Azzalini L, Uretsky B, Brilakis ES, Colombo A, Carlino M. Contrast modulation in chronic total occlusion percutaneous coronary intervention. *Catheter Cardiovasc Interv*. 2019;93(1):E24-E29.
7. Brilakis ES, Mashayekhi K, Tsuchikane E, et al. Guiding principles for chronic total occlusion percutaneous coronary intervention: a global expert consensus document. *Circulation*. 2019;140(5):420-433.
8. Carlino M, Azzalini L. What is the Carlino technique? *Eurointervention*. 2022. In press.
9. Karacsonyi J, Brilakis ES, Chandwaney RH. Guide-extension Carlino: a novel technique for crossing a microcatheter uncrossable proximal cap during chronic total occlusion interventions. *Catheter Cardiovasc Interv*. 2022;99(7):2038-2042.
10. Megaly M, Basir MB, Brilakis E, Alaswad K. Power arlino". *JACC: Cardiovasc Interv*. 2021;14(22):2521-2522.
11. Avran A, Boukhris M, Drogoul L, Brilakis ES. An algorithmic approach for the management of ostial right coronary artery chronic total occlusions. *Catheter Cardiovasc Interv*. 2018;92(3):515-521.
12. Amsavelu S, Carlino M, Brilakis ES. Carlino to the rescue: use of intralesion contrast injection for bailout antegrade and retrograde crossing of complex chronic total occlusions. *Catheter Cardiovasc Interv*. 2016;87(6):1118-1123.
13. Carlino M, Ruparelia N, Thomas G, et al. Modified contrast microinjection technique to facilitate chronic total occlusion recanalization. *Catheter Cardiovasc Interv*. 2016;87(6):1036-1041.
14. Ybarra LF, Rinfret S, Brilakis ES, et al. Definitions and clinical trial design principles for coronary artery chronic total occlusion therapies: CTO-ARC consensus recommendations. *Circulation*. 2021;143(5):479-500.
15. Song L, Maehara A, Finn MT, et al. Intravascular ultrasound analysis of intraplaque versus subintimal tracking in percutaneous intervention for coronary chronic total occlusions and association with procedural outcomes. *JACC: Cardiovasc Interv*. 2017;10(10):1011-1021.
16. Azzalini L, Carlino M, Brilakis ES, et al. Subadventitial techniques for chronic total occlusion percutaneous coronary intervention: the concept of "vessel architecture.". *Catheter Cardiovasc Interv*. 2018;91(4):725-734.
17. Michael TT, Papayannis AC, Banerjee S, Brilakis ES. Subintimal dissection/reentry strategies in coronary chronic total occlusion interventions. *Circ: Cardiovasc Interv*. 2012;5(5):729-738.
18. Tajti P, Karmpaliotis D, Alaswad K, et al. The hybrid approach to chronic total occlusion percutaneous coronary intervention. *JACC: Cardiovasc Interv*. 2018;11(14):1325-1335.

How to cite this article: Azzalini L, Boudou N, Avran A, et al. Role of the retrograde Carlino technique for chronic total occlusion percutaneous coronary intervention. *Catheter Cardiovasc Interv*. 2023;1-6. doi:10.1002/ccd.30565

1522726x, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ccd.30565 by IRCCS Ospedale San Raffaele, Wiley Online Library on [25/01/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License