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Antegrade dissection and re-entry versus parallel wiring in chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO registry

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Abstract

Background: The comparative efficacy and safety of parallel wiring versus antegrade dissection and re-entry (ADR) in chronic total occlusion (CTO) percutaneous coronary intervention (PCI) is controversial.

Methods: We compared the clinical and angiographic characteristics and outcomes of parallel wiring versus ADR after failed antegrade wiring in a large, multicenter CTO PCI registry.

Results: A total of 1725 CTO PCI procedures with failed antegrade wiring with a single wire were approached with parallel wiring (692) or ADR (1033) at the discretion of the operator. ADR patients were older (65 ± 10 vs. 62 ± 10, years, $p < 0.001$) and had higher prevalence of comorbidities, such as diabetes mellitus (43% vs. 32%, $p < 0.001$), prior coronary artery bypass graft surgery (31% vs. 19%, $p < 0.001$), and lower left ventricular ejection fraction (50 ± 14 vs. 53 ± 11%, $p < 0.001$). The ADR group had higher J-CTO (2.8 ± 1.1 vs. 2.1 ± 1.3, $p < 0.001$) and PROGRESS-CTO (1.6 ± 1.1 vs. 1.2 ± 1.0, $p < 0.001$) scores. Equipment use including guidewires, balloons, and microcatheters was higher, and the procedures

lasted longer in the ADR group. Technical success (78% vs. 75%, $p = 0.046$) and major adverse cardiovascular events (composite of all-cause mortality, stroke, acute myocardial infarction, emergency surgery or re-PCI, and pericardiocentesis) (3.7% vs. 1.9%, $p = 0.029$) were higher in the ADR group, with similar procedural success (75% vs. 73%, $p = 0.166$).

Conclusion: In lesions that could not be crossed with antegrade wiring, ADR was associated with higher technical but not procedural success, and also higher MACE compared with parallel wiring.

KEYWORDS

antegrade dissection and re-entry, chronic total occlusion, parallel wiring, percutaneous coronary intervention

1 | INTRODUCTION

Antegrade wiring (AW) is the first crossing strategy in most coronary artery chronic total occlusion (CTO) percutaneous coronary interventions (PCI). In addition to retrograde crossing, parallel wiring and antegrade dissection and re-entry (ADR) can be used after failed AW, as described in several CTO crossing algorithms.[1–3] We evaluated the clinical and angiographic characteristics and contemporary outcomes of a parallel wiring strategy versus ADR after failed antegrade wiring in a large multicenter CTO PCI registry.

2 | METHODS

We compared the clinical, angiographic, and in-hospital procedural outcomes of parallel wiring versus ADR after failed AW in CTO PCIs included in the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO registry, NCT02061436). Data were collected and managed using the Research Electronic Data Capture (REDCap) tool at the Minneapolis Heart Institute Foundation.[4] The study was approved by the institutional review board of each participating center.

2.1 | Definitions

CTOs were defined according to the definition of the CTO Academic Research Consortium, with the absence of antegrade flow through the lesion with a presumed or documented duration of ≥3 months with Thrombolysis In Myocardial Infarction Grade 0 flow.[5]

Calcification was assessed by angiography and was classified as mild (spots), moderate (involving ≤50% of the reference lesion diameter), or severe (>50%). Blunt/no stump was defined as a lack of tapering at the proximal cap of the CTO lesion.

Technical success was defined as successful canalization of the CTO vessel with <30% residual stenosis and final Thrombolysis in Myocardial Infarction 3 flow. Major adverse cardiovascular events (MACE) were defined as the composite of all-cause mortality, myocardial infarction (MI), stroke, urgent repeat revascularization (re-PCI or coronary artery bypass grafting [CABG]), and cardiac tamponade requiring pericardiocentesis or surgery. Procedural success was defined as technical success in the absence of in-hospital MACE. Myocardial infarction was defined using the Third Universal Definition of MI (type 4a).[6] PROGRESS CTO, J-CTO (Multicenter CTO Registry in Japan), and PROGRESS-CTO complication scores were calculated as described by Christokopoulos et al.,[7] Morino et al.,[8] and Danek et al.,[9] respectively.

2.2 | Statistical analysis

Continuous variables were presented as mean ± standard deviation and compared using the independent *t*-test or Mann–Whitney *U* test, as appropriate. Categorical variables were presented as absolute numbers and percentages and compared using Chi-square or Fisher's exact test, as appropriate. Statistical analyses were performed using Stata v17.0 (StataCorp).

3 | RESULTS

Of 10,900 patients who underwent CTO PCI between 2012 and 2022 at 42 centers and seven countries (mainly the United States, followed by Russia, Turkey, Greece, Canada, Egypt, and Lebanon), ADR was used in 1033 (9.5%) and parallel wiring in 692 (6.3%) cases after failed AW (Figure 1).

3.1 | Demographics

Patients in the ADR group were older, more likely to be men, and had a higher prevalence of comorbidities, such as prior CABG, and lower left ventricular ejection fraction (Table 1).

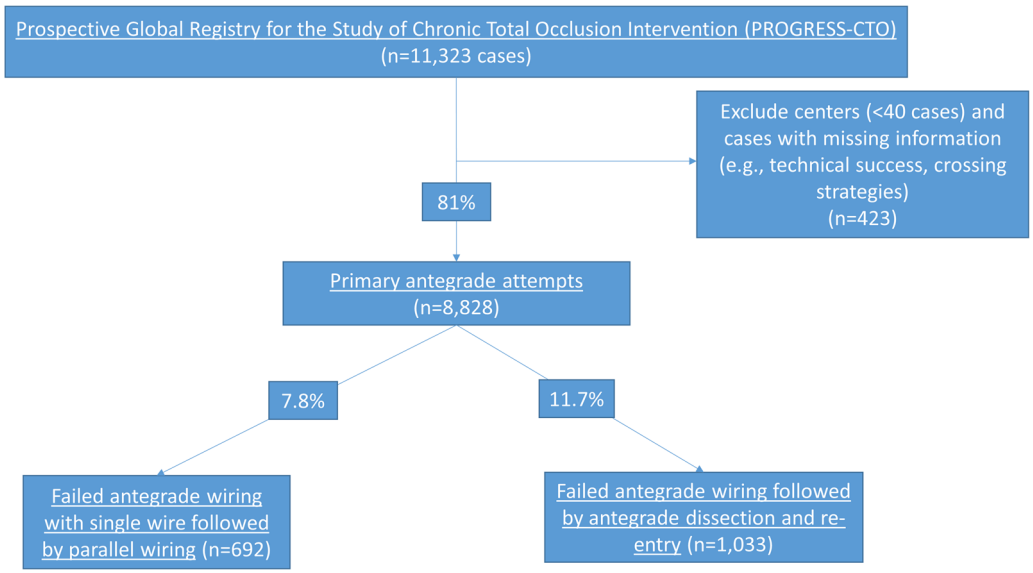

FIGURE 1 Flow diagram of the study design. [Color figure can be viewed at wileyonlinelibrary.com]

3.2 | Angiographic characteristics

ADR lesions were more likely to have proximal cap ambiguity, moderate/severe proximal tortuosity, moderate/severe calcification, and had higher J-CTO, PROGRESS-CTO, and PROGRESS-CTO complication scores (Table 1).

3.3 | Procedural details and outcomes

The most common CTO target vessel was the right coronary artery, followed by the left anterior descending and the left circumflex in both groups. Equipment utilization including guidewires, balloons, microcatheters, and support catheters was higher in the ADR group. Contrast volume was similar but fluoroscopy time and procedure time were longer in the ADR group compared with the parallel wiring group (Table 1).

The most common dissection strategy was knuckle wire advancement (71%), followed by the use of the CrossBoss catheter (25%), and the scratch and go technique (9%).[10,11] The most common re-entry strategy was the Stingray balloon 69%, followed by subintimal tracking and re-entry (26%), and limited antegrade subintimal tracking (11%) in the ADR cases. The most commonly used guidewires for parallel wiring were the Pilot 200 (38%), Gaia 2nd (19%), Gaia 3rd (17%), Pilot 150 (17%), Fielder XT-A (16%), Progress 80 (15%), Progress 40 (14%), and Confianza Pro 12 (13%). In parallel wiring, dual lumen microcatheters were used in 33%.

Technical success was higher in the ADR group (78% vs. 75%, $p = 0.046$). The incidence of MACE was nearly two-fold in the ADR group (3.7% vs. 1.9%, $p = 0.029$) (Table 2) (Figure 2 - Central Illustration), but procedural success was similar (75% vs. 73%, $p = 0.166$).

4 | DISCUSSION

The main finding of our study is that both ADR and parallel wiring are commonly used during CTO PCI after AW failure. ADR was used in more complex patients and lesions and was associated with higher technical success but also higher MACE, with similar procedural success.

4.1 | ADR and parallel wiring in crossing algorithms

The global CTO crossing algorithm indicates that if AW fails, both parallel wiring/intravascular ultrasound and ADR are acceptable next crossing options.[3] Similarly, The Asia Pacific CTO Club (APCTO) algorithm states that if AW fails, parallel wiring or (if the re-entry zone is suitable) ADR (e.g., Stingray) can be considered.[2] In the Japan CTO club algorithm, parallel wiring, and ADR strategies are considered potential options in cases where AW lasts >20 min, or if the operator switches from a primary retrograde to an antegrade crossing strategy.[12] The Euro CTO club algorithm also recommends ADR or parallel wiring when AW with a single wire fails.[1]

When AW fails, antegrade crossing options include redirection of the guidewire, parallel wiring, or ADR.[13] Selection is based on lesion characteristics, local equipment availability, and expertise. The creation of extraplaque hematoma should be minimized, as it adversely affects all antegrade strategies.[13] In patients with a feasible retrograde option,[3] retrograde crossing may enable crossing even after extraplaque hematoma formation.

4.2 | Characteristics and outcomes

In our study, ADR was performed in patients with more comorbidities and more complex occlusions, as demonstrated by higher J-CTO and

TABLE 1 Baseline characteristics, comorbidities, angiographic characteristics, and procedural outcomes stratified by crossing strategy

Characteristic/procedural outcomes	Antegrade dissection and re-entry (*n* = 1033)	Parallel wiring (*n* = 692)	*p* Value
Age in years, mean ± SD	65 ± 10 (*n* = 959)	62 ± 10 (*n* = 654)	<0.001
Men, *n*, (%)	833 (85)	548 (82)	0.046
Hypertension, *n*, (%)	862 (90)	593 (90)	0.736
Dyslipidemia, *n*, (%)	890 (93)	418 (63)	<0.001
Atrial fibrillation, *n*, (%)	85 (13)	59 (10)	0.079
Dyspnea, *n*, (%)	641 (70)	410 (64)	<0.001
Diabetes mellitus, *n*, (%)	410 (43)	210 (32)	<0.001
Peripheral arterial disease, *n*, (%)	119 (18)	70 (11)	0.283
Family history of premature coronary artery disease, *n*, (%)	266 (33)	167 (27)	0.022
Prior myocardial infarction, *n*, (%)	429 (47)	361 (57)	<0.001
Prior heart failure, *n*, (%)	271 (29)	206 (32)	0.181
Prior percutaneous coronary intervention, *n*, (%)	589 (62)	377 (59)	0.183
Prior coronary artery bypass graft surgery, *n*, (%)	300 (31)	124 (19)	<0.001
Left ventricular ejection fraction (%), mean ± SD	50 ± 14 (*n* = 809)	53 ± 11 (*n* = 609)	<0.001
Proximal cap ambiguity, *n*, (%)	409 (41)	214 (32)	<0.001
Moderate/severe proximal tortuosity, *n*, (%)	371 (38)	165 (25)	<0.001
Moderate/severe calcification, *n*, (%)	540 (55)	200 (30)	<0.001
CTO length in mm, mean ± SD	27 ± 20 (*n* = 1007)	32 ± 20 (*n* = 692)	<0.001
J-CTO score, mean ± SD	2.8 ± 1.1 (*n* = 1024)	2.1 ± 1.3 (*n* = 677)	<0.001
PROGRESS-CTO score, mean ± SD	1.6 ± 1.1 (*n* = 639)	1.2 ± 1.0 (*n* = 863)	<0.001
PROGRESS-CTO complications score, mean ± SD	3.2 ± 1.8 (*n* = 722)	2.3 ± 1.9 (*n* = 624)	<0.001
CTO target vessel, *n*, (%)			0.501
LAD	247 (24)	166 (24)	
LCx	216 (21)	127 (18)	
RCA	538 (53)	390 (57)	
Ad-hoc CTO PCI, *n*, (%)	52 (7.8)	60 (6.3)	0.236
Total number of guidewires, mean ± SD	8.1 ± 4.5 (*n* = 658)	5.4 ± 2.8 (*n* = 605)	<0.001
Total number of balloons, mean ± SD	4.5 ± 3.0 (*n* = 653)	2.8 ± 2.1 (*n* = 604)	<0.001
Total number of microcatheters, mean ± SD	1.8 ± 1.1 (*n* = 657)	1.0 ± 1.1 (*n* = 604)	<0.001
Total number of support catheters, mean ± SD	0.6 ± 1.2 (*n* = 542)	0.3 ± 1.1 (*n* = 541)	<0.001
Procedure time (min), mean ± SD	164 ± 93 (*n* = 911)	115 ± 58 (*n* = 638)	<0.001
Contrast volume (ml), mean ± SD	275 ± 130 (*n* = 945)	267 ± 131 (*n* = 658)	0.209
Air kerma Fluoroscopy Dose (Gray), mean ± SD	3.3 ± 2.25 (*n* = 769)	3.8 ± 4.9 (*n* = 315)	0.014
Fluoroscopy time (min), mean ± SD	61 ± 32 (*n* = 925)	50 ± 29 (*n* = 651)	<0.001
Technical success, *n*, (%)	803 (77.7)	509 (73.5)	0.046
Procedural success, *n*, (%)	758 (75.6)	494 (72.6)	0.166

Abbreviations: CABG, coronary artery bypass graft surgery; CTO, chronic total occlusion; DM, diabetes mellitus; HF, heart failure; HTN, hypertension; J-CTO, The Japanese Multicenter CTO Registry score; LAD, left anterior descending; LCx, left circumflex; LV, left ventricle; LVEF, left ventricular ejection fraction; MI, myocardial infarction; PROGRESS-CTO, Prospective Global Registry for the Study of Chronic Total Occlusion Intervention score; RCA, right coronary artery; RHC, right heart catheterization; SVG, saphenous vein graft; PCI, percutaneous coronary intervention.

TABLE 2 In-hospital clinical outcomes and events stratified by crossing strategy

In-hospital events	Antegrade dissection and re-entry (n = 1033)	Parallel wiring (n = 692)	p Value
All-cause mortality, *n*, (%)	7 (0.7)	2 (0.3)	0.328
Major adverse cardiovascular events, *n*, (%)	38 (3.7)	13 (1.9)	0.029
Acute myocardial infarction, *n*, (%)	11 (1.1)	2 (0.3)	0.088
Stroke, *n*, (%)	3 (0.3)	0 (0.0)	0.278
Re-PCI, *n*, (%)	3 (0.3)	0 (0.0)	0.278
Emergency coronary artery bypass graft surgery, *n*, (%)	1 (0.1)	1 (0.1)	1.000
Tamponade, *n*, (%)	21 (2.0)	10 (1.4)	0.361
Pericardiocentesis, *n*, (%)	19 (1.8)	10 (1.4)	0.525
Equipment loss, *n*, (%)	4 (0.4)	0 (0.0)	0.153
Perforation, *n*, (%)	71 (6.9)	49 (7.1)	0.887
Vascular access site complication, *n*, (%)	10 (1.0)	4 (0.6)	0.426

Abbreviation: PCI, percutaneous coronary intervention.

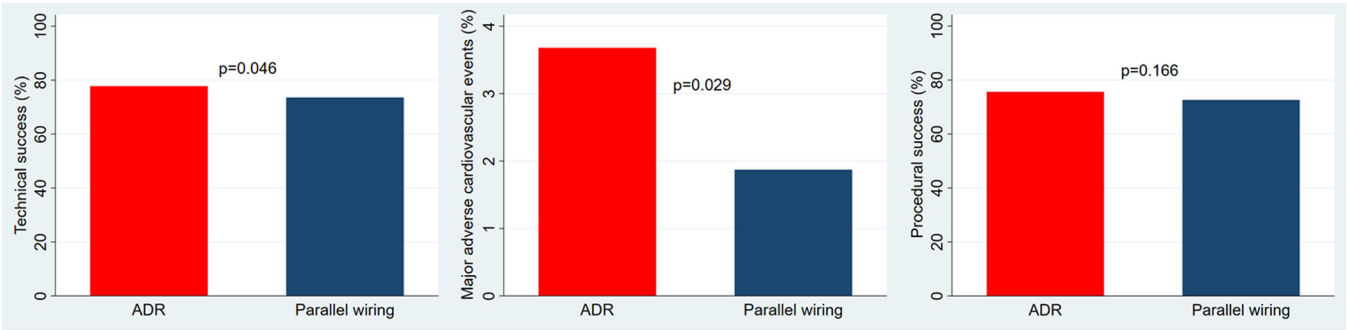

FIGURE 2 (Central Illustration): Technical success, major adverse cardiovascular events, and procedural success stratified by crossing strategy. [Color figure can be viewed at wileyonlinelibrary.com]

PROGRESS-CTO scores (Table 1). In contrast, in a recent study with a similar design, angiographic characteristics were similar between patients that were treated with ADR or parallel wiring.[14] In that study, technical success was similar between ADR and parallel wiring (74.5% and 79.8%, p = 0.46), whereas in our study, ADR had slightly higher technical success. In the J-CTO registry, while parallel wiring was used in 19.3% of cases that were started with AW, overall use of parallel wiring among all CTOs was 31%. In cases with parallel wiring as the initial approach, technical success was 85.9%, and cases that required both retrograde wiring and antegrade parallel wiring had a technical success of 67.1%.[15]

In our study, ADR cases had longer duration (164 ± 93 vs. 115 ± 58 min, p < 0.001) but required similar contrast volume with parallel wiring, in contrast to another study by Qin et al., where ADR required more contrast use (442 mL vs. 362 mL, p < 0.001)[14] ADR cases also required more equipment use including guidewires, balloons, and microcatheters.

In our study all-cause mortality, acute MI, stroke, re-PCI, emergency CABG, cardiac tamponade, pericardiocentesis, perforation, and vascular access site complication rates were similar between ADR and parallel wiring, but overall MACE was higher in the ADR group when compared with parallel wiring (3.7% vs. 1.9%, p = 0.029). In another study, in-hospital all-cause mortality, acute MI, cardiac tamponade were similar between the two groups; while statistically not significant, perforations were more common (7.3% vs. 1.8%, p = 0.055) in the ADR group.[14]

While overall technical success was both in the 70%–80% range in our study and the aforementioned study from China,[14] the differences in comorbidities and success rates can potentially be explained by different patient populations and operator preferences in crossing strategies. In addition, the relatively low success rate could be attributable to the group definition that required a failed primary AW attempt before either parallel wiring or ADR before comparing ADR with parallel wiring. Parallel wiring approaches may

improve by use of next-generation dual lumen catheters (e.g., ReCross) and steerable guidewires.

Our results demonstrate that ADR and parallel wiring are associated with satisfactory, but not perfect success rates after a failed AW attempt. A large and straight re-entry zone without side branches and without a bifurcation at the distal cap, lack of extraplaque hematoma and availability of re-entry equipment (such as Stingray, Boston Scientific) favor ADR. A soft distal cap, preserved antegrade wire control, large distal true lumen, and calcium in the re-entry zone favor parallel wiring.[16]

Our study has limitations. First, the PROGRESS-CTO registry is observational in design and cases entered into the registry might be subject to selection bias. Second, statistical analyses were not prespecified or adjusted for multiple comparisons. Third, our registry did not have clinical event adjudication. Fourth, core laboratory analysis of angiographic images was not performed. Fifth, PROGRESS-CTO operators are highly experienced in CTO PCI, which could limit the external validity of our findings. Sixth, patient selection and the choice of crossing strategy was left to the discretion of the operators. Seventh, we do not have long-term clinical outcomes for the compared groups.

4.3 | Conclusion

Despite higher patient and lesion complexity, ADR was associated with a higher technical success rate but also higher MACE, and similar procedural success as compared with parallel wiring after failed AW.

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CONFLICT OF INTEREST

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DATA AVAILABILITY STATEMENT

Research data are not shared.

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