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Percutaneous coronary intervention of chronic total occlusions involving a bifurcation: Insights from the PROGRESS-CTO registry

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Percutaneous coronary intervention of chronic total occlusions involving a bifurcation: Insights from the PROGRESS-CTO registry

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A B S T R A C T

Background: The impact of bifurcations at the proximal or distal cap on the outcomes of chronic total occlusion (CTO) percutaneous coronary intervention (PCI) has received limited study.

Methods: We analyzed the clinical, angiographic, and procedural data of 4,584 cases performed in patients between 2012 and 2020 in a global CTO PCI registry. We compared 4 groups according to the bifurcation location: "proximal cap," "distal cap," "proximal and distal cap," and "no bifurcation."

Results: The CTO involved a bifurcation in 67% cases, as follows: proximal cap (n = 1451, 33%), distal cap (n = 622, 14%), or both caps (n = 954, 21%). "Proximal and distal cap" cases had higher J-CTO compared with "proximal cap," "distal cap," and "no bifurcation" cases (2.9 ± 1.1 vs 2.5 ± 1.1 vs 2.4 ± 1.2 vs 2.0 ± 1.2, $P < 0.0001$), and they were also associated with a lower technical success rate (79% vs 85% vs 85% vs 90%, $P < 0.0001$), higher pericardiocentesis rate (1% vs 1% vs 0.2% vs 0.3%, $P = 0.02$), and higher emergency coronary artery bypass graft surgery rate (0.3% vs 0% vs 0% vs 0%, $P = 0.01$).

Conclusion: More than two-thirds of CTO PCIs involve a bifurcation, which is associated with lower technical success and higher risk of complications.

The impact of a side branch in the proximal or distal cap on the success and complication rates of chronic total occlusion percutaneous coronary intervention (CTO PCI) has received limited study.

We analyzed clinical, angiographic, and procedural data of 4,584 CTO PCIs performed in 4,479 patients between 2012 and 2020 in a global CTO PCI registry (NCT02061436). We compared 4 groups according to the bifurcation location: "proximal and distal," "proximal cap," "distal cap," and "no bifurcation." The study was approved by the Institutional Review Board of each center.

Bifurcations were defined by the presence of a side branch of diameter >2 mm within 5 mm of the proximal or distal cap of the CTO lesion. The presence of a bifurcation was visually assessed by the operator after dual injection and before any attempt to cross. A procedure was defined as retrograde if an attempt was made to cross the lesion through a collateral vessel or bypass graft supplying the target vessel distal to the lesion; if not, the procedure was classified as antegrade-only. Technical success was defined as successful CTO revascularization (main vessel only) with an achievement of <30% residual diameter stenosis and Thrombolysis in Myocardial Infarction (TIMI) 3 antegrade flow. In-hospital major adverse cardiovascular events (MACE) include death, myocardial infarction, recurrent angina requiring urgent repeat target vessel or target lesion revascularization (with PCI or coronary artery bypass graft surgery), stroke, and tamponade requiring pericardiocentesis. Myocardial infarction was defined as per the Third Universal Definition of Myocardial Infarction Type 4[1].

Categorical variables are presented as percentages and were compared with the chi-square test. Continuous variables are summarized by mean ± standard deviation or median [interquartile range] and compared with the t-test, analysis of variance, or Wilcoxon rank-sum test. All *P*-values refer to overall significance testing between the four groups, unless reported otherwise.

The CTO involved a bifurcation in 67% of all cases, as follows: proximal cap (n = 1451, 32%), distal cap (n = 622, 14%), or both proximal and distal caps (n = 954, 21%). "Proximal and distal cap" patients were more likely to have had myocardial infarction compared with "proximal cap," "distal cap," and "no bifurcation" patients and also had a higher J-CTO score, greater use of the retrograde approach (Table), and lower technical success (Fig.). In-hospital MACE rates differed significantly between the groups, driven by difference in rates of emergency Coronary Artery Bypass Grafting (CABG) and pericardiocentesis (Table). Two of the three emergency CABG surgeries happened in cases with perforation that required pericardiocentesis. Perforation rates, especially Ellis class 2 and cavity spilling, were higher in the "proximal" and "proximal and distal cap" groups (Table). The mechanism of perforation did not differ according to the location of the bifurcation (Table).

We performed logistic regression analysis adjusting for lesion characteristics (blunt/no stump, lesion length>20 mm, moderate/severe proximal tortuosity, and moderate/severe calcification), the presence of the bifurcation, and intravascular ultrasound (IVUS) use. After adjustment, presence of a bifurcation was significantly

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Table

Clinical technical and procedural characteristics and outcomes according to the presence of a bifurcation at the proximal or distal cap or both.

VARIABLE	No bifurcation n = 1,557	Proximal cap n = 1,451	Distal Cap n = 622	Proximal and distal caps n = 954	*P*-value
Age, years, mean ± SD	67 ± 10	67 ± 10	65 ± 10	64 ± 10	0.4
Previous MI, %	40	41	35	47	<.0001
Target vessel,%					<.0001
• RCA	53	45	56	55	
• LAD	26	35	16	23	
• LCX	19	18	25	21	
• Other	2	2	3	1	
J-CTO score, mean ± SD	2 ± 1.2	2.5 ± 1.1	2.4 ± 1.2	2.9 ± 1	<.0001
Crossing strategies used, %					
• AWE	89	90	87	85	<.0001
• ADR	22	24	24	26	0.06
• Retrograde	17	27	35	43	<.0001
First crossing strategy, %					
• AWE	86	86	81	85	<.0001
• ADR	6	4	6	3	
• Retrograde	6	9	11	17	
Successful crossing strategy, %					
• AWE	65	56	50	41	<.0001
• ADR	17	16	13	15	
• Retrograde	9	14	22	22	
MCS use, %	3.6	2.4	1.9	2.4	0.08
• Prophylactic	2.3	1.9	1.1	1.4	0.2
• Urgent	0.5	0.3	0.5	0.7	0.45
Technical success, %	91	85	85	78	<.0001
Procedure time, min, median [IQR]	101 [67,150]	113 [74,166]	120 [85,173]	133 [91,190]	<.0001
Contrast volume, mL, median [IQR]	209 [150,300]	220 [155,300]	220 [155,300]	240 [170,300]	<.0001
AK radiation dose, Gy, median [IQR]	2.3 [1.2,3.5]	2 [1.1,3.4]	2.3 [1.3,3.8]	2.5 [1.5,4.1]	<.0001
Perforation, %	1.93	3.8	3	4.6	0.0009
Class					
• Ellis 1	33	24	44	23	0.08
• Ellis 2	22	40	37	51	
• Ellis 3	41	27	19	13	
• Cavity-spilling	3.7	9	0	13	
Mechanism					
• Wire	38	51	26	51	0.18
• Microcatheter	3	9	0	12	0.18
• Balloon	7	11	11	12	0.92
• Stent	10	7	11	2	0.44
In-hospital MACE, %	1	2	1	2.4	0.04
• Death	0.4	0.3	0.2	0.2	0.78
• MI	0.3	0.5	0.7	1	0.21
• Re-PCI	0.1	0.1	0	0	0.79
• Re-CABG	0	0	0	0.3	0.01
• Stroke	0.1	0.2	0.2	0.2	0.94
• Pericardiocentesis	0.3	1	0.2	1	0.02

CTO, chronic total occlusion; PCI, percutaneous coronary intervention; MI, myocardial infarction; CABG, coronary artery bypass graft; RCA, right coronary artery; LAD, left anterior descending; LCX, left circumflex; J-CTO, Japanese multicenter chronic total occlusion registry; MCS, mechanical circulatory support; AK, air kerma; Gy, gray; MACE, major adverse cardiovascular events; SD, standard deviation; IQR, interquartile range.

associated with a lower technical success when compared with absence of any bifurcation (odds ratio [OR] for the proximal cap: 0.63; 95% confidence intervals [CI]: 0.44 to 0.89; *P*-value = 0.009, OR for the distal cap: 0.59; 95% CI: 0.39 to 0.89; *P*-value = 0.01, OR for proximal and distal caps: 0.54; 95% CI: 0.37 to 0.77; *P*-value < 0.001). A first-order interaction term of intravascular ultrasound (IVUS) use and bifurcation presence was not significantly associated with a technical success (OR for the proximal cap: 1.81; 95% CI: 0.78 to 4.26; *P*-value = 0.17, OR for the distal cap: 1.57; 95% CI: 0.55 to 4.48; *P*-value = 0.39, OR for proximal and distal caps: 1; 95% CI: 0.44 to 2.25; *P*-value = 0.99).

We performed the same analysis for the endpoint of perforation. After adjustment, presence of a proximal and distal cap bifurcation was significantly associated with higher perforation rates when compared with absence of any bifurcation (OR for the proximal cap: 2.16; 95% CI: 0.97 to 4.81; *P*-value = 0.06, OR for the distal cap: 2.29; 95% CI: 0.89 to 5.87; *P*-value = 0.08, OR for proximal and distal caps: 2.38; 95% CI: 1.05 to 5.43; *P*-value = 0.04). An interaction term of IVUS use and bifurcation presence was not associated with perforation rates (OR for the proximal cap: 0.48; 95% CI: 0.16 to 1.47; *P*-value = 0.19, OR for the distal cap: 0.38; 95% CI: 0.09 to 1.58; *P*-value = 0.18, OR for proximal and distal caps: 0.29; 95% CI: 0.08 to 1; *P*-value = 0.05).

Bifurcations involving the CTO were more common in our study compared with previous CTO PCI series that used the visual inspection of the angiogram and the same definition[2,3]. Our study did not assess for side branches within the CTO segment, as performed in previous studies. In addition, we included any side branch present within 5 mm of the proximal or distal cap, irrespective of the degree of stenosis.

CTO lesions involving a bifurcation had lower technical success rates. As reported in previous studies, CTOs involving a bifurcation also had a higher risk of complications, namely emergency CABG[2,3] and perforation. In contrast to previous studies[4], the rate of

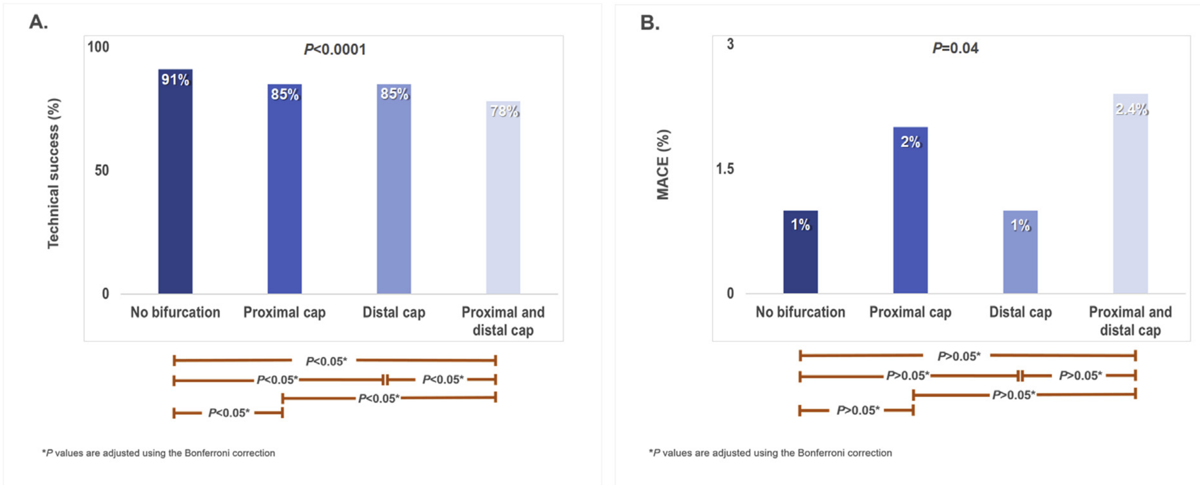

Figure. In-hospital outcomes after chronic total occlusion percutaneous coronary intervention according to the presence of a bifurcation at the proximal or distal cap or both. MACE, major adverse cardiovascular events; CABG, coronary artery bypass graft.

periprocedural MI was not higher in lesions involving a bifurcation, possibly because systematic biomarker measurements were not performed in our study.

Our study does not assess the incidence and impact of side branch occlusion or use of specific bifurcation wiring and stenting techniques.[5] In addition, we cannot determine which technique (antegrade wiring, dissection/re-entry, or retrograde) caused each perforation. Finally, bifurcations were operator-reported and not based on core laboratory adjudication.

In conclusion, two-thirds of CTO lesions involve a bifurcation, most commonly at the proximal cap. The presence of a bifurcation is associated with a lower technical success and higher risk of complications, especially when there is a bifurcation in both the proximal and the distal cap.

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