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Simple Crossover Stenting for the Left Main Bifurcation Lesions in Patients with Acute Coronary Syndrome: A Case Series

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Case Report

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ABSTRACT

Background: Coronary bifurcation lesions challenge percutaneous coronary interventions, especially in unprotected left main (LM) coronary artery disease due to significant myocardial risk. This study assesses the efficacy of simple crossover provisional stenting (PS) technique from the LM to the left anterior descending artery, supplemented by proximal optimization technique, in acute coronary syndrome (ACS) patients with distal LM bifurcation lesions.

Case Presentation: We detail eight ACS cases with true and non-true LM distal bifurcation lesions that were treated using PS, achieving post-procedure thrombolysis in myocardial infarction III flow and no major adverse cardiac events over six months (minimum follow-up). Post-procedure, all patients achieved thrombolysis in myocardial infarction (TIMI) III flow. During follow-up, which ranged from a minimum of six months to two years, no major adverse cardiac events (MACE) were

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observed. Each case demonstrated successful revascularization, highlighting the effectiveness of the PS technique in this patient population.
Conclusions: This method provides a simplified revascularization strategy with improved outcomes, meriting further investigation through large-scale, long-term studies to validate its efficacy.

Keywords: Left main distal bifurcation; crossover stenting; acute coronary syndrome; percutaneous coronary intervention.

ABBREVIATIONS

ACS : Acute Coronary Syndrome
AWMI : Anterior Wall Myocardial Infarction
CABG : Coronary Artery Bypass Graft
CAG : Coronary Angiography
CBL : Coronary Bifurcation Lesions
DES : Drug-eluting Stent
DK : Double Kissing
EBC : European Bifurcation Club
LAD : Left Anterior Descending
LCx : Left Circumflex
LM : Left Main
LMCA : Left Main Coronary Artery
MACE : Major Adverse Cardiac Events
MB : Main Branch
MI : Myocardial Infarction
NC : Non-compliant
NSTEMI : Non-ST-elevation MI
PCI : Percutaneous Coronary Intervention
POT : Proximal Optimization Technique
PS : Provisional Stenting
SB : Side Branch
TLF : Target Lesion Failure
ULMCA : Unprotected Left Main Coronary Artery

1. INTRODUCTION

Coronary bifurcation lesions (CBLs) are the most complex lesions subset, accounting for 20% of percutaneous coronary interventions (PCI) [1]. A 5% incidence of severe left main coronary artery (LMCA) disease occurs in patients undergoing coronary angiograms for various medical conditions. Patients with unprotected left main coronary artery (ULMCA) disease are considerably susceptible because a larger proportion of the myocardium is in jeopardy [2]. Based on anatomical complexity, the treatment of these patients with chronic coronary syndrome is well-proven and involves PCI and coronary artery bypass grafting (CABG), both of which offer an array of pros and cons [3]. Treating ULMCA in ACS is tough due to acute symptoms and limited planning time, with high mortality risks. Patients with MI and bifurcation lesions lack sufficient trial data and outcomes [4]. The international guidelines of the American College of Cardiology/American Heart Association and the European Society of Cardiology have recommended revascularization for patients with LMCA stenosis ≥50%, regardless of symptoms or associated ischemic burden [5]. Bifurcation lesions can be treated with provisional stenting (PS) or an upfront two-stent approach, depending on the plaque density and angle between the left anterior descending (LAD) and left circumflex (LCx) arteries. It nevertheless remains controversial which bifurcation stenting technique is most effective for addressing coronary bifurcation anatomy. The EBC's 15th Consensus favours a "keep it simple and safe" approach for bifurcation treatment [6].

The DK CRUSH-V trial showed that the DK crush technique had lower rates of stent thrombosis, target vessel MI, and TLF compared to provisional stenting (PS) for distal LM bifurcation lesions [7]. However, other trials like EBC MAIN, Nordic, British Bifurcation, and COBIS III supported PS as safe, with some suggesting better outcomes and lower mortality when avoiding side branch intervention [8,9,10].

Significant stenosis in the main branch (MB) and SB (>50%) distinguishes a ‘true’ bifurcation lesion (Medina 1,1,1 or 1,0,1 or 0,1,1) from a ‘non-true’ lesion (Medina 0,0,1 or 1,0,0 or 0,1,0), according to the Medina classification [11]. Here, we report a series of ACS patients with LM distal bifurcation lesions (true/non-true). These patients underwent simple crossover PS from the LM into the LAD without SB opening, and they were monitored for a minimum of six months following the procedure.

2. CASE PRESENTATION

2.1 Case 1

A 44-year-old female with no co-morbidities was presented with acute anterior wall myocardial infarction (AWMI). Coronary angiography (CAG) revealed 80% stenosis at the ostium proximal of the LAD with Medina class 0,1,0 non-true LM distal bifurcation lesion (Fig. 1a). The LCx was

dominant with no disease at ostium, and the bifurcation angle appeared wide between the LAD and LCx. Primary angioplasty was performed by a simple crossover PS from LM into the LAD with a drug-eluting stent (DES). Then, proximal optimization technique (POT) was performed with a non-compliant (NC) balloon (Fig. 1b). This patient was followed up for two years without any MACE.

2.2 Case 2

A 60-year-old male without co-morbidities presented with acute AWMI and cardiogenic shock. The CAG showed a true lesion (Medina class 1,1,0) at the LM distal bifurcation with 100% occlusion of the LAD (Fig. 1c). Minor non-obstructive plaque was visible in the LCx ostium. The angle between LAD and LCx was narrow. A simple crossover PS was applied from LM to LAD using DES. Finally, POT was performed with an NC balloon (Fig. 1d). This patient was followed up for two years without any MACE.

2.3 Case 3

A 35-year male patient without comorbid conditions presented with AWMI. The CAG confirmed LM distal non-true lesion (Medina 0,1,0) with 100% occlusion at the LAD ostium (Fig. 2a). The LCx was non-dominant with no disease at the ostium and had a wide angle with LAD. Using a simple crossover PS and a DES, primary angioplasty was performed from the LM to the LAD. POT was performed with NC balloon (Fig. 2b). This patient was followed up for two years without any MACE.

2.4 Case 4

A 57-year-old male hypertensive patient presented with acute AWMI and cardiogenic shock. The CAG indicated a true lesion (Medina 1,1,1) at LM distal bifurcation with 90% LAD ostio-proximal lesion (Fig. 2c). The angle between the LAD and LCx was narrow, the distal LM distal revealed 50% stenosis, and the LCx was the dominant vessel with 60 to 70% ostio-proximal lesion. Primary angioplasty was performed from the LM to LAD by simple crossover PS with DES, while POT was done with NC balloon (Fig. 2d). This patient was followed up for one year without any MACE.

2.5 Case 5

A 71-year-old male with diabetes was diagnosed with AWMI. The CAG showed true lesion (Medina 1,1,0) at LM distal bifurcation with 95% occlusion of LAD (Fig. 3a). The LCx ostium was devoid of disease and had a wide angle with LAD. Primary angioplasty was done from the LM to LAD using a PS procedure with DES, followed by POT with NC balloon (Fig. 3b). This patient was followed up for six months without any MACE.

2.6 Case 6

A 71-year-old geriatric female who had diabetes, hypertension and other comorbidities was presented with non-ST-elevation MI (NSTEMI) and acute pulmonary edema. CAG confirmed true lesion (Medina 1,1,0) at the LM distal bifurcation with 80% occlusion of LAD (Fig. 3c). LCx ostium had minor plaque and wide angle with LAD. Primary angioplasty was done from LM to LAD by simple crossover PS approach with DES and POT was performed with NC balloon (Fig. 3d). This patient was followed up for six months without any MACE.

2.7 Case 7

A 48-year-old male patient presented with AWMI. CAG showed a non-true bifurcation lesion (medina 0,1,0 lesion) at left main distal bifurcation with 95% occlusion of LAD (Fig. 4a). LCX ostium was disease free and had wide angle with LAD. Primary angioplasty was done from left main to LAD by simple cross-over PS stent with 3.5 x 48 Xience expedition stent and POT was done with 4 x 8 mm NC balloon (Fig. 4b). Post stenting there was TIMI III flow in LCX. No side branch opening or final kissing was done. The patient has completed 2 years of follow-up with no further events.

2.8 Case 8

A 50-year-old male patient presented with AWMI. CAG showed a non-true bifurcation lesion (medina 0,1,0 lesion) at LM distal bifurcation with 80% occlusion of LAD (Fig. 4c). LCX ostium was disease free and had wide angle with LAD. Primary angioplasty was done from LM to LAD by simple cross-over PS stent with 3.5 x 15 Xience expedition stent and POT was done with 4.5x 8 mm NC balloon (Fig. 4d). Post stenting there was TIMI III flow in LCX. No side branch opening or final kissing was done. The patient has completed 6 months of follow-up with no further events.

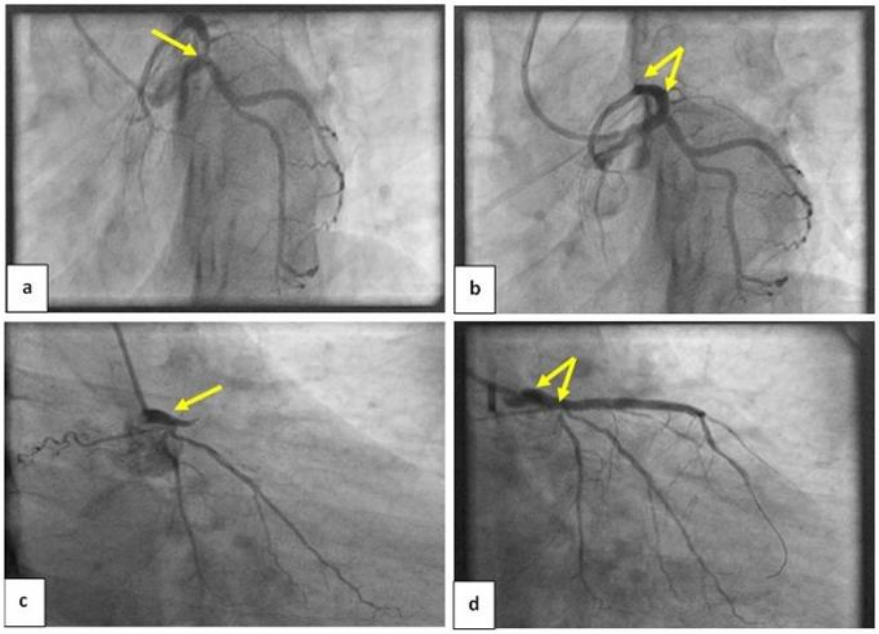

Fig. 1. Coronary angiograms for cases 1 (a, b) and 2 (c, d)
(a) CAG illustrating LM bifurcation lesion involving 80% stenosis of the ostio proximal LAD (LAO caudal view)
(b) Restored flow in the LCx after PS and POT (LAO caudal view)
(c) LM bifurcation lesion with 100% stenosis of LAD (RAO caudal view) (RAO = right anterior oblique)
(d) Reperfusion accomplished in the LCx following POT (RAO caudal view)

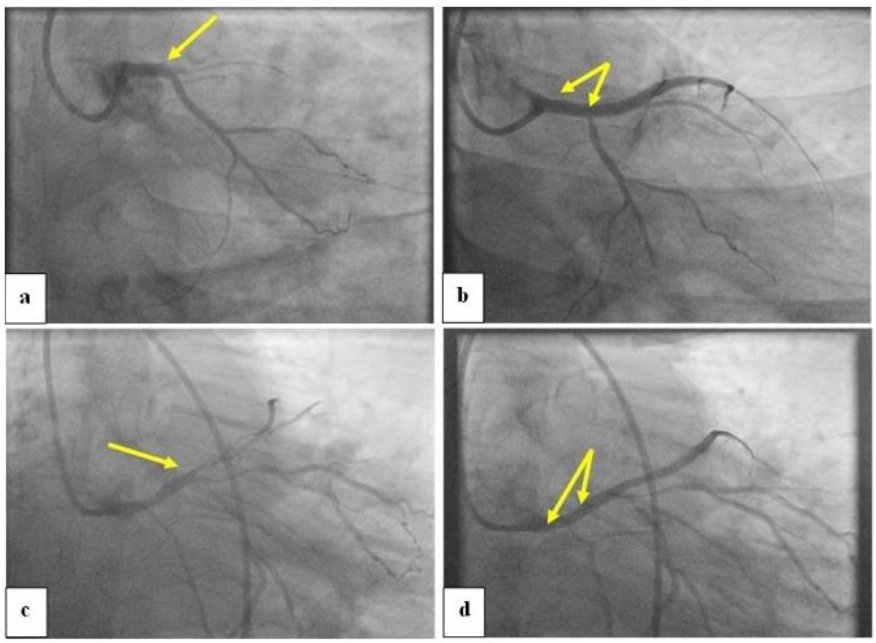

Fig. 2. Coronary angiograms for cases 3 (a, b) and 4 (c, d)
(a) CAG shows LM bifurcation lesion involving 100% stenosis of the ostium LAD (PA caudal view)
(b) Blood flow was restored in the LCx following POT (PA caudal view)
(c) LM bifurcation lesion with the involvement of LM distal 50%, LAD ostio-proximal 90% and LCx ostio-proximal 60-70% stenosis (PA caudal view)
(d) Perfusion reestablished after LCx-focused POT was done (PA caudal view)

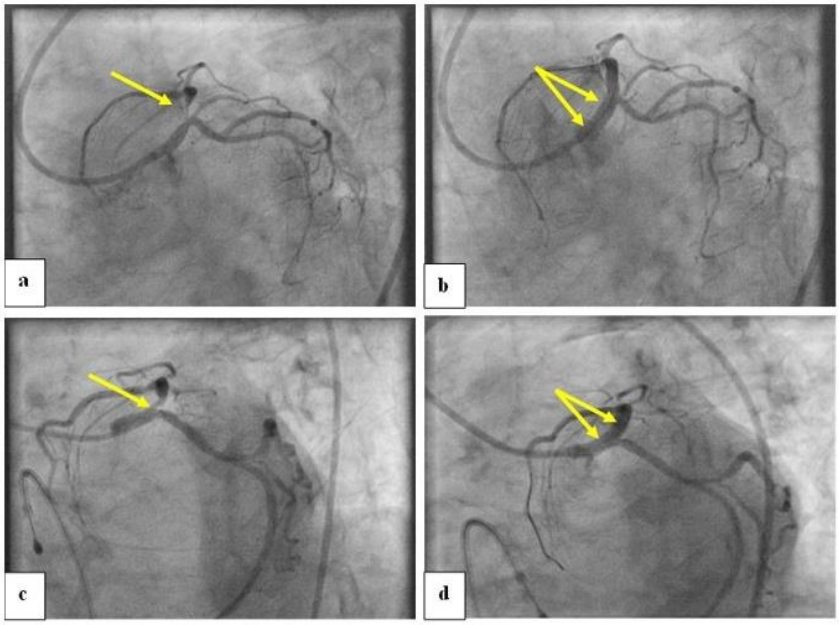

Fig. 3. Coronary angiograms for cases 5 (a, b) and 6 (c, d)
(a) CAG depicting LM bifurcation lesion with 95% stenosis of LAD (LAO caudal view)
(b) Final flow in the LCx after POT (LAO caudal view)
(c) LM bifurcation lesion with 80% stenosis of the LAD and minor plaque at ostial region of LCx (LAO caudal view)
(d) Established blood supply in the LCx after the POT was done (LAO caudal view)

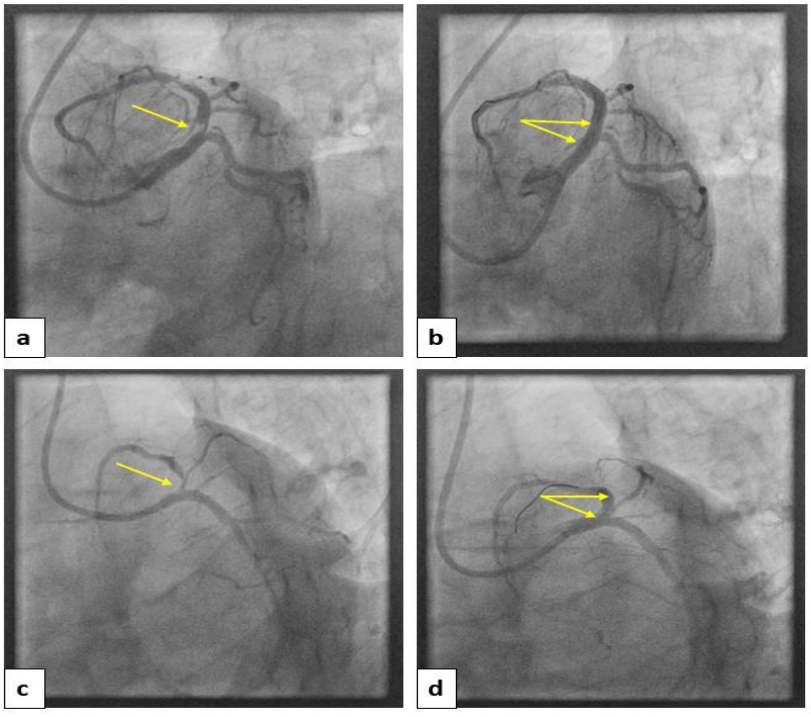

Fig. 4. Coronary angiograms for cases 7 (a, b) and 8 (c, d)
(a) CAG depicting LM bifurcation lesion with 95% stenosis of LAD (LAO caudal view)
(b) Final flow in the LCx after POT (LAO caudal view)
(c) LM bifurcation lesion with 80% stenosis of the LAD and minor plaque at ostial region of LCx (LAO caudal view)
(d) Established blood supply in the LCx after the POT was done (LAO caudal view)

Table 1. The baseline, anatomical and procedural characteristics of patients who underwent simple crossover PS

Variable	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Age (years)	44	60	35	57	71	71	48	50
Gender	F	M	M	M	M	F	M	M
Complaints/ Indication	AWMI	AWMI/ Cardiogenic shock	AWMI	AWMI/ Cardiogenic shock	AWMI	NSTEMI	AWMI	AWMI
Comorbidities	None	None	None	Hypertension	Diabetes mellitus	Diabetes mellitus and Hypertension	None	None
Bifurcation Lesion	Bifurcation lesions involving LM, LAD and LCx							
Size/Stent	Xience Xpedition (3.5 x 23 mm)		Xience Prime (3.5 x 33 mm)	Xience Xpedition (3 x 48 mm)	Resolute onyx (3.5 x 34 mm)	Resolute onyx (3.5 x 18 mm)	Xience expedition (3.5 x 48 mm)	Xience expedition (3.5 x 15 mm)
Manufactures details	Abbott Vascular, Santa Clara, CA, USA		Abbott Vascular, Santa Clara, CA, USA	Abbott Vascular, Santa Clara, CA, USA	Medtronic, Santa Rosa, CA	Medtronic, Santa Rosa, CA	Abbott Vascular, Santa Clara, CA, USA	
Post-procedural TIMI flow	TIMI-III							
Medina classification	0,1,0 (non-true)	1,1,0 (true)	0,1,0 (non-true)	1,1,1 (true)	1,1,0 (true)	1,1,0 (true)	0,1,0 (non-true)	0,1,0 (non-true)
POT balloon size	4.0 x 10 mm NC balloon	4.0 x 10 mm NC balloon	4.0 x 12 mm NC balloon	3.5 x 10 mm NC balloon	5 x 10 mm NC balloon	4.5 x 8 mm NC balloon	4 x 8 mm NC balloon	4.5x 8 mm NC balloon
Follow-up	2-year	2-year	2-year	1-year	6 months	6 months	2-year	6 months

AWMI: anterior wall myocardial infarction; BMI: Body mass index; NSTEMI: non-ST-elevated myocardial infarction; POT: proximal optimization technique; TIMI: thrombolysis in myocardial infarction

2.9 Provisional Stenting Procedure and follow-up

PCI was performed following the standard guidelines for bifurcation lesion treatment. MV and SB wiring was performed. However, the predilation was left to the operator's discretion. Drug-eluting stents were inserted in the bifurcation lesions followed by the POT using non-compliant balloons. Details are provided in Table 1.

Clinical and echocardiographic evaluations were conducted for all cases during the follow-up, and no adverse events were observed in any patient throughout the follow-up period.

3. DISCUSSION

The most effective approach for treating bifurcation lesions in ACS patients is not widely recognized. The myocardium is particularly at higher risk for infarction in ACS patients with LM distal bifurcation lesions. Therefore, establishing reperfusion in the culprit's vessel as swiftly as possible with a simple, short, and safe stenting strategy is imperative. In this case series, to avoid pre-, peri- and post-procedural difficulties, the PS technique was considered to address the LM distal bifurcation lesions in ACS (acute AWMI or NSTEMI) patients. These lesions were successfully treated with the PS technique without opening SB or balloon kissing technique. Post-procedure TIMI III flow was achieved in all patients. Indeed, none of the patients experienced MACE during the follow-up, indicating the feasibility of PS technique as safe and effective treatment in the subset of the ACS population.

A substantial knowledge gap regarding the management of ACS patients with LMCA disease in acute settings has led to the exclusion of these patients from a number of studies. Earlier studies did not reveal any significant benefits of planned two-stent techniques over simple PS. Although the two-stent approach remains the recommended option for complex LM bifurcation lesions, the PS is a highly preferred strategy if the SB is devoid of disease [1]. Compared to the DK crush technique, PS is simple, and can be converted to T stent/ T and small protrusion/culotte procedures if "bail-out" is required for SB stenting (≥10 mm) [7,12]. Another benefit is that patients are treated gradually using step-by-step approach, deploying a single stent and only a one-fifth of patients required a second stent in comparison to a more complex dual-stent implantation procedure. On top of this, while performing simple crossover PS, an additional multifaceted complex procedure for SB opening is not mandatory [9,10]. In ACS settings, simple crossover PS can lead to shorter procedural and fluoroscopy times with a reduced amount of contrast media [13].

Multiple randomized/nonrandomized trials have shown that CBLs treated with PS technique have lower long-term mortality rates and cardiac events than the upfront dual approach. According to DKCRUSH-V study, rate of target lesion revascularization was comparable (7% in the PS group vs 8% in DK group) at 1-year [7]. Similarly, the EBC trial showed MACE rates of 15% and 18% (PS group vs dual stenting) at 1-year in patients with true bifurcation LM lesions [8]. Further, in the COBIS III registry, the 5-year TLF rate was comparable across the two groups (7.0% in the simple crossover group vs. 6.7% SB opening group [9]. A significant flaw in these studies is the exclusion of high-risk patients with cardiogenic shock, severely calcified LM lesions requiring atherectomy, in-stent restenosis, acute MI, chronic total occlusion of either vessel and LM trifurcation with all three vessels [7,8]. Thus, inadvertent prejudices are likely to have influenced the outcomes of these trials. Despite the favorable outcomes of the DK crush strategy, recent guidelines from the 13th Consensus Document from the EBC recommend the PS technique as the standard approach for complex CBLs. For instance, in the DK CRUSH-V study, the POT was not performed after the primary stent was implanted in MV, whereas in the EBC trial, it was done in 85% of cases. Comparing the exclusion criteria of the aforementioned trials, the current study includes patients with AWMI, NSTEMI, and cardiogenic shock, and comorbidities like diabetes and hypertension. In the subset of patients with diabetes, treatment of bifurcation lesions with the PS approach showed a lower TLF rate compared to the dual-stent procedure [14].

The PS technique remains the gold standard for treating coronary bifurcation lesions due to its simplicity and effectiveness, as demonstrated by its widespread use in 15-20% of PCI cases. This approach not only minimizes procedural complexity but also results in significant improvements in myocardial function, particularly in the LAD territory, where it has shown superior

outcomes compared to two-stent techniques. Studies have highlighted its positive impact on left ventricular mechanics, with notable enhancements in global and regional longitudinal strain. Moreover, provisional stenting reduces the risk of periprocedural myocardial injury, offering a safer and more efficient option for bifurcation management [15]. Future large-scale studies can focus on the long-term outcomes of PS in high-risk patients, such as those with diabetes or cardiogenic shock. Randomized trials comparing PS with more complex stenting strategies will help establish its role in managing left main bifurcation lesions.

Furthermore, POT serves as an optimization step to PS, opposing the stent at the bifurcation. In comparison to surplus SB opening, simple crossover stenting with adequate POT has improved clinical outcomes [8]. Our results revealed PS procedure with POT can be used to treat both true/non-true bifurcation lesions, even in critical scenarios including patients with cardiovascular risk factors like diabetes mellitus and hypertension. These patients did not experience MACE events up to a 2-year follow-up. However, intravascular imaging should be performed at long-term follow-up to explore the anatomical and physiological characteristics of the lesions, and to monitor the feasibility of the PS technique beyond 2 years. This will eventually allow for the accurate design of long-term randomized and large-scale clinical trials.

4. CONCLUSION

The findings of this series imply that a side branch opening may not always be linked with favorable clinical outcomes compared with simple crossover stenting without a side branch opening. In ACS patients with distal left main bifurcation lesions simple crossover stenting from left main with optimal POT is a feasible strategy for revascularization.

CONSENT

We have obtained permission from the patients to publish their medical information and images in a medical journal, respecting their autonomy and individual rights.

ETHICAL APPROVAL

The authors have adhered to the ethical principles as directed under the Declaration of Helsinki.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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