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Research Article

Clinical outcomes of one-stent crossover approach for left main bifurcation in a single center

Sol ana koroner arter bifurkasyonu için tek stentli crossover yaklaşımın tek merkez klinik sonuçları

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Abstract

Aim: For the majority of left main coronary artery (LM) bifurcation lesions treated with percutaneous coronary intervention, one-stent crossover technique and provisional approach to the side branch is recommended, which is simpler compared to complex two-stent techniques. In this study, we aimed to reveal the clinical outcomes of one-stent crossover approach for LM bifurcation.

Material and Methods: Patients who underwent one-stent crossover technique for unprotected LM bifurcation lesion between May 2020 and November 2023 in our center were included in this retrospective observational study. Clinical and procedural characteristics of the patients were recorded. All patients or their relatives were called to inquire about clinical outcomes. The primary endpoint was determined as target lesion failure (TLF), which was defined as clinically driven target lesion revascularization (TLR), target lesion-related myocardial infarction (TL-MI), or sudden cardiac death (SCD).

Results: A total of 86 patients were included in the study. Crossover stenting was performed from the LM to the left anterior descending artery (LAD) in 76 patients and from the LM to the left circumflex artery (LCX) in 8 patients. The median follow-up time was 22 (3-54) months. Clinically driven TLR occurred in 2 patients, TL-MI in 1 patient, and SCD in 1 patient. TLF criteria were met in only 3 patients. Of these patients, 2 had undergone LM-LAD and 1 had undergone LM-LCX crossover stenting.

Conclusion: One-stent crossover approach for LM bifurcation lesions is associated with very good clinical outcomes.

Keywords: one-stent; crossover stenting; left main bifurcation

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Öz

Amaç: Perkütan koroner girişim ile tedavi edilen sol ana koroner arter (LM) bifurkasyon lezyonlarının çoğunda, kompleks çift stentleme tekniklerine kıyasla daha basit olan tek stentli crossover teknik ve yan dala provizyonel yaklaşım önerilmektedir. Bu çalışmada, LM bifurkasyonu için tek stentli crossover yaklaşımın klinik sonuçlarını ortaya koymayı amaçladık.

Gereç ve Yöntemler: Merkezimizde Mayıs 2020 ile Kasım 2023 tarihleri arasında, korumasız LM bifurkasyon lezyonuna tek stentli crossover teknik uygulanan hastalar retrospektif gözlemsel bu çalışmaya dahil edildi. Hastaların klinik ve prosedürel özellikleri kaydedildi. Tüm hastalar veya yakınları aranarak klinik sonuçlar sorgulandı. Birincil sonlanım noktası; kliniğe dayalı hedef lezyon revaskülarizasyonu (TLR), hedef lezyonla ilişkili miyokart enfarktüsü (TL-MI) veya ani kardiyak ölüm (SCD) olarak tanımlanan hedef lezyon başarısızlığı (TLF) olarak belirlendi.

Bulgular: Toplam 86 hasta çalışmaya dahil edildi. Bu hastaların 76'sında LM'den sol ön inen artere (LAD) doğru, 8'inde LM'den sol sirkumfleks artere (LCX) doğru crossover stentleme yapılmıştı. Ortanca takip süresi 22 (3-54) aydı. Hastaların 2'sinde kliniğe dayalı TLR, 1'inde TL-MI, 1'inde SCD gelişmişti. TLF kriterleri yalnızca 3 hastada gerçekleşmişti. Bu hastaların 2 tanesine LM-LAD, 1 tanesine LM-LCX crossover stentleme uygulanmıştı.

Sonuç: LM bifurkasyon lezyonları için tek stentli crossover yaklaşım oldukça iyi klinik sonuçlarla ilişkilidir.

Anahtar Kelimeler: tek stent; crossover stentleme; sol ana koroner arter bifurkasyonu

Introduction

Progress in interventional cardiology has led to an increasing utilization of percutaneous coronary intervention (PCI) in the management of unprotected left main coronary artery (LM) bifurcation disease. For the majority of LM bifurcation lesions treated with PCI, one-stent crossover technique and provisional approach to the side branch (SB) is recommended, which is simpler compared to complex two-stent techniques [1].

The evidence derived from the non-randomized studies indicated that a two-stent strategy for the treatment of LM bifurcation disease resulted in inferior outcomes [2,3]. However, the recent randomized studies have shown that a two-stent strategy for complex bifurcation lesions may be associated with a lower incidence of target lesion revascularization (TLR) in comparison to a provisional approach [4,5]. Conversely, the EBC MAIN trial furnished evidence to substantiate the efficacy of a provisional strategy for the management of true LM bifurcation lesions [6].

One-stent crossover technique and provisional approach to the SB remains the most common PCI strategy for LM bifurcation disease. In this study, we aimed to reveal the clinical outcomes of one-stent crossover approach for LM bifurcation in our center.

Material and Methods

Patients who underwent one-stent crossover technique for unprotected LM bifurcation lesion between May 2020 and November 2023 in our center were included in this retrospective observational study. The exclusion criteria were dual stenting of the LM bifurcation, prior stent implantation to the LM bifurcation, prior coronary artery bypass grafting, the presence of a ramus intermedius artery larger than 2 mm, cardiogenic shock at presentation, and lack of technical success. Technical success was accepted as Thrombolysis In Myocardial Infarction (TIMI) grade 3 flow in the left anterior descending artery (LAD) and the left circumflex artery (LCX) with residual stenosis <30% in the LM and crossover stented branch, and <75% in the ostium of the stentless branch. The study was approved by the local ethics committee, and informed consent was obtained from all participants.

The clinical characteristics of the patients were documented. Age, gender, smoking status, and body mass index were recorded. History of hypertension, diabetes, and prior PCI were noted. Hypercholesterolemia was accepted as total cholesterol higher than 240 mg/dL at any time [7]. Glycated hemoglobin level at presentation was recorded. The Modification of Diet in Renal Disease (MDRD) formula was utilized to ascertain the glomerular filtration rate (GFR). Patients exhibiting a GFR of less than 60 mL/min/1.73 m^2 for a minimum of 3 months were deemed to have chronic kidney disease [8]. Patients on maintenance dialysis were also noted. The modified Simpson method was employed for the estimation of the left ventricular ejection fraction. The diagnosis at admission was also documented.

Two-dimensional quantitative coronary angiography (2D-QCA) analysis was used to estimate the reference vessel diameter, diameter stenosis, and lesion length. The Medina classification of the LM bifurcation was noted. Moderate or severe calcification was defined as calcification more than just spots [9]. The bifurcation angle between the LAD and LCX was measured by 2D-QCA analysis in the left anterior oblique caudal view. Access site, intravascular ultrasound (IVUS) use, aorto-ostial stenting, total stent length per lesion, number of stents per lesion, the LM stent diameter, final kissing balloon inflation (KBI), final proximal optimization technique (POT), reached diameter with PCI in the LM and crossover stented branch, final diameter stenosis in the ostium of the stentless branch, and the choice of P2Y12 inhibitor were also recorded.

All patients or their relatives were called to inquire about clinical outcomes, which were also checked from the National Health Record System. Follow-up time, major bleeding, any coronary revascularization, TLR, target lesion-related myocardial infarction (TL-MI), in-stent restenosis, definite stent thrombosis, ischemic stroke, sudden cardiac death (SCD), all-cause death, target lesion failure (TLF), and time to TLF were documented. Major bleeding was accepted as Bleeding Academic Research Consortium (BARC) type 3 or 5 bleeding [10]. Clinically driven TLR was accepted as any repeat revascularization of a lesion within or 5 mm borders adjacent to the stent on the basis of clinical features of ischemia. SCD was defined as sudden, unexpected death from cardiovascular causes with loss of consciousness within 1 hour of symptom onset. The primary endpoint was determined as TLF, which was defined as clinically driven TLR, TL-MI, or SCD.

The Statistical Package for Social Sciences (SPSS) version 25 was utilized to upload and analyze the research data. Categorical variables are presented in terms of frequency and percentage. The Kolmogorov-Smirnov test was used to determine whether numerical variables were normally distributed. Numerical variables with a normal distribution are given as mean ± standard deviation, and those without a normal distribution are given as median (minimum-maximum).

Results

A total of 86 patients were included ultimately. Crossover stenting was performed from the LM to the LAD in 76 patients and from the LM to the LCX in 8 patients. The baseline and procedural characteristics of patients undergoing LM-LAD crossover stenting are presented in Table 1, and those of patients undergoing LM-LCX crossover stenting are presented in Table 2.

The median follow-up time was 22 (3-54) months. Major bleeding occurred in 2, any coronary revascularization in 6, TLR in 2, TL-MI in 1, in-stent restenosis in 1, definite stent thrombosis in 1, ischemic stroke in 3, SCD in 1, and all-cause death in 8 patients. TLF criteria were met in 3 patients, and the median time to TLF was 24 (16-30) months (Table 3). Of these patients, 2 had undergone LM-LAD and 1 had undergone LM-LCX crossover stenting.

Discussion

One-stent crossover technique is the accepted standard PCI approach for LM bifurcation disease in the absence of true bifurcation lesions. However, a recent randomized trial conducted by the European Bifurcation Club (EBC) suggested evidence in favor of a provisional stepwise approach also in true bifurcation lesions of the LM [6]. In our study, in which 13 of 86 patients had true bifurcation lesions, TLF occurred in only 3 patients.

The provisional stepwise approach adopted by the EBC implies evaluating the results at each step of the procedure. After crossover stenting and POT, the SB should be rewired and KBI performed with non-compliant balloons in the presence of a suboptimal SB result, as indicated by a TIMI grade <3 flow or >75% diameter stenosis. In the event that KBI is to be performed, it is recommended to complete with a final POT. Switching to a two-stent technique should only be reserved for a TIMI grade <3 flow in the SB, >90% diameter stenosis in the SB ostium, SB dissection type >A, abnormal physiology in the SB, or high-risk for SB closure [11].

In vitro data have shown that floating struts in the SB ostium may be associated with an increased susceptibility to thrombus formation [12]. However, clinical data have not demonstrated the benefit of routine KBI after LM crossover stenting [13]. In case of performing KBI, a final POT is advisable to restore proximal stent circularity [14]. Of the 86 patients in our study, 24 had undergone final KBI and 22 of these cases had been completed with final POT. Of the 3 patients with TLF, 1 had undergone final KBI and all of these cases had been completed with POT.

In contrast to LM-LAD crossover stenting, LM-LCX crossover stenting is not a well-defined technique. However, in some LM bifurcation lesions, LM-LCX crossover stenting may be an option due to lack of ostial LAD involvement, relatively larger LCX diameter, or unrevascularized chronic total occlusion in the LAD. In a study comparing LM-LAD and LM-LCX crossover stenting, the LCX ostium demonstrated a propensity for restenosis in both groups. Moreover, LM-LCX crossover

Table 1. Baseline and procedural characteristics of patients undergoing LM-LAD crossover stenting		
Variable		LM-LAD crossover stenting (n=78)
Age (year)		62.9 ± 11.3
Gender	Male (%*)	53 (67.9)
	Female (%*)	25 (32.1)
Smoking	Current (%*)	13 (16.7)
	Past (%*)	30 (38.5)
	Never (%*)	35 (44.9)
Hypertension (%*)		42 (53.8)
Diabetes (%*)		31 (39.7)
HbA1c (%)		6.0 (4.5-12.7)
Hypercholesterolemia (%*)		28 (35.9)
Body mass index (kg/m2)		28.8 (18.4-38.6)
Chronic kidney disease (%*)		17 (21.8)
GFR (mL/min/1.73 m2)		77.1 ± 24.9
Dialysis (%*)		3 (3.8)
Prior PCI (%*)		22 (28.2)
LVEF (%)		50 (30-72)
Diagnosis at admission	CCS (%*)	34 (43.6)
	UA (%*)	5 (6.4)
	NSTEMI (%*)	32 (41.0)
	STEMI (%*)	7 (9.0)
Medina classification	111 (%*)	7 (9.0)
	110 (%*)	26 (33.3)
	101 (%*)	1 (1.3)
	100 (%*)	5 (6.4)
	011 (%*)	2 (2.6)
	010 (%*)	37 (47.4)
Reference vessel diameter (mm)	LM	5.16 ± 0.42
	LAD	4.02 ± 0.29
	LCX	3.58 ± 0.54
Diameter stenosis (%)	LM	45 (0-99)
	LAD	80 (0-100)
	LCX	20 (0-70)
Lesion length (mm)	LM	7.5 (0-15)
	LAD	10 (0-75)
	LCX	5 (0-30)
Moderate/severe calcification	LM-LAD (%*)	25 (32.0)
	LCX (%*)	7 (9.0)
Bifurcation angle (°)		100 (40-160)
Access site	Femoral (%*)	58 (74.4)
	Radial (%*)	20 (25.6)
IVUS use (%*)		15 (19.2)
Aorto-ostial stenting (%*)		37 (47.4)
Total stent length per lesion (mm)		30 (16-104)
Number of stents per lesion		1 (1-4)
LM stent diameter (mm)		4.0 (3.0-4.5)
Final kissing balloon inflation (%*)		21 (26.9)
Final POT (%*)		76 (97.4)
Reached diameter with PCI (mm)	LM	5.00 ± 0.49
	LAD	4.05 ± 0.30
Final LCX diameter stenosis (%)		30 (0-70)
$P2Y_{12}$ inhibitor	Prasugrel (%*)	27 (34.6)
	Ticagrelor (%*)	31 (39.7)
	Clopidogrel (%*)	20 (25.6)

CCS, chronic coronary syndrome; GFR, glomerular filtration rate; HbA1c, glycated hemoglobin; IVUS, intravascular ultrasound; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main coronary artery; LVEF, left ventricular ejection fraction; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; POT, proximal optimization technique; STEMI, ST-segment elevation myocardial infarction; UA, unstable angina. *Column percentage.

Table 2. Baseline and procedural characteristics of patients undergoing LM-LCX crossover stenting		
Variable		LM-LCX crossover stenting (n=8)
Age (year)		70.0 ± 15.4
Gender	Male (%*)	5 (62.5)
	Female (%*)	3 (37.5)
Smoking	Current (%*)	2 (25.0)
	Past (%*)	4 (50.0)
	Never (%*)	2 (25.0)
Hypertension (%*)		7 (87.5)
Diabetes (%*)		3 (37.5)
HbA1c (%)		5.8 (5.4-8.2)
Hypercholesterolemia (%*)		3 (37.5)
Body mass index (kg/m2)		26.5 (24.1-33.2)
Chronic kidney disease (%*)		0
GFR (mL/min/1.73 m2)		82.9 ± 16.8
Dialysis (%*)		0
Prior PCI (%*)		3 (37.5)
LVEF (%)		55 (40-60)
Diagnosis at admission	CCS (%*)	1 (12.5)
	UA (%*)	0
	NSTEMI (%*)	6 (75.0)
	STEMI (%*)	1 (12.5)
Medina classification	101 (%*)	3 (37.5)
	100 (%*)	1 (12.5)
	001 (%*)	4 (50.0)
Reference vessel diameter (mm)	LM	5.14 ± 0.26
	LAD	3.78 ± 0.28
	LCX	3.91 ± 0.33
Diameter stenosis (%)	LM	40 (0-80)
	LAD	30 (0-40)
	LCX	87.5 (20-99)
Lesion length (mm)	LM	8.5 (0-12)
	LAD	4.5 (0-15)
	LCX	8 (5-15)
Moderate/severe calcification	LM-LAD (%*)	3 (37.5)
	LCX (%*)	1 (12.5)
Bifurcation angle (°)		85 (80-150)
Access site	Femoral (%*)	5 (62.5)
	Radial (%*)	3 (37.5)
IVUS use (%*)		0
Aorto-ostial stenting (%*)		3 (37.5)
Total stent length per lesion (mm)		22 (16-32)
Number of stents per lesion		1 (1-1)
LM stent diameter (mm)		3.75 (3.5-4.0)
Final kissing balloon inflation (%*)		3 (37.5)
Final POT (%*)		7 (87.5)
Reached diameter with PCI (mm)	LM	4.98 ± 0.49
	LCX	4.11 ± 0.30
Final LAD diameter stenosis (%)		30 (0-50)
$P2Y_{12}$ inhibitor	Prasugrel (%*)	1 (12.5)
	Ticagrelor (%*)	3 (37.5)
	Clopidogrel (%*)	4 (50.0)

CCS, chronic coronary syndrome; GFR, glomerular filtration rate; HbA1c, glycated hemoglobin; IVUS, intravascular ultrasound; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main coronary artery; LVEF, left ventricular ejection fraction; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; POT, proximal optimization technique; STEMI, ST-segment elevation myocardial infarction; UA, unstable angina. *Column percentage.

stenting was associated with a higher rate of TLR in the LAD ostium. The LAD ostium was involved in 5 of the 6 patients with TLR in the LM-LCX group, although final KBI had been performed in 4 of these patients [15]. In our study, among the 8 patients undergoing LM-LCX crossover stenting, TLR occurred in 1 patient, in whom the LAD ostium was totally occluded, and final KBI had not been performed in this case.

Table 3. Clinical outcomes of patients undergoing LM crossover stenting

Variable	LM crossover stenting (n=86)
Follow-up time (month)	22 (3-54)
Major bleeding (%*)	2 (2.3)
Any coronary revascularization (%*)	6 (7.0)
Target lesion revascularization (%*)	2 (2.3)
Target lesion-related MI (%*)	1 (1.2)
In-stent restenosis (%*)	1 (1.2)
Definite stent thrombosis (%*)	1 (1.2)
Ischemic stroke (%*)	3 (3.5)
Sudden cardiac death (%*)	1 (1.2)
All-cause death (%*)	8 (9.3)
Target lesion failure (%*)	3 (3.5)
Time to target lesion failure (month)	24 (16-30)

LM, left main coronary artery; MI, myocardial infarction.
*Column percentage.

Coronary bifurcation lesions are associated with an elevated risk of platelet reactivity and are therefore deemed to be a predisposing factor for ischemic events. However, current evidence is insufficient regarding the regimen and duration of dual antiplatelet therapy (DAPT) after PCI of the LM bifurcation. The diagnosis at admission, assessment of the bleeding risk, and stenting strategy should be taken into account in determining the DAPT regimen and duration [11].

Our study had several limitations. It was underpowered, with a small sample size and no comparison group, which limits the ability to draw firm conclusions. The decision to perform additional PCI to the SB following crossover stenting was at the discretion of the operator. Coronary physiological assessment was never utilized for the purpose of evaluating the severity of the SB subsequent to crossover stenting. Finally, intracoronary imaging guidance by IVUS, a proven method to improve the outcomes of LM PCI, was infrequent in our study.

Conclusion

One-stent crossover approach for LM bifurcation lesions is associated with very good clinical outcomes.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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