Original Article

Clinical and Angiographic Profile of Patients Undergoing Coronary Bifurcation Percutaneous Coronary Intervention and Short-Term Outcomes

Akash Karwa[1], Jayal Shah[1], Gourav Behra[1]*, Riyaz Charaniya[1], Krutika Patel[2], Kishan Hibare[1], Sagar Vejani[1], Megh Shah[1]

[1] Department of Cardiology, U. N. Mehta Institute of Cardiology and Research Centre (UNMICRC), Civil Hospital Campus, Asarwa, Ahmedabad-380016, Gujarat, India.

[2] Department of Research, U. N. Mehta Institute of Cardiology and Research Centre (UNMICRC), Civil Hospital Campus, Asarwa, Ahmedabad-380016, Gujarat, India.

Citation: Karwa A, Shah J, Behra G, Charaniya R, Patel K, Hibare K, et al. Clinical and Angiographic Profile of Patients Undergoing Coronary Bifurcation Percutaneous Coronary Intervention and Short-Term Outcomes. Res Heart Yield Transl Med 2026; 21(4): 263-273.

https://doi.org/10.18502/rhythm.v21i4.23089

Highlights

- A significant prevalence of complex coronary lesions, particularly in the left main and bifurcation regions, highlighting the challenges associated with their management.
- This study shows that severe left ventricular dysfunction is the primary predictor of mortality among our study patients undergoing bifurcation PCI, rather than the complexity of the procedure or the quantity of stents utilized.
- It reinforces the adoption of provisional stenting as the standard method and implies that treatment should be tailored according to the patient's specific anatomy and a comprehensive evaluation of their risks to enhance outcomes.

Article info:

Received: 08 Jun. 2026
Revised: 27 Jun. 2026
Accepted: 19 Jul. 2026

*** Corresponding Author:**
Gourav Behra
Assistant Professor, Department of Cardiology, U.N. Mehta Institute of Cardiology and Research Centre, Ahmedabad-380016, India.
Tel: 91 9575 0087 44
Fax: 079 2268 2092
Email: siddhu2691@gmail.com

ABSTRACT

Background: Coronary bifurcation lesions pose substantial challenges in percutaneous coronary intervention (PCI). This study aimed to assess the clinical and angiographic characteristics of patients undergoing PCI for bifurcation lesions in a South Asian population and to evaluate short-term outcomes.

Methods: This prospective observational study was performed from June 2022 through September 2023 at a tertiary cardiac care center in individuals undergoing PCI for coronary bifurcation lesions.

Results: A total of 259 participants were enrolled, with a mean (SD) age of 57.4 (10.9) years; 78.8% were male.The Medina classification indicated that the most common bifurcation lesion was left main–left anterior descending (LM–LAD) (43.2%). A total of 206 participants had LM bifurcation lesions, whereas 53 had non-LM lesions, with the LAD being the most frequently involved culprit vessel (94.2%). Ostial lesions were present in 68.3% of cases, and calcification was significantly more common in LM lesions (14.6%) than in non-LM lesions (1.9%; P=.01). Provisional stenting was the most common technique (62.6%), with double kiss crush used more frequently in LM bifurcation lesions (20.4% vs 3.8%; P < .001). Major adverse cardiovascular events (MACE) occurred in 38 participants (14.7%); they included 18 cardiac deaths (6.9%) and 13 cases of target vessel failure (TVF) (5.0%). No significant differences in MACE (P=.23) or death (P=.10) were observed between bifurcation lesion types or stenting strategies. Intravascular ultrasonography (IVUS) guidance was utlized in 70.3% of participants and was potentially associated with improved outcomes. Kaplan–Meier analysis revealed that severe left ventricular dysfunction was associated with a nearly 3-fold greater risk of death (hazard ratio [HR], 2.96; 95% CI, 0.98 to 8.96) and was the only independent predictor of all-cause mortality (HR, 3.23; 95% CI, 1.14 to 9.14; P=.027).

Conclusion: Procedural complexity and lesion-related factors were not significantly associated with short-term mortality. These findings emphasize the importance of addressing myocardial dysfunction in risk stratification and management to improve outcomes in this high-risk population.

Keywords: Bifurcation; Complex Coronary Intervention; Follow-up; Percutaneous Coronary Intervention; India

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Introduction

Coronary bifurcation lesions account for nearly 20% of all percutaneous coronary interventions (PCIs) and remain among the most technically challenging Lesion subsets because of anatomic complexity, altered flow dynamics, and the risk of side branch (SB) compromise.[1] Endothelial shear stress plays a central role in plaque development; regions of low and oscillatory shear stress at the lateral walls predispose to atherosclerotic progression, whereas the carina is relatively protected.[2-4] True bifurcation disease, defined by significant ostial involvement of the SB, is clinically important because SB occlusion increases the risk of periprocedural myocardial infarction and subsequent target lesion failure (TLF).[5,6]

The Medina classification, which assigns binary values to the proximal main vessel, distal main vessel, and SB segments, remains the most widely used angiographic classification system for bifurcation lesions.[7] Therapeutically, provisional stenting is the default strategy for most lesions because of its procedural simplicity and equivalent outcomes in many clinical scenarios.[8] Planned 2-stent approaches-such as double kiss (DK) crush, culotte, T and protrusion (TAP), and modified T techniques-are reserved for anatomically complex or true bifurcation lesions, particularly those involving large or flow-significant SBs.[9,10] Midterm results from randomized trials and registry data suggest broadly comparable outcomes between provisional and planned 2-stent strategies, although lesion complexity, left main (LM) involvement, and procedural optimization influence the risks of restenosis and stent thrombosis.[11-13]

South Asian populations experience premature coronary atherosclerosis driven by diabetes, hypertension, central obesity, and tobacco exposure.[14,15] In India, coronary events occur at a younger age and contribute substantially to cardiovascular mortality, with coronary artery disease–related deaths increasing sharply over the past 3 decades.[16] Despite increasing PCI volumes, contemporary Indian data describing the clinical, angiographic, and procedural characteristics of bifurcation PCI and their association with short-term outcomes remain sparse and are often limited to retrospective analyses with short follow-up.[17,18]

To address this evidence gap in the Indian population, we conducted a prospective observational study to evaluate the clinical and angiographic characteristics of individuals undergoing coronary bifurcation PCI and their short-term outcomes.

Methods

This prospective observational study was conducted at a tertiary cardiac care center from June 2022 through September 2023. Individuals undergoing coronary bifurcation PCI were included. The study protocol was reviewed and approved by the institutional ethics committee (reference No. UNMICRC/CARDIO/2022/06).

Methodology

Demographic data, including age and sex, were collected. Clinical examinations were performed for all participants. Hematologic and radiographic investigations were performed as clinically indicated. Preprocedural evaluation included a complete blood count, blood typing, and serum biochemistry (urea, creatinine, lipid profile, electrolyte levels). Diagnostic evaluation included chest radiography, electrocardiography, and echocardiography (Philips HD 7). Participants undergoing angiography were categorized into 3 clinical groups: chronic stable angina, unstable angina or non–ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI). Lesions were classified according to the Medina classification, and vascular involvement was recorded for each participant.

Follow-up

The stenting procedure was recorded for all participants. Outcomes were assessed at 3-month, 6-month, and 1-year follow-up points and included all-cause mortality; MACE (cardiac death, nonfatal myocardial infarction, unstable angina, coronary revascularization); and TVF and TLF (repeat revascularization at the target lesion, myocardial infarction in the territory supplied by the treated lesion, cardiac death). Unstable angina was defined according to the Fourth Universal Definition of Myocardial Infarction and the

European Society of Cardiology criteria for non–ST-elevation acute coronary syndrome as new-onset, worsening, or rest angina accompanied by new or dynamic ischemic electrocardiographic changes and/or objective evidence of ischemia, with cardiac troponin concentrations below the diagnostic threshold for myocardial infarction.[19]

Outcomes were compared according to stenting technique, left ventricular (LV) function, and participants' clinical presentation. Stent burden was defined as the use of 2 or more drug-eluting stents (DES) in comparison with fewer than 2 DES. Severe left ventricular dysfunction (LVD) was defined as a left ventricular ejection fraction (LVEF) of 30% or less on transthoracic echocardiography, consistent with the LVEF categories reported in (Table 1).

Statistical Analysis

All statistical analyses were performed using SPSS, version 26.0 (IBM Corp). Quantitative data were presented as mean (SD), and categorical variables were presented as frequency and percentage. Clinical and angiographic characteristics of participants were compared using the $\chi 2$ or Student t test. Survival outcomes were assessed with Kaplan-Meier analysis and compared with the log-rank test. Cox proportional hazards regression was performed to identify independent predictors of mortality. A P value less than .05 was considered statistically significant.

Results

A total of 259 individuals were enrolled, with a mean (SD) age of 57.4 (10.9) years. The majority were male (78.8%), and 34.4% were current smokers. Baseline demographic and clinical characteristics are summarized in (Table 1).

The angiographic profile and stenting details are shown in (Table 2). The most frequently involved culprit vessel was the left anterior descending coronary artery (LAD) (94.2%), followed by the left circumflex coronary artery (LCx) (64.5%), right coronary artery (RCA) (42.5%), and left main coronary artery (LMCA) (27.8%). Ostial lesions were noted in 177 participants (68.3%), whereas thrombus and calcification were each noted in 27 (10.4%). The predominant Medina classifications were 1-1-1 (34.0%), 0-1-0 (33.6%), 0-1-1 (18.9%), and 1-1-0 (10.4%). True bifurcation lesions accounted for 52.9% of the study population, and nontrue bifurcation lesions accounted for 44.0%.

Bifurcation involvement most commonly included the LM–LAD (43.2%), followed by the LM–LAD–LCx (31.3%) and LAD–D1 (15.1%). A total of 114 participants (44.0%) required 2 DES, whereas 87 (33.6%) required 1 DES and 50 (19.3%) required 3 DES. Four and 5 DES were utilized in 7 participants (2.7%) and 1 participant (0.4%), respectively.

Final kissing balloon inflation was performed in 118 participants (45.6%), and intravascular ultrasonography (IVUS) guidance was drawn upon in 182 (70.3%). Rotational atherectomy was required in 24 participants (9.3%). The mean (SD) procedure duration was 95.61 (46.46) minutes, the mean (SD) contrast volume was 192.95 (70.91) mL, and the mean (SD) fluoroscopy time was 29.25 (16.41) minutes. Radial access was used in 65.3% of participants, whereas femoral access was employed in 34.7%. Regarding antiplatelet therapy, ticagrelor was prescribed for 221 participants (85.3%), prasugrel for 28 (10.8%), and clopidogrel for 10 (3.9%).

Distribution of Participants According to Lesion Type

Among the participants, 206 had LM bifurcation lesions and 53 had non-LM bifurcation lesions (Table 2). Analysis of lesion complexity indicated that thrombus was present in 12.8% of participants, with a greater prevalence in non-LM bifurcation lesions (17.0%) than in LM bifurcation lesions (11.7%) (P=.30). Calcification was significantly more common in LM bifurcation lesions (14.6%) than in non-LM bifurcation lesions (1.9%) (P=.01). The provisional stenting strategy was the most commonly used technique (162 participants [62.6%]), followed by DK crush (16.6%), culotte (9.3%), TAP (7.3%), and mini-crush (4.3%). Technique distribution varied by bifurcation location, with LM–LAD and LM–LCx lesions predominantly treated with provisional stenting, whereas LM–LAD–LCx lesions more frequently required 2-stent strategies (DK crush, 20.0%; culotte, 9.3%; TAP, 5.4%; mini-crush, 4.4%).

Regarding DES use, 1 DES was employed in

33.6% of participants, with a higher proportion in non-LM bifurcation lesions (47.2%) than in LM bifurcation lesions (30.1%) (P=.02). When stratified by lesion location, provisional stenting did not differ significantly between the 2 groups (P=.33). Nonetheless, the DK crush technique was used more frequently in LM bifurcation lesions (20.4%) than in non-LM bifurcation lesions (3.8%) (P=.001) (Table 3).

Outcomes

MACE were observed in 38 participants (14.7%). Of these, 18 (6.9%) died of cardiac causes, and 13 (5.0%) experienced TVF or TLF at the 1-year follow-up. Outcomes were analyzed according to bifurcation lesion type and stenting strategy; no statistically significant differences were observed concerning MACE (P=.23 and P=.77, respectively) or death (P=.10 and P=.95, respectively). The TVF/TLF rate was 5.0%, and there were no significant differences according to bifurcation lesion type or stenting strategy (P=.64 and P=.77, respectively).

IVUS guidance was used in 182 participants (70.3%). Among these individuals, bifurcation involvement most commonly included the LM–LAD (46.2%), followed by the LM–LAD–LCx (40.1%). This finding suggests that IVUS guidance may be associated with improved clinical outcomes, particularly in complex bifurcation lesions. At the 1-year follow-up, 29 participants experienced MACE, 14 died, and TVF/TLF occurred in 11 individuals.

Kaplan-Meier analysis revealed no significant differences in survival according to MACE (log-rank P=.564), TVF/TLF (log-rank P=.405), or stent burden (2 or more DES vs fewer than 2 DES; log-rank P=.186). Participants with severe LVD demonstrated markedly reduced survival, with a strong trend toward statistical significance (log-rank P=.055) (Figure 1).

On univariable Cox proportional hazards analysis, severe LVD was associated with a nearly 3-fold greater risk of death (hazard ratio [HR], 2.96; 95% confidence interval [CI], 0.98 to 8.96), whereas MACE, stent burden (2 or more DES), and TVF/TLF were not significantly associated with mortality. In the multivariable Cox proportional hazards model, severe LVD was the only independent predictor of all-cause mortality (HR, 3.23; 95% CI, 1.14 to 9.14; *P* = .027). MACE (HR, 3.91; 95% CI, 0.76 to 20.21), stent burden (2 or more DES) (HR, 2.22; 95% CI, 0.71 to 6.99), and TVF/TLF (HR, 0.67; 95% CI, 0.17 to 2.64) were not independently associated with mortality (Figure 2 and Table 4). The model demonstrated acceptable discrimination (Harrell *C* index, 0.73; 95% CI, 0.62 to 0.83).

Table 1. Demographic and clinical characteristics of the study population

Variable	N=259 (%) or mean (SD)
mean (SD), y	57.4 (10.9)
Sex	
Male sex, No. (%)	204 (78.8)
Female sex, No. (%)	55 (21.2)
Comorbidity	
Smoking, No. (%)	89 (34.4)
Hypertension, No. (%)	111 (42.7)
Type 2 diabetes, No. (%)	88 (34.0)
Dyslipidemia, No. (%)	70 (27.0)
Chronic kidney disease, No. (%)	7 (2.7)
Prior Cardiac Interventions	
PTCA, No. (%)	35 (13.5)
CABG, No. (%)	9 (3.5)
Diagnosis	
STEMI, No. (%)	118 (45.6)
NSTEMI, No. (%)	75 (29.0)
Unstable angina, No. (%)	39 (15.1)
Stable angina, No. (%)	27 (10.4)
LVEF, No. (%)	

Normal (>55%)	73 (28.2)
Mild LVD (45%–54%)	62 (23.9)
Moderate LVD (31%–44%)	55 (21.2)
Severe LVD (<30%)	69 (26.6)
Vessel Involvement, No. (%)	
LAD	244 (94.2)
LCx	167 (64.5)
RCA	110 (42.5)
LMCA	72 (27.8)
Outcome, No. (%)	
MACE	38 (14.7)
Death	18 (6.9)
In-hospital	7
3 mo	6
6 mo	2
12 mo	3
TVF/TLF	13 (5.0)

CABG: coronary artery bypass grafting; LAD: left anterior descending artery; LCx: left circumflex coronary artery; LMCA: left main coronary artery; LVD: left ventricular dysfunction; LVEF: left ventricular ejection fraction; MACE: major adverse cardiac events; NSTEMI: non–ST-segment elevation myocardial infarction; PTCA: percutaneous transluminal coronary angioplasty; RCA: right coronary artery; SD: standard deviation; STEMI: ST-segment elevation myocardial infarction; TVF/TLF: target vessel failure/target lesion failure

Table 2. Distribution of patients according to left main bifurcation and non-left main bifurcation

Variable	Total (N=259)	LM Bifurcation (N=206)	Non–LM Bifurcation (N=53)	P
Lesion Complexity				
Thrombus, No. (%)	33 (12.8)	24 (11.7)	9 (17.0)	.30
Calcification, No. (%)	31 (12.0)	30 (14.6)	1 (1.9)	.01
No. of DES Implanted				
1, No. (%)	87 (33.6)	62 (30.1)	25 (47.2)	.02
2, No. (%)	114 (44.0)	91 (44.2)	23 (43.4)	.92
3, No. (%)	50 (19.3)	46 (22.3)	4 (7.5)	.02
4, No. (%)	7 (2.7)	6 (2.9)	1 (1.9)	.68
5, No. (%)	1(0.4%)	1(0.5%)	0	.46
Stenting Technique				
Provisional, No. (%)	162 (62.6)	125 (60.7)	36 (67.9)	.33
DK crush, No. (%)	43 (16.6)	42 (20.4)	2 (3.8)	<.001
Culotte, No. (%)	24 (9.3)	18 (8.7)	6 (11.3)	.56
TAP, No. (%)	19 (7.3)	12 (5.8)	7 (13.2)	.07
Mini crush, No. (%)	11 (4.3)	9 (4.4)	2 (3.8)	.85
Outcome				
MACE, No. (%)	38 (14.7)	33 (16.0)	5 (9.4)	.23
Death, No. (%)	18 (6.9)	17 (8.3)	1 (1.9)	.10
TVF/TLF, No. (%)	13 (5.0)	11 (5.3)	2 (3.8)	.64

DES: drug-eluting stent; DK crush: double-kissing crush; LM: left main; MACE: major adverse cardiovascular events; TAP: T and protrusion; TVF/TLF: target vessel failure/target lesion failure
A *P* value <0.05 shows statistical significance.

Table 3. Outcome according to stenting strategy

Variable	Total (N=259)	Provisional (N=161)	DK Crush (N=44)	Culotte (N=24)	TAP (N=19)	Mini Crush (N=11)	P
Lesion Complexity							
Thrombus, No. (%)	33 (12.8)	28 (17.3)	1 (2.3)	2 (8.3)	1 (5.3)	1 (9.1)	.06
Calcification	31 (12)	20 (12.4)	6 (13.6)	2 (8.3)	2 (10.5)	1 (9.1)	.97

No. of DES Implanted							
1, No. (%)	87 (33.6)	85 (52.8)	1 (2.3)	1 (4.2)	0	0	<.001
2, No. (%)	114 (44)	65 (40.4)	25 (56.8)	10 (41.7)	9 (47.4)	5 (45.5)	0.41
3, No. (%)	50 (19.3)	11 (6.8)	14 (31.8)	13 (54.2)	6 (31.6)	6 (54.5)	<.001
4, No. (%)	7 (2.7)	0	4 (9.1)	0	3 (15.8)	0	<.001
5, No. (%)	1 (0.4)	0	0	0	1 (5.3)	0	.01
Bifurcation Lesion							
LM-LAD, No. (%)	112 (43.2)	111 (68.9)	0	0	1 (5.3)	0	<.001
LM-LCX, No. (%)	13 (5)	13 (8.1)	0	0	0	0	.08
LM-LAD and LCX, No. (%)	82 (31.7)	2 (1.2)	42 (95.5)	18 (75)	11 (57.9)	9 (81.8)	<.001
LAD-D1, No. (%)	39 (15.1)	28 (17.4)	2 (4.5)	2 (8.3)	5 (26.3)	2 (18.2)	.12
LCX-OM, No. (%)	15 (5.8)	8 (5)	0	4 (16.7)	3 (15.8)	0	.02
Outcome							
MACE, No. (%)	38 (14.7)	22 (13.7)	8 (18.2)	5 (20.8)	2 (10.5)	1 (9.1)	.77
Death, No. (%)	18 (6.9)	10 (6.2)	4 (9.1)	2 (8.3)	1 (5.3)	1 (9.1)	.95
TVF/TLF, No. (%)	13 (5)	6 (3.7)	3 (6.8)	2 (8.3)	1 (5.3)	1 (9.1)	.77

D1: first diagonal branch; DES: drug-eluting stent; DK crush: double-kissing crush; LAD: left anterior descending artery; LCx: left circumflex coronary artery; LM: left main; MACE: major adverse cardiovascular events; OM: obtuse marginal branch; TAP: T and protrusion; TVF/TLF: target vessel failure/target lesion failure

Table 4. Kaplan–Meier and Cox regression analysis for all-cause mortality

Variable	χ^2	Univariable HR (95% CI)	Kaplan–Meier Log-Rank (*P*)	Multivariable HR (95% CI)	P
MACE	0.33	1.51 (0.37–6.09)	.56	3.91 (0.76–20.21)	.10
≥2 DES	1.75	1.96 (0.72–5.31)	.19	2.22 (0.71–6.99)	.17
Severe LVD	3.67	2.96 (0.98–8.96)	.06	3.23 (1.14–9.14)	.03
TVF/TLF	0.69	0.60 (0.18–1.98)	.41	0.67 (0.17–2.64)	.57

DES: drug-eluting stent; LVD: left ventricular dysfunction; MACE: major adverse cardiovascular events; TVF/TLF: target vessel failure/target lesion failure

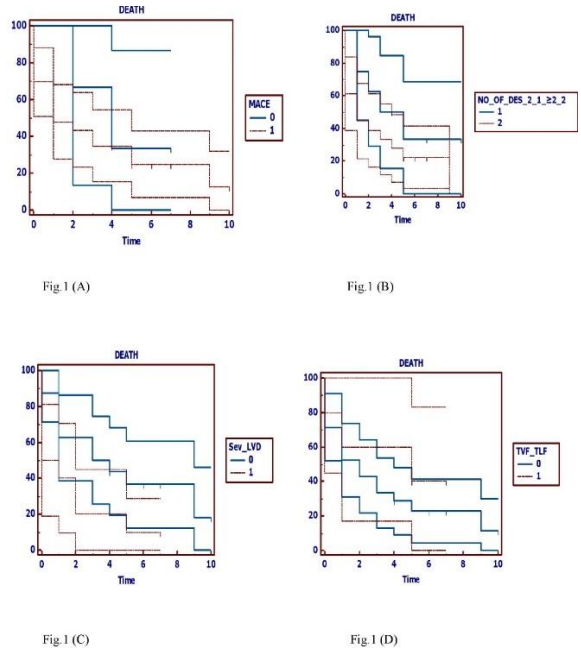


Figure 1. Kaplan–Meier survival analysis for all-cause mortality
Kaplan-Meier curves depicting all-cause mortality according to (A) occurrence of major adverse cardiovascular events (MACE), (B) number of drug-eluting stents (<2 vs ≥2), (C) severe left ventricular dysfunction (LVD), and (D) target vessel failure/target lesion failure (TVF/TLF).

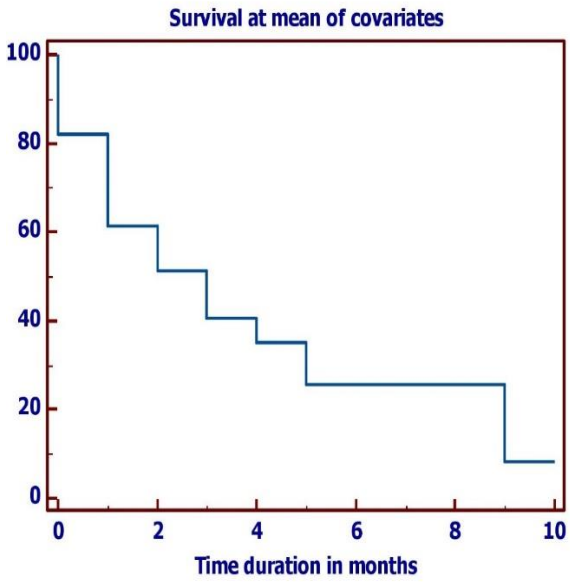


Figure 2. Cox proportional-hazards regression
Hazard ratios (HRs) and 95% confidence intervals (CIs) for predictors of all-cause mortality. The model showed good discriminatory ability, with a Harrell C-index of 0.73 (95% CI, 0.62 to 0.83), indicating acceptable separation between survivors and nonsurvivors.

Discussion

The present single-center observational study provides a comprehensive overview of the clinical profile, angiographic characteristics, procedural strategies, and short-term outcomes of individuals undergoing coronary bifurcation PCI in a real-world setting. The principal finding was that baseline severe LVD was the only independent predictor of all-cause mortality, whereas procedural complexity and lesion-related adverse events, including MACE, TVF/TLF, and stent burden, were not independently associated with survival. These findings highlight the dominant prognostic role of myocardial dysfunction over anatomic or procedural factors in this high-risk cohort.

Clinical and Demographic Profile

The mean age of 57.4 years and the predominance of male participants (78.8%) observed in this cohort are consistent with findings from large bifurcation PCI registries reported by Nathan et al18 and Gajakosh et al,[20] in which men constituted more than 70% of the study population. The prevalence of smoking (34.4%) was also consistent with findings from Asian and South Asian cohorts and underscores the contribution of modifiable risk factors to complex coronary artery disease.[16] Compared with Western registries, this cohort represents a relatively younger population, which reflects the earlier onset of coronary artery disease reported in the Indian subcontinent.

Angiographic Characteristics and Bifurcation Anatomy

LAD involvement was observed in more than 90% of cases, with LMCA involvement in nearly one-third of participants. This distribution is consistent with findings from the EBC MAIN and DKCRUSH trials, which reported LAD and LM bifurcations as the most frequently treated lesions.[21] Medina 1-1-1 and 0-1-0 lesions constituted the majority in this study, highlighting a high proportion of true bifurcation lesions. Similar lesion complexity has been reported by Zhang et al,[13] emphasizing that real-world bifurcation PCI frequently involves anatomically complex disease.

Stenting Strategy and Procedural Techniques

Provisional stenting was the predominant strategy in this cohort (62.6%), particularly for LM–LAD and noncomplex bifurcation lesions. This practice is consistent with current European Bifurcation Club recommendations and is supported by randomized trials such as EBC MAIN, in which a stepwise provisional approach demonstrated favorable outcomes in LM bifurcations.[22] Two-stent techniques were more commonly used in LM–LAD–LCx lesions, reflecting appropriate tailoring of the revascularization strategy to lesion anatomy.

Among 2-stent techniques, DK crush was the most frequently used, followed by culotte and TAP. Although DK crush has shown superiority over provisional stenting in selected true LM bifurcation lesions in the DKCRUSH-V trial, this study did not demonstrate significant differences in MACE, mortality, or TLF among stenting techniques.[23] This finding may be attributable to careful lesion selection, extensive use of IVUS, and operator expertise.

The high application of IVUS (70.3%) in this cohort exceeds that reported in many previous registries and reflects increasing adherence to evidence supporting imaging-guided PCI. Studies by Mintz et al[24] and Zhang et al[13] consistently demonstrated improved outcomes with IVUS-guided bifurcation PCI, particularly for LM disease. The acceptable procedure duration, contrast volume, and fluoroscopy time further suggest procedural efficiency despite lesion complexity.

Clinical Outcomes and Predictors of Adverse Events

In this single-center PCI cohort, severe LVD emerged as the primary determinant of mortality, whereas procedural and lesion-related factors-including MACE, TVF/TLF, and stent burden-were not independently associated with all-cause mortality. Participants with severe LVD demonstrated markedly reduced survival in the Kaplan–Meier analysis and a more than 3-fold greater hazard of death in the multivariable Cox proportional hazards model. These findings are

consistent with contemporary PCI trials and registries showing that LV systolic function outweighs angiographic complexity and revascularization strategy as a predictor of survival, irrespective of stent type or procedural technique.[25,26] In this cohort, the early separation of the Kaplan–Meier survival curves suggests that mortality among participants with severe LVD may have been driven predominantly by pump failure or malignant arrhythmias rather than ischemic or device-related complications. This finding underscores the prognostic importance of myocardial dysfunction over coronary anatomy.

In contrast, procedural complexity, reflected by the use of 2 or more DES, and lesion-related adverse events (MACE and TVF/TLF) were not independently associated with mortality. This dissociation between ischemic end points and survival has been consistently reported in contemporary studies of complex and bifurcation PCI, in which repeat revascularization and target lesion events were more frequent but were not independent predictors of death.[5,13,23]

In the current study, the 12-month mortality rate was 6.9% (18 of 259 participants), which is higher than rates reported in large bifurcation PCI data sets. For instance, the National Inpatient Sample analysis by Nathan et al[18] reported a mortality rate of 3.8%, whereas a single-center United Kingdom cohort study by Protty et al[27] reported mortality rates of 1.9% at 30 days and 8.2% at 1 year. This difference may be attributable to the high prevalence of severe LVD (26.6%) and STEMI presentation (45.6%) in this study population. These findings emphasize the importance of baseline risk stratification in this population.

The findings of the present study indicate broadly comparable outcomes between provisional and 2-stent techniques, consistent with several contemporary randomized trials. By way of example, the EBC MAIN trial demonstrated similar 12-month MACE rates between a stepwise provisional strategy and systematic 2-stent techniques (14.7% vs 17.7%; P=.34) in participants with LM bifurcation disease, supporting provisional stenting as the default strategy for LM interventions.[22] The MACE rate in this study was 14.7%, which is concordant with those findings.

In contrast, the DKCRUSH-V trial, which involved a more anatomically complex LM bifurcation population, reported lower 12-month TLF rates with the DK crush technique than with provisional stenting (5.0% vs 10.7%; P=.02).[22] Similarly, DKCRUSH-III reported higher 3-year MACE rates with the culotte technique than with DK crush in distal LM bifurcations (23.7% vs 8.2%; P<.001).[28] These studies suggest that the choice of strategy may depend on lesion complexity, a finding echoed in this study's subgroup analyses.

Moreover, the DEFINITION II trial, which used an objective complexity score, found that a 2-stent approach significantly reduced 12-month TLF in lesions meeting criteria for anatomic complexity (6.1% vs 11.4%; P=.019).[13] This finding highlights that outcome do not uniformly favor one approach but are influenced by the specific characteristics of the lesions being treated.

In this study, the high use of IVUS (70.3%) may have contributed to the favorable outcomes observed with both provisional and 2-stent strategies. The data presented in the tables further illustrate the complexity of the treated lesions, with notable differences in calcification and stent burden, which could affect outcomes. These findings suggest that the choice between provisional and 2-stent strategies should be tailored to lesion complexity, consistent with the varying outcomes reported in the literature.

An important observation from this study is the lack of an independent association between MACE or TVF/TLF and all-cause mortality. Although these adverse events are clinically relevant and reflect procedural or lesion-level failure, they were not independently associated with mortality. A similar dissociation between ischemic end points and survival has been reported in bifurcation and real-world PCI registries, in which repeat revascularization and target lesion events were common but did not independently predict death.[13,22] The findings of this study demonstrate that participants who experienced MACE had an increased risk of subsequent mortality, which chimes with existing literature suggesting that MACE serves as a key indicator of overall cardiovascular health. Although MACE includes mortality as a component, this analysis suggests that the occurrence of MACE events may provide valuable prognostic information to guide treatment strategies and risk

management.

Clinical Implications

By comparison with earlier Indian reports conducted in the era of first-generation DES and without systematic intravascular imaging, the present study represents an updated treatment paradigm incorporating second-generation DES, refined 2-stent techniques (particularly DK crush), and widespread use of IVUS and optical coherence tomography (OCT). The findings support a contemporary, anatomy-driven approach to bifurcation PCI, emphasizing provisional stenting as the default strategy, selective use of 2-stent techniques for complex lesions, and routine use of intravascular imaging. The comparable outcomes across techniques suggest that operator experience, lesion selection, and procedural optimization may be more influential than the choice of stenting technique alone.

Study Limitations

The single-center design may limit the generalizability of these findings. Although outcome assessments were conducted at 3-, 6-, and 12-month follow-up, the median follow-up duration was only 3 months, which is generally considered short-term and may limit the assessment of long-term outcomes. Moreover, the use of the proximal optimization technique (POT), final kissing balloon inflation, re-POT, and other optimization strategies was not recorded. Accordingly, the findings should be interpreted with caution, and future multicenter studies are needed to validate these results.

Conclusion

In this single-center study of individuals undergoing PCI for complex coronary bifurcation lesions, a high prevalence of complex coronary anatomy was observed, particularly in the LM region. This finding highlights the challenges associated with management. Most of the studied patients underwent successful stenting, with provisional stenting as the predominant technique. Despite lesion complexity and a high prevalence of comorbidities, the overall incidence of MACE at 12 months was relatively low, and severe LVD was identified as the sole independent predictor of all-cause mortality. The findings suggest that although advanced strategies-such as IVUS guidance and the use of DES-were associated with procedural optimization, they did not significantly affect 12-month mortality or MACE after adjustment for confounding factors. These data indicate that careful participant selection and optimization of LV function are essential for improving outcomes in complex coronary artery disease. Future studies should continue to evaluate the effects of different stenting strategies and the role of advanced imaging in long-term outcomes, particularly among individuals with significant LVD. Overall, these results provide insight into the management of bifurcation lesions and underscore the importance of individualized treatment approaches in this high-risk population.

Declarations:

Ethical Approval

The study has been approved by the institutional ethics committee (EC/Approval/06/Cardio/13/06/2022).

Funding

This work was supported by U. N. Mehta Institute of Cardiology and Research Centre itself and received no specific grant from any funding agency, commercial or not for profit sectors.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article'.

Acknowledgments

The authors have no acknowledgement to disclose.

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