Section: Cardiology

Original Research Article

PROFILE OF CORONARY ARTERY BIFURCATION LESIONS IN PATIENTS PRESENTED WITH CORONARY ARTERY DISEASE AND THEIR OUTCOMES AFTER PERCUTANEOUS INTERVENTION

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ABSTRACT

Background: Coronary artery disease (CAD) remains a leading cause of morbidity and mortality worldwide. Among angiographic subsets, bifurcation lesions constitute a technically demanding group during percutaneous coronary intervention (PCI) and are associated with higher complication rates and restenosis compared to non-bifurcation lesions. Detailed evaluation of their distribution and outcomes with different stenting strategies is essential for guiding clinical practice. The study aimed to assess the prevalence and angiographic profile of coronary bifurcation lesions in CAD patients, classify them by the Medina system, and analyze outcomes following provisional versus two-stent strategies. **Materials and Methods:** This hospital-based, cross-sectional observational study was conducted in the Department of Cardiology, Jawaharlal Nehru Medical College and Hospital, AMU, Aligarh, between July 2023 and July 2025. One hundred patients aged above 18 years undergoing coronary angiography were enrolled after informed consent. Exclusion criteria included renal dysfunction, contrast allergy, coagulopathy, and decompensated heart failure. Clinical features, risk factors, and angiographic findings were recorded, and PCI outcomes were assessed using SPSS version 28. **Result:** The study population had a mean age of 57.9 ± 9.45 years with male predominance (86.7%). Smoking (48.1%) was the leading risk factor, and acute coronary syndrome (82%) the main presentation. LAD–Diagonal bifurcations were most common (69%). Provisional stenting was favoured in simpler lesions, while two-stent strategies predominated in LM and complex disease, showing varied complications at three months. **Conclusion:** Bifurcation lesions, especially in the LAD territory, represent a significant burden in CAD interventions. Both stenting strategies yielded comparable outcomes, underscoring the need for individualized technique selection based on lesion anatomy.

INTRODUCTION

Coronary artery disease remains one of the most significant threats to public health across the globe, contributing substantially to mortality, morbidity, and health care burdens. Percutaneous coronary intervention (PCI) has revolutionized management of obstructive coronary lesions, offering patients less invasive options with quicker recovery and better symptomatic relief.[1] Despite technological advances—drug-eluting stents, adjunctive imaging, refined procedural techniques—the anatomical complexity of certain lesion types continues to challenge interventional cardiologists. Among these, coronary bifurcation lesions, where plaque involves or lies close to a branch point of a main coronary vessel, are especially demanding in both execution and prognostication.[2]

Bifurcation lesions are encountered in a substantial proportion of PCIs; estimates from large registries and studies place their prevalence at around 15-25% of all coronary interventions.[3] These lesions are not uniform: they may involve significant disease in the main vessel only, in the side branch only, or in both—often termed "true" bifurcations. Classification systems such as Medina and Movahed try to capture

this variability by noting whether the main branch proximal, distal, and the side branch are involved, but even these tools may not fully account for factors like branch angles, lesion length, plaque distribution, or vessel size mismatch, all of which influence procedural difficulty and outcomes.[4]

The anatomy of bifurcation lesions presents multiple obstacles. Accessing and protecting the side branch during stenting of the main vessel, achieving proper stent deployment, ensuring full apposition especially in curved or branching anatomy, and avoiding strut mal-apposition are technical hurdles.[5] Post-deployment optimization methods—such as proximal optimization technique (POT), final kissing-balloon inflation, stent post-dilation—and the use of intracoronary imaging (IVUS, OCT) are approaches employed to manage these challenges. These strategies aim to reduce acute complications like side branch occlusion, dissection, or compromised flow, as well as late events such as restenosis and stent thrombosis.[6] Studies comparing simple (often a single stent in the main branch with optional treatment of the side branch) versus more complex two-stent strategies show that operator choice must consider branching geometry, side branch size and angle, lesion length, and clinical risk factors.[7]

Clinical outcomes for bifurcation PCI remain inferior compared to non-bifurcation lesions. Several recent analyses have shown that patients undergoing PCI for bifurcation lesions have higher rates of procedural complications, in-hospital mortality, myocardial infarction, bleeding, coronary perforation, and longer procedural times.[8] For example, a large inpatient US series from 2016-2020 showed that, even after adjusting for age, sex, comorbidities, and other risk factors, PCI involving bifurcation lesions was associated with a significantly higher risk of death, myocardial infarction, procedural bleeding, tamponade, and other complications compared with PCI of non-bifurcation lesions.[9] Long-term follow-up data similarly document greater rates of target lesion revascularization (TLR), target vessel failure, and major adverse cardiovascular events (MACE) among those with true bifurcation anatomy, small branch diameters, or unfavorable angles.[10]

Some insights into which strategies yield better long-term outcomes have emerged. One study of bifurcation lesions involving the left anterior descending artery and its diagonal branch (LAD-D1) reported that more complex PCI techniques (e.g. two stents or systematic final kissing balloon inflation) achieved lower rates of adverse events over one year than simpler main-vessel-only strategies.[7] The role of intracoronary imaging has also been emphasized: guiding stent deployment and ensuring optimal stent expansion and positioning appears to reduce the incidence of MACE in complex bifurcations versus angiography alone.[11]

Despite this accumulating evidence, important gaps remain, especially in regional or real-world contexts. Many published studies come from high-volume centers or registry datasets in developed countries, and the patient populations may differ in demographics, comorbid conditions, access to imaging, operator experience, and follow-up infrastructure compared to other settings.[12] There is also variation in how bifurcation lesions are categorized, what procedural techniques are chosen, and how outcomes are defined—making comparisons difficult. For many regions, data on procedural strategy choices (provisional vs planned two-stent), extent of use of adjunctive imaging, and predictors of adverse outcomes after PCI in bifurcation lesions are limited.[13]

Given this background, a focused study to characterize bifurcation lesions among patients presenting with CAD in a specific center or population is of high value. Such a study can describe the types of bifurcations encountered (true vs non-true, side branch sizes, branch angles, vessel diameters), patient characteristics (age, comorbidities like diabetes, kidney disease, left ventricular function etc.), and procedural details (whether provisional or planned two-stent strategy was used, use of imaging guidance, optimization techniques).[14] Correlating these lesion and procedural features with short-term and long-term outcomes—procedural success, in-hospital complications, mortality, MACE, TLR, etc.—will help identify risk factors specific to that population. That in turn can guide operator decision-making, help optimize procedural protocols, better allocate resources (e.g. for imaging tools), and improve patient counseling about risks and benefits.[15]

The present study aims to determine the prevalence of bifurcation lesions in patients with coronary artery disease, to identify the specific vessels involved and classify the lesions using the Medina system, and to assess the outcomes following different stenting techniques employed for the management of these complex lesions. By addressing these objectives, the study seeks to provide insights into anatomical distribution and therapeutic responses that guide optimal interventional strategies.

MATERIALS AND METHODS

The study was a hospital-based, cross-sectional observational analysis conducted in the Department of Cardiology, Jawaharlal Nehru Medical College and Hospital, AMU, Aligarh, from July 2023 to July 2025. Patients aged above 18 years with clinical features of coronary artery disease undergoing coronary angiography were enrolled after informed consent, while those with contrast allergy, renal impairment, decompensated heart failure, infection, coagulopathy, or refusal for CAG were excluded. A total of 98 patients were evaluated using clinical examination, ECG, echocardiography, and coronary angiography, with bifurcation lesions classified by Medina criteria. Statistical analysis was performed using SPSS version 28.

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RESULTS

The age distribution of participants, grouped in 10-year intervals, revealed a mean age of 57.9 ± 9.45 years, indicating that most patients were between 48 and 67 years, representing a middle-aged to elderly population. Participants below 30 and above 80 years were nearly absent, suggesting that coronary or interventional cases mainly affect this age group. A marked gender imbalance was noted, with 86.7% males and 13.3% females, consistent with the higher prevalence of coronary artery disease and referrals for intervention among men.

Table 1: Risk factors among patients

Risk factors	Percentage
Smoking	48.08
Diabetes	27.88
Hypertension	21.15
CKD	1.92

The table shows that smoking (48.08%) was the most prevalent risk factor among patients, followed by diabetes (27.88%) and hypertension (21.15%), while chronic kidney disease (1.92%) was comparatively rare. This indicates that lifestyle-related factors, particularly smoking, dominate the risk profile, whereas comorbidities like CKD contribute minimally in this cohort.

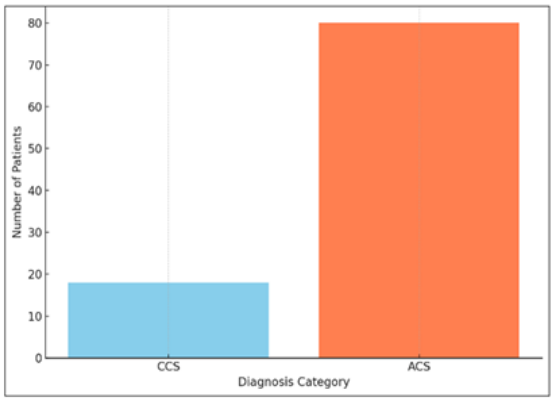

Figure 1: Bar Diagram Comparing ACS and CCS

The bar diagram demonstrates that acute coronary syndrome (ACS) cases (80 patients) were far more frequent compared to chronic coronary syndrome (CCS) cases (18 patients), highlighting a predominance of acute presentations in this cohort. This indicates that patients commonly sought medical attention during acute episodes rather than with stable or chronic manifestations.

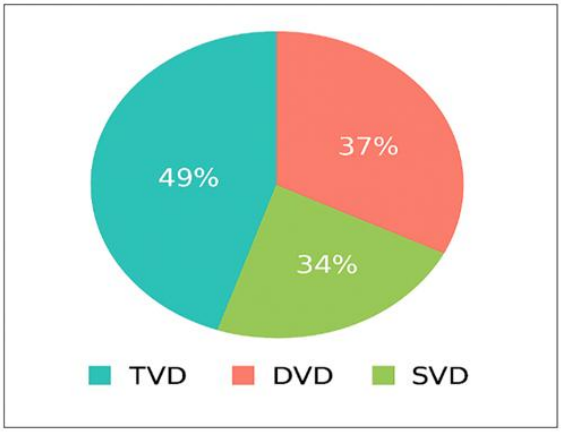

Figure 2: Pie Distribution of Coronary Lesion

The pie chart illustrates that triple vessel disease (TVD) was the most common coronary lesion, affecting 49% of patients, followed by double vessel disease (DVD) at 37% and single vessel disease (SVD) at 34%. This highlights a higher burden of multivessel involvement, indicating advanced disease patterns in the studied population.

Table 2: Lesions spectrum comparing provisional vs 2 stent

	Upfront 2 stent	Provisional
SVD	15(23%)	11(32%)
DVD	22(34%)	16(47%)
TVD	27(42%)	7(20%)

The table shows that provisional stenting was more commonly applied in single vessel (32%) and double vessel disease (47%), whereas upfront two-stent strategy was predominantly used in triple vessel disease (42%). This indicates that complex lesions with extensive vessel involvement were preferentially managed with upfront two-stent techniques, while provisional stenting was favored in less extensive disease.

Table 3: bifurcation lesion among participated patients

Lesions	Numbers	Percentage
LAD-D	68	69
LM-LAD/LCX	15	15
LCX-OM	10	10
RCA-PDA/PLV	5	5

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The table demonstrates that the majority of bifurcation lesions occurred at the LAD–Diagonal (69%), followed by LM–LAD/LCX (15%), LCX–OM (10%), and RCA–PDA/PLV (5%). This indicates a strong predilection for bifurcation disease in the LAD territory, reflecting its clinical importance and higher vulnerability compared to other coronary sites.

Table 4: distribution of lesion in both ps and 2 stent strategies

Lesions	Provisional	2 stent
LAD-D	27(79%)	41(64%)
LM-LAD/LCX	1(3%)	14(22%)
LCX-OM	3(9%)	7(11%)
RCA-PDA/PLV	3(9%)	2(3%)

The table shows that LAD–Diagonal lesions were treated predominantly by both strategies, though provisional stenting (79%) was slightly more common than the 2-stent approach (64%). In contrast, LM–LAD/LCX bifurcations were largely managed with the 2-stent technique (22% vs 3%), while LCX–OM and RCA–PDA/PLV lesions had relatively lower representation, with modest use of both strategies. This highlights lesion-specific preferences in stenting techniques.

Table 5: stent used for PCI

S. No	Stent Type	Count	Percentage (%)
1	ETERNIA(EES)	42	42.86%
2	XIENCE(EES)	20	20.41%
3	DESTINY(SES)	19	19.39%
4	PROFICIENT(SES)	11	11.22%
5	ONYX(ZES)	4	4.08%
6	ULTIMASTER	2	2.1

The table reveals that ETERNIA (EES) was the most frequently used stent in PCI, accounting for 42.86% of cases, followed by XIENCE (20.41%) and DESTINY (19.39%). Less commonly used stents included PROFICIENT (11.22%), ONYX (4.08%), and ULTIMASTER (2.1%), indicating a strong preference for everolimus-eluting stents, particularly ETERNIA, in the majority of interventions.

The bar chart shows that the incidence of TIMI 2 flow was slightly higher in the upfront 2-stent group (9.4%) compared to the provisional stenting group (8.8%). This suggests that both strategies achieved comparable outcomes, with only a marginal difference in suboptimal post-intervention blood flow between the two techniques.

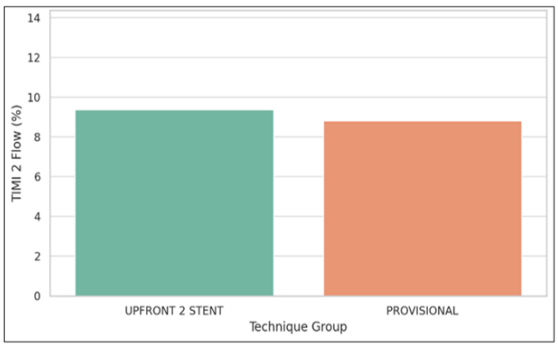

Figure 3: The Bar Chart Compares the Incidence of Timi 2 Flow (Incomplete or Suboptimal Blood Flow Post-Intervention) Between Two Stenting Strategies.

Table 6: Showing Statistics Analysis Between Different Techniques and Immediate Complications

Test	Table (rows = technique, cols = complication)	Result
Overall 2 × 4 Chi-square	LSD / PERF / SB / SF	$\chi^2 = 12.0$, df = 3, p = 0.007
Focused 2 × 2 Fisher (SB vs not)	SB present vs other complications	OR ≈ ∞ (no SB in "2 Stent"), p = 0.0015

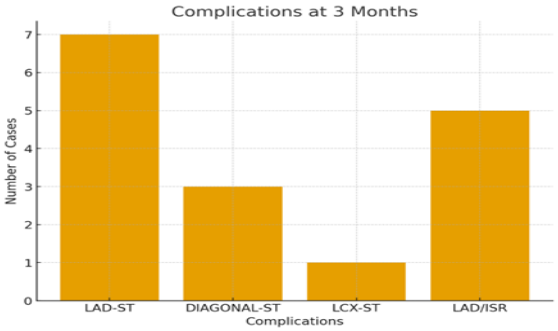

Figure 4: Distribution of Complications at 3 Months

The statistical analysis shows a significant association between stenting technique and immediate complications ($\chi^2 = 12.0$, df = 3, p = 0.007). Fisher's exact test further revealed that side branch (SB) complications were strongly linked with the provisional approach, while no SB complications occurred in the 2-stent group (OR ≈ ∞, p = 0.0015). This highlights that provisional stenting carried a higher risk of SB-related complications compared to the 2-stent strategy.

The chart shows that at 3 months, LAD stent thrombosis (LAD-ST) was the most common complication (7 cases), followed by in-stent restenosis in the LAD (LAD/ISR, 5 cases), diagonal branch stent thrombosis (3 cases), and LCX stent thrombosis (1 case). This indicates that the LAD remained the most frequent site for both thrombosis and restenosis, underscoring its higher vulnerability to adverse outcomes.

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Table 7: comparing provisional with upfront 2 stent techniques after 3 month follow up

	Provisional	2 stent
LAD-ST	2(5.4)	4(6.6%)
D-ST	3(8.1%)	1(1.6%)
LCX-ST	1	0
LAD-ISR	2(5.4%)	6(9.8%)

The table shows that after 3 months, LAD stent thrombosis was slightly more frequent in the 2-stent group (6.6%) compared to provisional (5.4%), while diagonal branch thrombosis was higher with provisional stenting (8.1% vs 1.6%). LCX stent thrombosis occurred only in the provisional group, whereas LAD in-stent restenosis was more common in the 2-stent group (9.8% vs 5.4%). This indicates differing complication patterns, with restenosis predominating in the 2-stent strategy and branch thrombosis more frequent in provisional stenting.

DISCUSSION

Across multiple landmark trials, the demographic profile of patients undergoing percutaneous coronary intervention (PCI) for bifurcation lesions consistently demonstrated a predominance of middle-aged to elderly individuals. Arunothayaraj et al. (2023) reported mean ages in the early 60s, which was comparable to the EBC TWO Trial, where the mean ages were 63.5 ± 12.1 years in the Culotte group and 62.9 ± 10.8 years in the Provisional group. Similarly, the DKCRUSH-III study showed mean ages of 64.3 ± 10.3 and 63.3 ± 9.2 years between DK crush and Culotte groups, with no significant difference (p=0.296). The DKCRUSH-V trial demonstrated mean ages of 65 ± 9 versus 64 ± 10 years (p=0.15), while pooled analyses of COBIS III, RAIN, and ULTRA registries including 6,548 patients showed a mean of 66 ± 11.3 years. In comparison, the mean age of the present cohort was 57.9 ± 9.45 years, with most patients between 48–67 years.[16]

Gender distribution strongly favored males across studies. In DKCRUSH-V, males constituted 77.7% in the Provisional and 82.9% in the DK crush arm (p=0.17). DKCRUSH-III reported 79.9% males in Culotte versus 77.1% in DK groups (p=0.552). The ULTRA-BIFURCAT registry confirmed 76.7% male predominance overall, regardless of bifurcation type. Similarly, 85 of 98 patients (86.7%) in the present study were men.Traditional risk factors showed variability. Diabetes prevalence ranged from 25–35% across DKCRUSH-V, DKCRUSH-III, and ULTRA-BIFURCAT registries, with 28% observed in this study. Hypertension was present in 65–73% of patients in registry data and trials, while only 21% were hypertensive in the current cohort. Smoking prevalence was 31–40% in DKCRUSH-V and Chen et al. (2017), whereas it was higher at 48% in this series. Hyperlipidemia was consistently reported in ~47–51% of registry patients, aligning with previous findings, while prior CABG remained uncommon. Renal dysfunction, a predictor of stent thrombosis (OR 11.5), was noted in 11–16% in ULTRA-BIFURCAT, but rare in this cohort.[17,18]

Clinical presentation varied, with most studies demonstrating a predominance of acute coronary syndromes (ACS). Girasis et al. (2009) reported ACS in 64.5% of cases, while DKCRUSH-I and DKCRUSH-V highlighted unstable angina in ~70% of patients. This study mirrored those results, with ACS observed in 82% compared to 18% with chronic coronary syndrome (CCS), the majority being NSTE-ACS (49%).[19]

Coronary vessel involvement highlighted frequent multivessel disease. DKCRUSH-V reported 88.2% multivessel CAD, while DKCRUSH-III showed ~70% in both Culotte and DK arms. EBC TWO demonstrated SVD in 65–76%, DVD in ~18–29%, and TVD in ~5–6%. DKCRUSH-II highlighted broader distribution, with SVD in 30–35%, DVD in 28–40%, and TVD in ~29–39%. In this study, proportions were 11%, 47%, and 20% for SVD, DVD, and TVD respectively.

Left ventricular function was preserved in most trial populations (mean LVEF ~60%), with no differences between groups (DKCRUSH-III, p=0.551). However, 30% of patients in this study had LVEF <40%. Bifurcation location varied, with LAD-diagonal most common. DKCRUSH-II reported LAD-D lesions in ~60% of cases, similar to 64–79% in this study. LM bifurcations comprised 27.5% in ULTRA-BIFURCAT but only 3–22% in this series. LCX-OM and RCA bifurcations occurred less frequently in both datasets.

Procedural success exceeded 97% in EBC TWO (Park et al., 2022), with TIMI 3 flow achieved consistently. However, side branch loss was reported in Definition II (8.6–11%) and PROTECT-SB (18% vs 4%). This study also demonstrated 10% SB loss with provisional stenting (p=0.007).[20]

Short-term outcomes showed stent thrombosis rates lower with DK crush in DKCRUSH-V (0.4% vs 3.3%). Meta-analyses confirmed lower early ST risk with single-stent strategies (Erglis et al., 2015; Park et al., 2022). Nonetheless, EBC TWO at 5 years showed no significant differences in ST or MACE between groups. In this series, 3-month outcomes demonstrated comparable stent thrombosis between groups, with main vessel ISR numerically higher in two-stent strategies (9.8% vs 5.4%), but not statistically significant (p>0.05).[20-22]

CONCLUSION

Bifurcation lesions, especially in the LAD territory, represent a significant burden in CAD interventions. Both stenting strategies yielded comparable

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outcomes, underscoring the need for individualized technique selection based on lesion anatomy.

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