



Comparison of Bifurcation and Trifurcation Anatomy in Distal Left Main Coronary Artery Stenting

Distal Sol Ana Koroner Arter Stentlemede Bifürkasyon ve Trifürkasyon Anatomisinin Karşılaştırılması

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ABSTRACT

Aim: Although there is a lot of data comparing bifurcation and non-bifurcation lesions in left main coronary artery (LMCA) percutaneous coronary intervention (PCI), the specific influence of trifurcation anatomy on procedural outcomes and long-term prognosis is poorly understood. Given the technical complexities and probable disparities in clinical outcomes, a thorough research of these anatomical subgroups is required. This study aimed to compare procedural and clinical outcomes between bifurcation and trifurcation LMCA lesions.

Material and Methods: This retrospective study analyzed patients who underwent distal LMCA stenting between January 2019 and June 2024. Patients with stable coronary artery disease (CAD) without prior coronary artery bypass grafting (CABG) and who underwent intravascular ultrasound (IVUS)-guided stenting and who have high surgical risk, as assessed by a heart team, or patient preference for PCI were included. Those with acute coronary syndrome at presentation, prior CABG, or PCI performed without IVUS guidance were excluded. A total of 43 eligible patients were identified from institutional records. Data were collected retrospectively, including procedural details, clinical outcomes, and follow-up findings.

Results: There were no significant differences in baseline characteristics, including biochemical parameters and comorbidities, between the two groups ($p>0.05$). Trifurcation lesions required significantly longer stents ($p=0.008$). Ischemic events were more common in the trifurcation group (33.3% vs. 4.5%, $p=0.015$), and major adverse cardiac event (MACE) rates were significantly higher in the trifurcation group compared to the bifurcation group (57.1% vs. 9.1%, $p=0.001$). Bleeding events and mortality rates did not significantly differ between the groups ($p>0.05$).

Conclusion: Patients with LMCA trifurcation lesions undergoing PCI exhibit higher ischemic event rates and MACE compared to those with bifurcation lesions, despite IVUS guidance. Further prospective studies are warranted to optimize treatment strategies for this high-risk population.

Key words: angiography; bifurcation; IVUS; LMCA stenting; trifurcation

ÖZET

Amaç: Sol ana koroner arter (LMCA) perkütan koroner girişiminde (PKG) bifürkasyon ve bifürkasyon dışı lezyonları karşılaştıran çok sayıda veri olmasına rağmen, trifürkasyon anatomisinin prosedürel sonuçlar ve uzun vadeli prognoz üzerindeki spesifik etkisi tam olarak anlaşılamamıştır. Teknik karmaşıklıklar ve klinik sonuçlardaki olası farklılıklar göz önüne alındığında, bu anatomik alt grupların kapsamlı bir şekilde araştırılması gerekmektedir. Bu çalışma, bifürkasyon ve trifürkasyon LMCA lezyonları arasındaki prosedürel ve klinik sonuçları karşılaştırmayı amaçlamıştır.

Materyal ve Metot: Bu retrospektif çalışmada, Ocak 2019 ile Haziran 2024 tarihleri arasında distal LMCA stentleme yapılan hastalar analiz edildi. Daha önce koroner arter baypas greftleme (KABG) yapılmamış stabil koroner arter hastalığı (KAH) olan ve intravasküler ultrason (IVUS) kılavuzluğunda stent uygulanan ve bir kalp ekibi tarafından değerlendirildiği üzere yüksek cerrahi riski olan veya PKG hasta tercihi olan hastalar dâhil edildi. Başvuru sırasında akut koroner sendromu olanlar, daha önce KABG geçirmiş olanlar veya IVUS kılavuzluğu olmadan PKG uygulanmış olanlar çalışma dışı bırakılmıştır. Kurumsal kayıtlardan toplam 43 uygun hasta tespit edildi. Prosedürel ayrıntılar, klinik sonuçlar ve takip bulguları dâhil olmak üzere veriler retrospektif olarak toplandı.

Bulgular: İki grup arasında biyokimyasal parametreler ve komorbiditeler dâhil olmak üzere başlangıç özellikleri açısından anlamlı fark yoktu ($p>0,05$). Trifürkasyon lezyonları anlamlı olarak daha uzun stent gerektirdi ($p=0,008$). İskemik olaylar trifürkasyon grubunda daha yaygındı (%33,3'e karşı %4,5, $p=0,015$) ve major advers kardiyak olay (MACE) oranları trifürkasyon grubunda bifürkasyon grubuna kıyasla anlamlı derecede yüksekti (%57,1'e karşı %9,1, $p=0,001$). Kanama olayları ve mortalite oranları gruplar arasında anlamlı farklılık göstermedi ($p>0,05$).

Sonuç: PKG uygulanan LMCA trifürkasyon lezyonlu hastalar, IVUS kılavuzluğuna rağmen, bifürkasyon lezyonlu hastalara kıyasla daha yüksek iskemik olay oranları ve MACE sergilemektedir. Bu yüksek riskli popülasyona yönelik tedavi stratejilerini optimize etmek için daha ileri prospektif çalışmalara ihtiyaç vardır.

Anahtar kelimeler: koroner anjiyografi, bifürkasyon, trifürkasyon, IVUS, LMCA stentleme

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Introduction

Although the differences between bifurcation and non-bifurcation lesions in distal left main coronary artery (LMCA) stenting are well documented, the impact of trifurcation anatomy on clinical outcomes remains insufficiently studied. This study compared percutaneous coronary intervention (PCI) outcomes in bifurcation and trifurcation LMCA lesions, revealing significantly higher rates of ischemic events and major adverse cardiac events (MACE) in the trifurcation group. Our findings suggest that trifurcation lesions are associated with increased procedural complexity and worse clinical outcomes. Therefore, better patient selection, alternative revascularization strategies, and further research are needed to improve outcomes in this high-risk population.

Percutaneous coronary intervention (PCI) of the left main coronary artery (LMCA) is accepted as one of the most technically challenging and high-risk procedures in interventional cardiology. The LMCA provides an important source of the myocardium by its bifurcation into the left anterior descending (LAD) and left circumflex (LCx) arteries. In some cases, a trifurcation anatomy is present, adding an additional ramus intermedius branch to the distal LMCA, further complicating PCI. These anatomical variances create significant challenges for stent selection, position, and post-procedural results.

Distal LMCA stenting, particularly in the presence of bifurcation or trifurcation, necessitates careful planning and execution. Studies have demonstrated that bifurcation lesions are associated with increased procedural complexity, higher rates of restenosis, and greater risk of major adverse cardiac events (MACE) compared to non-bifurcation lesions^{1,2}. Trifurcation anatomy introduces additional complexities, including the need for multiple stents, risk of carina shift, and challenges in achieving optimal flow to all branches³. Despite these challenges, PCI of the LMCA remains a critical alternative to coronary artery bypass grafting (CABG) in appropriately selected patients, particularly those who are poor surgical candidates⁴.

Although there is a lot of data comparing bifurcation and non-bifurcation lesions in LMCA PCI, the specific influence of trifurcation anatomy on procedural outcomes and long-term prognosis is poorly understood. Given the technical complexities and probable disparities in clinical outcomes, a thorough research of these anatomical subgroups is required.

This study aims to compare the procedural and clinical outcomes of distal LMCA stenting in patients with bifurcation and trifurcation anatomy, hypothesizing that trifurcation anatomy is associated with increased procedural complexity and potentially worse outcomes compared to bifurcation.

Material and Methods

This retrospective study included patients who underwent distal LMCA stenting between January 2019 and June 2024. Eligible patients were selected based on the following inclusion criteria:

1. Stable coronary artery disease without prior history of coronary artery bypass grafting (CABG).
2. High surgical risk, as assessed by a heart team, or patient preference for percutaneous coronary intervention (PCI).
3. Optimal stent placement guided by intravascular ultrasound (IVUS).

Those with acute coronary syndrome at presentation, prior CABG, or PCI performed without IVUS guidance were excluded. A total of 43 patients meeting the inclusion and exclusion criteria were identified from institutional records. All data were collected retrospectively, including procedural details, clinical outcomes, and follow-up results. As this was a retrospective study, patients who did not want CABG were also included in the study, so surgical risks were not calculated. Xience stents were used in all procedures. The mean follow-up period of the patients was 22 months (min 13 to 61 months).

Ethical approval for the study was obtained from the Bakırçay University Non-Invasive Ethics Committee (no: 1927 date: 18/12/2024).

Procedural Technique

All interventions were performed using standard PCI protocols under fluoroscopic guidance, with adjunctive use of IVUS to optimize stent positioning and expansion. Distal LMCA stenting was performed with either single- or double-stent techniques, depending on lesion complexity and operator discretion. Bifurcation and trifurcation lesions were managed with strategies appropriate for each anatomical subtype, ensuring complete revascularization of all major branches. of 50% in the distal LMCA and its branches were considered severe in accordance with the Medina classification. The distal area of the main coronary

artery below 6 mm² was considered serious in IVUS evaluation. Antiaggregant treatment was continued for 1 year. Trifurcation lesion was accepted as the presence of ramus intermedius wider than 1.5 mm in the distal main coronary artery.

Drug-eluting stents (DES) were used in all patients who underwent single- or double-stent techniques (everolimus-eluting stents [Xience Pro, Abbott Vascular Devices])

Study Endpoints

The primary endpoints included:

1. Bleeding events classified according to the Bleeding Academic Research Consortium (BARC) criteria.
2. Ischemic outcomes, including stent thrombosis and target lesion revascularization.
3. Mortality (all-cause and cardiac-specific).
4. Composite endpoint, defined as a combination of mortality, myocardial infarction, bleeding and target lesion revascularization.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) based on data distribution and compared using the Student's t-test or Mann-Whitney U-test, as appropriate. Categorical variables were presented as frequencies and percentages and compared using the chi-square test or Fisher's exact test. Kaplan-Meier survival analysis was used to evaluate long-term outcomes, with differences between groups assessed using the log-rank test. Statistical significance was defined as a p-value <0.05.

Results

A total of 43 patients were retrospectively analyzed, with bifurcation anatomy present in 22 patients (51.2%) and trifurcation anatomy in 21 patients (48.8%).

No significant differences were found in biochemical parameters, including glucose, creatinine, or inflammatory markers such as CRP, between the bifurcation and trifurcation groups ($p > 0.05$). Comorbidities and laboratory characteristics of the patients are given in Table 1.

There was no statistically significant difference in left ventricular ejection fraction between the groups. When we compared the two groups in terms of procedural details, we observed that the number of provisional

Table 1. Comparison of laboratory parameters

Parameter	Bifurcation (n=22)	Trifurcation (n=21)	P value
Age	69.1 $\pm$ 10.4	68.3 $\pm$ 9.6	0.696
Female (n, %)	9(41.0%)	9(43.6%)	0.511
HT (n, %)	14 (63.6%)	17 (81.0%)	0.186
DM (n, %)	12 (54.5%)	15 (71.4%)	0.113
CKD (n, %)	5 (22.7%)	7 (33.3%)	0.412
COPD (n, %)	4(18.2%)	3(14.3%)	0.323
Glucose (mg/dL)	134.0 $\pm$ 47.2	125.7 $\pm$ 44.9	0.594
Creatinine (mg/dL)	0.93 $\pm$ 0.39	1.11 $\pm$ 0.37	0.145
Hemoglobin (g/dL)	13.3 $\pm$ 2.3	12.5 $\pm$ 2.8	0.381
WBC ($\times 10^3/\mu\text{L}$)	8.6 $\pm$ 4.7	8.8 $\pm$ 5.4	0.882
Neutrophil ($\times 10^3/\mu\text{L}$)	5.8 $\pm$ 4.6	6.0 $\pm$ 5.3	0.870
Platelets ($\times 10^3/\mu\text{L}$)	251.9 $\pm$ 117.3	241.7 $\pm$ 80.9	0.761
Albumin (g/dL)	42.0 $\pm$ 7.9	40.7 $\pm$ 1.5	0.789
LDL (mg/dL)	163.4 $\pm$ 32.5	170.0 $\pm$ 38.9	0.210
HDL (mg/dL)	41.6 $\pm$ 5.4	44.2 $\pm$ 6.1	0.198
Triglycerides (mg/dL)	125.0 $\pm$ 30.2	128.0 $\pm$ 32.4	0.311
LDL (mg/dL)	163.4 $\pm$ 32.5	170.0 $\pm$ 38.9	0.210
LVEF (%)	49.1 $\pm$ 11.5	45.2 $\pm$ 11.8	0.162

Table 2. Comparison of procedural details

Parameter	Bifurcation (n=22)	Trifurcation (n=21)	P value
Stent type	Xience	Xience	-
Syntax score	28.72 $\pm$ 5.31	29.23 $\pm$ 7.11	0.789
Stenting technique			
Provisional	17 (77.3)	19 (90.5)	0.412
Double-stent	5 (22.7)	2 (9.5)	
Stent size (mm)	3.73 $\pm$ 0.30	3.67 $\pm$ 0.37	0.284
Stent length (mm)	34.5 $\pm$ 18.8	43.2 $\pm$ 21.4	**0.008**
LVEF (%)	49.1 $\pm$ 11.5	45.2 $\pm$ 11.8	0.162
Kissing balloon (n, %)	16 (72.7%)	14 (66.7%)	0.665

Bifurcation group; DK Crush: 2, Culotte: 1, TAP: 2, Trifurcation group; DK Crush: 2.

stenting techniques was higher in both groups. The mean size of the stents used procedurally and the rate of kissing balloon use were similar. The length of the stents used in the trifurcation group was statistically significantly higher. A comparison of procedural details between the two groups is given in Table 2.

Ischemic outcomes were observed in 8 patients (18.6%), with a statistically significant higher prevalence in the trifurcation group compared to the bifurcation group ($p = 0.015$). Bleeding events occurred in only 1 patient (2.3%), with no significant differences between bifurcation and trifurcation groups ($p =$

0.300). Mortality was recorded in 5 patients (11.6%), with no statistically significant difference between the two anatomical groups ($p = 0.138$). Composite major adverse cardiac events (MACE) were significantly higher in the trifurcation group (57.1%) compared to the bifurcation group (9.1%, $p = 0.001$) (Table 3).

Table 3. Comparison of clinical outcomes

Outcome	Bifurcation (n=22)	Trifurcation (n=21)	P value
Bleeding (n, %)	0 (0%)	1 (4.8%)	0.300
Ischemic events (n, %)	1 (4.5%)	7 (33.3%)	**0.015**
Mortality (n, %)	1 (4.5%)	4 (19.0%)	0.138
Composite MACE (n, %)	2 (9.1%)	12 (57.1%)	**0.001**

Discussion

The management of distal left main coronary artery (LMCA) lesions, particularly in the context of bifurcation and trifurcation anatomies, remains a complex and debated area in interventional cardiology. Our study retrospectively analyzed 43 patients who underwent percutaneous coronary intervention (PCI) with intravascular ultrasound (IVUS) guidance, comparing outcomes between bifurcation and trifurcation anatomies. The findings revealed a significantly higher incidence of ischemic events and composite major adverse cardiac events (MACE) in the trifurcation group compared to the bifurcation group.

These results align with existing literature that underscores the increased procedural complexity and risk associated with trifurcation lesions. Although the syntax score determines the procedural complexity of the patients, many other criteria can be used. The presence of trifurcation lesions can be considered as an additional criterion^{5,6}. A study by Kovacevic et al.⁷ highlighted that trifurcation lesions often require more intricate stenting techniques and are associated with higher rates of adverse events compared to bifurcation lesions. The necessity for multiple stents and the challenge of achieving optimal flow to all branches in trifurcation anatomy may contribute to these outcomes. The study by Kovacevic et al.⁸ showed that LMCA trifurcation stenting was feasible, but no comparison was made with bifurcation lesions.

The use of IVUS guidance in our study aimed to optimize stent placement and expansion, which has been shown to improve procedural outcomes. However, despite IVUS guidance, the trifurcation group exhibited higher rates of ischemic events and MACE. This suggests that anatomical complexity may outweigh the benefits conferred by advanced imaging techniques^{9,10}.

The EXCEL trial reported no significant differences in clinical outcomes between distal LM bifurcation and trifurcation PCI at five-year follow-up¹¹. The disparity may be attributed to differences in study populations, procedural strategies, and lesion complexity. Notably, while our study identified a higher need for longer stents in trifurcation cases and a greater incidence of ischemic complications. These differences highlight the need for further prospective studies to refine PCI strategies in complex LMCA lesions and better identify patients who may benefit from alternative revascularization approaches.

In terms of bleeding events, our study observed no significant difference between the bifurcation and trifurcation groups. This finding is consistent with previous research indicating that bleeding complications are more closely related to patient-specific factors and antithrombotic therapy rather than the anatomical complexity of the lesion¹².

Mortality rates did not differ significantly between the two groups in our study. This may be attributed to the relatively small sample size and the short follow-up period. Long-term studies with larger cohorts are necessary to elucidate the impact of lesion complexity on mortality outcomes^{13,14}.

While dyslipidemia is a known risk factor for coronary artery disease, its direct relationship with lesion anatomy remains unclear. Future studies should explore the interplay between lipid profiles and coronary anatomy to better understand this association¹⁵.

According to the results of this study, CABG should be considered as the first choice in patients with complex LMCA lesions if the risk of surgery is not high, or optimal double stent strategies may be chosen rather than provisional methods. In addition, lifestyle modification should be followed more closely in these patients and more aggressive medical treatment options may be chosen.

This study demonstrates the need for randomized trials specifically in bifurcation and trifurcation LMCA stenting patients. Potent antiaggregant therapies may be selected in patients with trifurcation. It also raises the question, 'Should hemodynamic measurements be performed together with IVUS in the trifurcation patient group?'

Limitation

Our study has several limitations, including its retrospective design, small sample size, and lack of long-term follow-up. Additionally, the decision to use single or dual stent strategies was left to the operator's discretion, which

may introduce selection bias. Syntax scores were calculated from the coronary angiographies of the patients and found to be similar. Patients who underwent IVUS before PCI and stent control after PCI were included in the study. However, IVUS images have not been analyzed in detail. Plaque and calcification burden of the patients may have differed. Despite these limitations, our findings contribute to the growing body of evidence highlighting the challenges associated with PCI in trifurcation lesions.

Conclusion

In conclusion, patients with distal LMCA trifurcation lesions undergoing PCI exhibit higher rates of ischemic events and MACE compared to those with bifurcation lesions, even with the use of IVUS guidance. These findings underscore the need for meticulous procedural planning and consideration of alternative revascularization strategies in this high-risk population. Further prospective studies are warranted to develop tailored approaches that can improve outcomes in patients with complex coronary anatomies.

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