Am J Cardiovasc Dis 2024;14(3):180-187
www.AJCD.us /ISSN:2160-200X/AJCD0155448

Original Article

Percutaneous coronary intervention involving coronary bifurcation is associated with higher mortality and complications

Allistair Nathan[1], Mehrtash Hashemzadeh[1], Mohammad Reza Movahed[1,2]

[1]*University of Arizona, Phoenix, AZ, USA;* [2]*University of Arizona Sarver Heart Center, Tucson, AZ, USA*

Received January 14, 2024; Accepted May 16, 2024; Epub June 15, 2024; Published June 30, 2024

Abstract: Background: Percutaneous coronary intervention (PCI) in patients with bifurcation lesions is associated with higher complexity and adverse outcomes. The goal of this study was to evaluate the inpatient outcomes of patients with PCI of bifurcation lesions. Methods: The National Inpatient Sample (NIS) database, years 2016-2020, was studied using ICD 10 codes. Patients undergoing PCI for bifurcation lesions were compared to those undergoing PCI for non-bifurcation lesions, excluding chronic total occlusion lesions. We evaluated post-procedural inpatient mortality and complications. Results: PCI in patients with bifurcation lesions was associated with higher mortality and post-procedural complications. A weighted total of 9,795,154 patients underwent PCI; of those, 43,480 had a bifurcation lesion. The bifurcation cohort had a 3.79% mortality rate, and the rate in those with non-bifurcation lesions was 2.56% (OR, 1.50; CI: 1.34-1.68; P<0.001). Upon conducting multivariate analysis, which adjusted for age, sex, race, and significant comorbidities, PCI for bifurcation lesions remained significantly associated with a higher mortality rate compared to non-bifurcation lesion PCI (OR, 1.68; 95% CI, 1.49-1.88; P<0.001). Furthermore, PCI for bifurcation lesions was associated with higher rates of myocardial infarction (OR, 2.26; 95% CI, 1.68-3.06; P<0.001), coronary perforation (OR, 7.97; 95% CI, 6.25-10.17; P<0.001), tamponade (OR, 3.46; 95% CI, 2.49-4.82; P<0.001), and procedural bleeding (OR, 5.71; 95% CI, 4.85-6.71; P<0.001). Overall, post-procedural complications were 4 times more in patients with bifurcation lesions than in those without (OR, 4.33; 95% CI, 3.83-4.88; P<0.001). Conclusion: Using a large, national inpatient database, we demonstrate that both mortality rates and post-procedural complication rates were significantly higher in patients undergoing PCI for bifurcation lesions than in those undergoing PCI for non-bifurcation lesions.

Keywords: Bifurcation, percutaneous coronary intervention, stenting, angioplasty, outcome, perforation, coronary bifurcation classification, complex coronary intervention

Introduction

A bifurcation lesion occurs when an atherosclerotic plaque develops in a coronary artery at the point at which a side branch deviates from the main vessel branch [1]. About 15%-20% of all percutaneous coronary interventions (PCI) involve a bifurcation lesion. Coronary artery bifurcation sites are commonly affected by atherosclerotic processes due to endothelial shear stress. Indications for coronary intervention of bifurcation lesions are similar to non-coronary bifurcation lesions. Due to the complex nature of bifurcation lesions, procedural success and outcomes are worse in comparison to other lesions, excluding chronic total occlusions (CTO) [1]. PCI of bifurcation lesions is not only technically challenging but also associated with lower procedural success rates and higher complication rates [2]. Acute procedural risks include coronary artery dissection, no-reflow, perforation, acute side branch closure, jailed wire fracture, and side branch stent embolism. Long-term risks specific to the revascularization of bifurcation lesions include higher rates of early and late stent thrombosis, which is contributed to by the increased incidence of stent under-expansion and mal-apposition, as well as a higher metallic burden in the coronary tree [3-7].

https://doi.org/10.62347/XDDB4510

Currently, only two major bifurcation lesion classification systems are commonly used in clinical practice: The Movahed and the Medina systems [8-11]. The Medina classification system is used most commonly [9], despite it separating true bifurcation lesions into 3 unnecessary subgroups. Furthermore, the Medina system does not include important lesion characteristics such as angulation, the size of the healthy proximal segment, disease burden, length and location of the lesion. The Movahed bifurcation classification eliminates the redundancy of separating true bifurcation lesions into 3 unnecessary subgroups, while introducing additional suffixes that can be added if needed to describe any important anatomical details of a given bifurcation lesion. Furthermore, it is very easy to memorize [8, 10]. This classification is based on a system that is composed of a single prefix to which up to unlimited different suffixes can be added if desired. The description of this classification starts with the prefix B (for Bifurcation lesion) to which other suffixes can be added for a final description of a given bifurcation lesion. The true bifurcation lesions have only one description called B2 (B for bifurcation 2 meaning both bifurcation ostia have disease). If only the main branch has disease, it will be called B1m (B for bifurcation, 1m meaning only one main branch has disease) or 1s (meaning only 1 the side branch has disease). These summarize all bifurcation lesions into simple three categories called B2, B1m, and B1s lesions.

The importance of true bifurcation (B2) lesions in comparison to other non-true bifurcation lesions has been documented numerous times. In a large, randomized trial of bifurcation stenting, true bifurcation lesions (B2 lesions) were associated with a higher occurrence of myocardial infarction in comparison to lesions that have no side branch (B1m) [12]. Bifurcation angle is another important clinical feature that impacts clinical outcomes during the treatment of bifurcation lesions. By adding optional suffixes specifying bifurcation angle (V or T), the Movahed system has limitless options in describing a given bifurcation lesion. The suffix V describes shallow angles less than 70 degrees (like a V), and the suffix T describes a steep angle of more than 70 degrees (like a T). Steep angulation complicates side branch access after main branch stenting, thereby increasing the likelihood of poor outcomes [13, 14]. Furthermore, the Movahed bifurcation classification system has additional optional suffixes that can be added to describe the lesion with more specificity and accuracy, such as LM for left main, CA for calcification, and TR for thrombus-containing [15]. The major advantages of the Movahed classification in comparison to the Medina classification have been recognized and published [16-24]. Despite the risks and procedural complexity, PCI involving bifurcation lesions is not uncommon [25, 26]. Considering the well-documented complexity of bifurcation PCI, the goal of our study was to evaluate complications and mortality rates associated with bifurcation PCI using the largest available inpatient database representative of the whole US population.

Methods

Data source

This study's methodology was largely derived from that of the previous study conducted by Nathan et al., which considered percutaneous coronary intervention in patients with chronic total occlusion [27]. This study's patient cohort was generated using the National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), and Agency for Healthcare Research and Quality. The NIS database uses 20-25% of annual hospitalizations in the United States population [28]. NIS HCUP data is publicly available and is deidentified, thus the study was exempt from institutional review board approval.

Study population

The NIS database years 2016 to 2020 were considered when generating the study population. The NIS database was queried, and the study population was generated, using both International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) as well as International Classification of Diseases, Tenth Revision, Procedure Coding System (ICD-10-PCS) codes. As in the previous study conducted by Nathan et al., patients having undergone percutaneous coronary intervention were identified using the ICD-10-PCS codes 027-03(4-7)Z, 02703(D-G)Z, 02703TZ, 02713(4-7)Z, 02713(D-G)Z, 02713TZ, 02723(4-7)Z, 027-23(D-G)Z, 02723TZ, 02733(4-7)Z, 02733(D-G)Z,

02733TZ, 02H(0-3)3DZ, 02H(0-3)3YZ, 027(0-3)3ZZ, 02C(0-3)3Z7, 02C(0-3)3ZZ, 02F(0-3)3ZZ. This study cohort was further stratified using the ICD-10-PCS codes 02703(4-7)6, 02703(D-G,T,Z)6, 02713(4-7)6, 02713(D-G,T,Z)6, 02723(4-7)6, 02723(D-G,T,Z)6, 027-33(4-7)6, 02733(D-G,T,Z)6, and 02C(0-3)3Z6 to identify patients with a bifurcation lesion. Included were all patients older than 30 years old who had the above ICD-10 diagnosis consistent with PCI of coronary bifurcation lesions excluding PCI for chronic total occlusions (CTO). All patients under the age of 30 who had undergone CTO PCI were excluded. There were no other exclusions. Upon completion of the univariate analysis of high-risk baseline characteristics, any characteristics that were significantly different between the two populations were added to the multivariate analysis in addition to known cardiovascular risk factors.

Study outcomes

Examined patient outcomes included mortality, myocardial infarction (I97.89), contrast-induced nephropathy (N99.0), coronary perforation (I97.51), procedural bleeding (I97.410, I97.411, I97.610, I97.611, I97.630, I97.631), tamponade (I31.4), acute postprocedural respiratory failure (J95.821), postprocedural cerebrovascular infarction (I97.821), and major adverse cardiac events. Major adverse cardiac events included any previously mentioned cardiac complication, as well as mortality. Multivariate analysis of mortality was performed in a stepwise logistic regression model adjusting for age, gender, race, and comorbid conditions that were significantly different between the two groups.

Statistical analysis

Patient demographic, clinical, and hospital characteristics were summarized using means and standard deviations for continuous variables, and proportions with 95% confidence intervals for categorical variables. Logistic regression was employed to assess the odds of binary clinical outcomes relative to patient and hospital characteristics, as well as the odds of clinical outcomes over time. All statistical models were adjusted for confounding. Analyses were conducted following the implementation of population discharge weights. All *p*-values were calculated as 2-sided, with a significance level set at P<0.05. Data analysis was performed using STATA 17 (Stata Corporation, College Station, TX).

Results

A weighted total of 9,795,154 adult patients were identified in the NIS HCUP database who underwent percutaneous coronary intervention without chronic total occlusion from 2016 to 2020. Of these patients, 43,480 had a bifurcation lesion. The average patient age was 70.12 years (CI: 70.06-70.18), and more men (63.4%) underwent percutaneous coronary intervention for their bifurcation lesion than women (36.6%). Caucasian patients composed the majority of the study cohort (77.1%). These and other study cohort characteristics may be found in **Table 1**.

Univariate analysis demonstrated that in patients treated with percutaneous coronary intervention, those with a bifurcation lesion experienced a significantly higher rate of mortality than those without. The bifurcation group had a 3.79% mortality rate vs 2.56%, excluding CTOs (odds ratio [OR], 1.50; 95% confidence interval [CI], 1.34-1.68). Procedural complications were also significantly higher in those with a bifurcation lesion. Patients with a bifurcation lesion had significantly higher rates of myocardial infarction (OR, 2.26; 95% CI, 1.68-3.06; P< 0.001), perforation (OR, 7.97; 95% CI, 6.25-10.17; P<0.001), procedural bleeding (OR, 5.71; 95% CI, 4.85-6.71; P<0.001), and cardiac tamponade (OR, 3.46; 95% CI, 2.49-4.82; P<0.001) (**Figure 1**). Overall, these patients had higher rates of all post-procedural complications (OR, 4.33; 95% CI, 3.83-4.88; P<0.001) as well as major adverse cardiac events (OR, 2.16; 95% CI, 1.98-2.35; P<0.001).

Additionally, multivariate analysis was performed adjusting for diabetes mellitus, chronic kidney disease, age, gender, and race. Upon making these adjustments, the presence of a bifurcation lesion remained associated with a significantly higher risk of mortality when treated with percutaneous coronary intervention than in those without (OR, 1.68; 95% CI, 1.49-1.88; P<0.001).

Discussion

Bifurcation lesions have been reported to be involved in up to 21% of percutaneous coronary

Table 1. Characteristic of the population

	Total	Bifurcation	Non-Bifurcation	*p*-value
Total Population	9,795,154	43,480	9,751,674	
Age (Mean ± SD)	70.12±12.12	66.65±12.23	70.13±12.12	<0.001
Gender				<0.001
Male	63.43%	68.86%	63.40%	
Female	36.57%	31.14%	36.60%	
Race				<0.001
White	77.07%	76.14%	77.08%	
Black	10.62%	7.62%	10.64%	
Hispanic	7.07%	8.42%	7.06%	
Asian/Pac Isl	2.11%	3.20%	2.10%	
Native American	0.51%	0.94%	0.51%	
Others	2.62%	3.68%	2.61%	
Systolic Heart Failure	19.66%	24.06%	19.65%	<0.001
PCI Three Vessel	0.64%	10.17%	0.60%	<0.001
Diabetes	46.41%	41.41%	46.44%	<0.001
Chronic Kidney Disease	31.40%	23.78%	31.43%	<0.001
Hypertension	87.82%	83.13%	87.74%	<0.001
COPD	26.60%	15.34%	26.65%	<0.001
STEMI	9.09%	28.45%	9.01%	<0.001
Non-STEMI	13.66%	45.30%	13.52%	<0.001
Prior Percutaneous Coronary Intervention	81.79%	23.03%	82.07%	<0.001
History of Coronary Artery Bypass Graft	15.83%	7.57%	15.86%	<0.001
History of Anemia	0.04%	0.05%	0.04%	0.58
History of Cardiomyopathy	0.86%	0.52%	0.86%	<0.001
Previous Smokers	32.89%	26.24%	32.92%	<0.001
Current Smokers	14.43%	16.90%	14.42%	<0.001
Atrial Fibrillation/Flutter	27.29%	18.14%	27.34%	<0.001
Valvular Heart Disease	8.29%	10.36%	8.28%	<0.001
Endocarditis	0.09%	0.05%	0.09%	0.15
History of Stroke	2.47%	1.62%	2.47%	<0.001
Angina	0.06%	0.07%	0.06%	0.75

intervention (PCI) procedures [29]. Our study identified 43,480 bifurcation lesion interventions between 2016 and 2020. The disparity in the prevalence of bifurcation lesions reported in the literature and that found in the NIS database is likely due to the database not capturing all classifications of bifurcation lesions. The 2021 American College of Cardiology/American Heart Association Guideline for Coronary Artery Revascularization recommends coronary artery bypass grafting over percutaneous coronary interventions in the context of complex lesions [30]. Additionally, Serruys et al. found that in 1,800 patients with three-vessel or left main coronary artery disease, PCI was associated with higher major adverse cardiac events and cerebrovascular events when compared with coronary artery bypass grafting [31].

If the choice to treat a bifurcation lesion with PCI is made, there is a significantly higher risk for adverse events compared to treating a non-bifurcation lesion [32]. This is in large part due to the increased complexity of bifurcation procedures [33]. For example, Lam et al. found that peri-procedural myocardial infarction rates were higher in patients with bifurcation lesions than in those without, in their study investigating Resolute and Xience V stents [34, 35]. Additionally, a report from the SPIRIT V single-arm study found that 30-day rates of death, myocardial infarction, and target vessel revascularize-

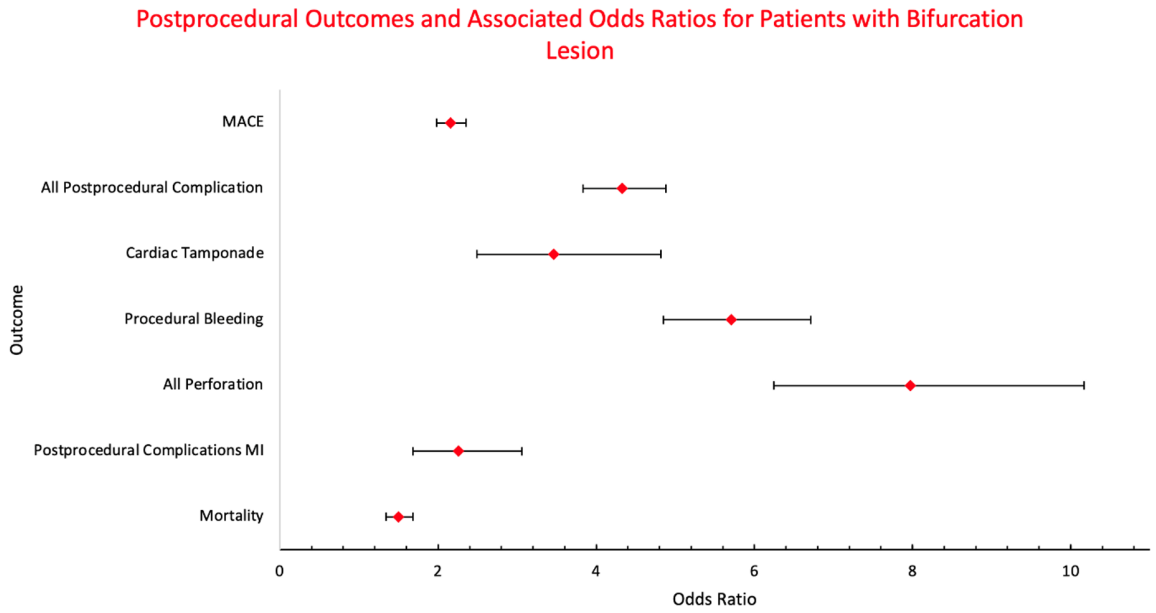

Figure 1. Bifurcation lesion percutaneous coronary intervention is associated with significantly increased risk of morbidity and mortality when compared to non-bifurcation lesions.

tion were higher in patients with bifurcation lesions PCI [33]. This increase in risk was found to persist well beyond 30 days, as Grundeken et al. found increased risk of death, myocardial infarction, and target vessel revascularization at the 5-year time point [36-38].

When the results of these previous studies are compared alongside those of our study, it is clear that PCI of bifurcation lesions carries a much higher risk than non-bifurcation lesions. Our study, which is the largest retrospective analysis of PCI outcomes in patients with and without bifurcation lesions, found significantly higher rates of morbidity and complications in those with bifurcation lesions. Even after multivariate analysis, our study found that mortality was still 68% more likely in patients with bifurcation lesions. This study and those previously mentioned demonstrate that the increased risk of PCI in patients with bifurcation lesions should not be underestimated.

In the specific context of bifurcation lesions, the particular arteries involved must be considered. This is well demonstrated by Kim et al., who found that only 20% of non-left main small branches supplied greater than 10% of fractional myocardial mass [39]. Suleiman et al. specifically discussed that if only the side branch has a lesion, initial medical therapy should be first considered due to the low myocardial mass often supplied by these lesions and the risk of main vessel damage with stenting. Thus, given these findings and the increased risk of bifurcation interventional management, our study has demonstrated that special consideration should be given to the particular vessels involved in a bifurcation lesion and the myocardial mass supplied when considering the choice of treatment. PCI should be reserved for highly unstable lesions supplying significant portions of the myocardium.

A significant limitation of this study and all bifurcation studies are related to using the Medina classification system that separates bifurcation lesions into three unnecessary subgroups (1,1,1; 1,0,1; 0,1,1) without any suffixes that could further characterize a specific bifurcation lesion [9]. Using a more specific classification system, such as the Movahed classification [8], which summarizes all true bifurcation lesions into one simple category would have aided in the isolation of true bifurcation lesions and enhanced the stratification of low and high-risk bifurcation lesions [8]. Furthermore, increasing the specificity of bifurcation lesion descriptions, as is done by the Movahed classification, would have allowed for more meaningful conclusions to have been drawn regarding PCI outcomes for a variety of bifurcation lesion sub-

types, increasing clinical relevance and applicability [16-24]. Thus, while our study demonstrated a very high risk associated with percutaneous coronary intervention of bifurcation lesions, the true risk is likely much lower if only non-true bifurcation lesions were evaluated, warranting future investigation.

It is important to recognize the other limitations of our study. IICD-10 coding has inherent limitations and many bifurcation lesions were most likely not coded as such. Furthermore, regarding the inability of NIS to attribute complications to specific procedures, potential misclassification of complications is another limitation of our study. Furthermore, while we consider significant medical comorbidities, the lack of follow-up data precludes the assessment of longer-term outcomes, such as quality of life metrics. Finally, as noted previously, the HCUP data structure and classification system prevented the isolation of true bifurcation lesions, limiting our results to all bifurcation lesion subgroups.

Conclusion

Considering our study's findings and those of the previous studies discussed, a significant body of evidence now highlights the complexity and risk of choosing to treat coronary bifurcation lesions with PCI. We have demonstrated that the treatment of non-CTO bifurcation lesions with percutaneous coronary intervention is associated with significantly higher morbidity and mortality than simple single-vessel PCI. Thus, the treatment of bifurcation lesions with PCI should be more selective.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Mohammad Reza Movahed, Department of Clinical Medicine, University of Arizona Sarver Heart Center, 1501 N Campbell Avenue, Tucson, AZ 85724, USA. Tel: 949-400-0091; E-mail: rmova@aol.com

References

[1] Latib A and Colombo A. Bifurcation disease: what do we know, what should we do? JACC Cardiovasc Interv 2008; 1: 218-226.

[2] Kırat T. Fundamentals of percutaneous coronary bifurcation interventions. World J Cardiol 2022; 14: 108-138.

[3] Burzotta F, Annone U, Paraggio L, D'Ascenzo F, Biondi-Zoccai G, Aurigemma C, Romagnoli E, Verdirosi D, Trani C and Crea F. Clinical outcome after percutaneous coronary intervention with drug-eluting stent in bifurcation and nonbifurcation lesions: a meta-analysis of 23 981 patients. Coron Artery Dis 2020; 31: 438-445.

[4] Stankovic G, Darremont O, Ferenc M, Hildick-Smith D, Louvard Y, Albiero R, Pan M, Lassen JF and Lefèvre T; European Bifurcation Club. Percutaneous coronary intervention for bifurcation lesions: 2008 consensus document from the fourth meeting of the European Bifurcation Club. EuroIntervention 2009; 5: 39-49.

[5] Lansky AJ, Yaqub M, Hermiller JB, Smith RS, Farhat N, Caputo R, Williams JE, Sanz M, Koo K, Sood P, Sudhir K and Stone GW. Side branch occlusion with everolimus-eluting and paclitaxel-eluting stents: three-year results from the SPIRIT III randomised trial. EuroIntervention 2010; 6 Suppl J: J44-J52.

[6] Zhou Y, Chen S, Huang L, Hildick-Smith D, Ferenc M, Jabbour RJ, Azzalini L, Colombo A, Chieffo A and Zhao X. Definite stent thrombosis after drug-eluting stent implantation in coronary bifurcation lesions: a meta-analysis of 3,107 patients from 14 randomized trials. Catheter Cardiovasc Interv 2018; 92: 680-691.

[7] Bechiri MY, Souteyrand G, Lefèvre T, Trouillet C, Rangé G, Cayla G, Dérimay F, Mangin L, Meneveau N, Caussin C, Motreff P and Amabile N. Characteristics of stent thrombosis in bifurcation lesions analysed by optical coherence tomography. EuroIntervention 2018; 13: e2174-e2181.

[8] Movahed MR and Stinis CT. A new proposed simplified classification of coronary artery bifurcation lesions and bifurcation interventional techniques. J Invasive Cardiol 2006; 18: 199-204.

[9] Medina A, Suarez de Lezo J and Pan M. A new classification of coronary bifurcation lesions. Rev Esp Cardiol 2006; 59: 183.

[10] Movahed MR. The movahed coronary bifurcation lesion classification introduces limitless optional suffixes that can easily be used for clinical use or coding purposes. Anatol J Cardiol 2023; 27: 295-296.

[11] Sanborn TA. Bifurcation classification schemes: impact of lesion morphology on development of a treatment strategy. Rev Cardiovasc Med 2010; 11 Suppl 1: S11-16.

[12] Baim DS, Cutlip DE, O'Shaughnessy CD, Hermiller JB, Kereiakes DJ, Giambartolomei A, Katz S, Lansky AJ, Fitzpatrick M, Popma JJ, Ho KK, Leon MB and Kuntz RE; NIRVANA Investigators (NIR Vascular Advanced North Ameri-

can Trial). Final results of a randomized trial comparing the NIR stent to the Palmaz-Schatz stent for narrowings in native coronary arteries. Am J Cardiol 2001; 87: 152-156.
[13] Dzavik V, Kharbanda R, Ivanov J, Ing DJ, Bui S, Mackie K, Ramsamujh R, Barolet A, Schwartz L and Seidelin PH. Predictors of long-term outcome after crush stenting of coronary bifurcation lesions: importance of the bifurcation angle. Am Heart J 2006; 152: 762-769.
[14] Aliabadi D, Tilli FV, Bowers TR, Benzuly KH, Safian RD, Goldstein JA, Grines C and O'Neill WW. Incidence and angiographic predictors of side branch occlusion following high-pressure intracoronary stenting. Am J Cardiol 1997; 80: 994-997.
[15] Sharma SK, Choudhury A, Lee J, Kim MC, Fisher E, Steinheimer AM and Kini AS. Simultaneous kissing stents (SKS) technique for treating bifurcation lesions in medium-to-large size coronary arteries. Am J Cardiol 2004; 94: 913-917.
[16] Movahed MR. Movahed coronary bifurcation classification should be the preferred classification for studying true bifurcation lesions as it summarizes true bifurcation lesions in only one simple category called B2 Lesion with limitless optional suffixes. Catheter Cardiovasc Interv 2023; 102: 1263-1264.
[17] Movahed MR. Major limitations of randomized clinical trials involving coronary artery bifurcation interventions: time for redesigning clinical trials by involving only true bifurcation lesions and using appropriate bifurcation classification. J Interv Cardiol 2011; 24: 295-301.
[18] Movahed MR. B2 lesions are true bifurcation lesions simply categorized as one group according to the Movahed bifurcation classification. J Invasive Cardiol 2010; 22: 252.
[19] Movahed MR. Studies involving coronary bifurcation interventions should utilize the most comprehensive and technically relevant Movahed coronary bifurcation classification for better communication and accuracy. Am J Cardiol 2010; 105: 1204-5.
[20] Movahed MR. Is it time to consider the Movahed classification as the preferred classification for coronary bifurcation lesions? EuroIntervention 2010; 5: 652.
[21] Movahed MR. Quantitative angiographic methods for bifurcation lesions: a consensus statement from the European Bifurcation Group. Shortcoming of the Medina classification as a preferred classification for coronary artery bifurcation lesions in comparison to the Movahed classification. Catheter Cardiovasc Interv 2009; 74: 817-8
[22] Movahed MR. What we should know about bifurcation disease. JACC Cardiovasc Interv 2008; 1: 595-6; author reply 596.
[23] Movahed MR, Kern K, Thai H, Ebrahimi R, Friedman M and Slepian M. Coronary artery bifurcation lesions: a review and update on classification and interventional techniques. Cardiovasc Revasc Med 2008; 9: 263-8.
[24] Movahed MR. Coronary artery bifurcation lesion classifications, interventional techniques and clinical outcome. Expert Rev Cardiovasc Ther 2008; 6: 261-74.
[25] Dash D. Recent perspective on coronary artery bifurcation interventions. Heart Asia 2014; 6: 18-25.
[26] Boden WE, O'Rourke RA, Teo KK, Hartigan PM, Maron DJ, Kostuk WJ, Knudtson M, Dada M, Casperson P, Harris CL, Chaitman BR, Shaw L, Gosselin G, Nawaz S, Title LM, Gau G, Blaustein AS, Booth DC, Bates ER, Spertus JA, Berman DS, Mancini GB and Weintraub WS; COURAGE Trial Research Group. Optimal medical therapy with or without PCI for stable coronary disease. N Engl J Med 2007; 356: 1503-1516.
[27] Nathan A, Hashemzadeh M and Movahed MR. Percutaneous coronary intervention of chronic total occlusion associated with higher inpatient mortality and complications compared with non-CTO lesions. Am J Med 2023; 136: 994-999.
[28] Gacutan K. Healthcare cost and utilization project - HCUP. Published online 2020.
[29] Suleiman S, Coughlan JJ, Touma G and Szirt R. Contemporary management of isolated ostial side branch disease: an evidence-based approach to medina 001 bifurcations. Interv Cardiol 2021; 16: e06.
[30] Writing Committee Members; Lawton JS, Tamis-Holland JE, Bangalore S, Bates ER, Beckie TM, Bischoff JM, Bittl JA, Cohen MG, DiMaio JM, Don CW, Fremes SE, Gaudino MF, Goldberger ZD, Grant MC, Jaswal JB, Kurlansky PA, Mehran R, Metkus TS Jr, Nnacheta LC, Rao SV, Sellke FW, Sharma G, Yong CM and Zwischenberger BA. 2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. J Am Coll Cardiol 2022; 79: e21-e129.
[31] Sruys PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, Ståhle E, Feldman TE, van den Brand M, Bass EJ, Van Dyck N, Leadley K, Dawkins KD and Mohr FW; SYNTAX Investigators. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med 2009; 360: 961-972.
[32] Burzotta F, Annone U, Paraggio L, D'Ascenzo F, Biondi-Zoccai G, Aurigemma C, Romagnoli E, Verdirosi D, Trani C and Crea F. Clinical outcome after percutaneous coronary interven-

tion with drug-eluting stent in bifurcation and nonbifurcation lesions: a meta-analysis of 23 981 patients. Coron Artery Dis 2020; 31: 438-445.

[33] Tsuchida K, Colombo A, Lefèvre T, Oldroyd KG, Guetta V, Guagliumi G, von Scheidt W, Ruzyllo W, Hamm CW, Bressers M, Stoll HP, Wittebols K, Donohoe DJ and Serruys PW. The clinical outcome of percutaneous treatment of bifurcation lesions in multivessel coronary artery disease with the sirolimus-eluting stent: insights from the Arterial Revascularization Therapies Study part II (ARTS II). Eur Heart J 2007; 28: 433-442.

[34] Lam MK, Sen H, van Houwelingen KG, Löwik MM, van der Heijden LC, Kok MM, de Man FH, Linssen GC, Tandjung K, Doggen CJ and von Birgelen C. Three-year clinical outcome of patients with bifurcation treatment with second-generation Resolute and Xience V stents in the randomized TWENTE trial. Am Heart J 2015; 169: 69-77.

[35] Džavík V, Kaul U, Guagliumi G, Chevalier B, Smits PC, Stuteville M, Li D, Sudhir K and Grube E. Two-year outcomes after deployment of XIENCE V everolimus-eluting stents in patients undergoing percutaneous coronary intervention of bifurcation lesions: a report from the SPIRIT V single arm study. Catheter Cardiovasc Interv 2013; 82: E163-172.

[36] Grundeken MJ, Wykrzykowska JJ, Ishibashi Y, Garg S, de Vries T, Garcia-Garcia HM, Onuma Y, de Winter RJ, Buszman P, Linke A, Ischinger T, Klauss V, Eberli F, Corti R, Wijns W, Morice MC, di Mario C, Meier B, Jüni P, Yazdani A, Copt S, Windecker S and Serruys PW. First generation versus second generation drug-eluting stents for the treatment of bifurcations: 5-year follow-up of the LEADERS all-comers randomized trial. Catheter Cardiovasc Interv 2016; 87: E248-260.

[37] Al-Lamee R, Thompson D, Dehbi HM, Sen S, Tang K, Davies J, Keeble T, Mielewczik M, Kaprielian R, Malik IS, Nijjer SS, Petraco R, Cook C, Ahmad Y, Howard J, Baker C, Sharp A, Gerber R, Talwar S, Assomull R, Mayet J, Wensel R, Collier D, Shun-Shin M, Thom SA, Davies JE and Francis DP; ORBITA investigators. Percutaneous coronary intervention in stable angina (ORBITA): a double-blind, randomised controlled trial. Lancet 2018; 391: 31-40.

[38] Hachamovitch R, Hayes SW, Friedman JD, Cohen I and Berman DS. Comparison of the short-term survival benefit associated with revascularization compared with medical therapy in patients with no prior coronary artery disease undergoing stress myocardial perfusion single photon emission computed tomography. Circulation 2003; 107: 2900-2907.

[39] Kim HY, Doh JH, Lim HS, Nam CW, Shin ES, Koo BK, Lee JM, Park TK, Yang JH, Song YB, Hahn JY, Choi SH, Gwon HC, Lee SH, Kim SM, Choe Y and Choi JH. Identification of coronary artery side branch supplying myocardial mass that may benefit from revascularization. JACC Cardiovasc Interv 2017; 10: 571-581.