Research Article

Impact of Bifurcation Angle on Side Branch Occlusion in Provisional Bifurcation Stenting

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Abstract

Background: Bifurcation angle (BA) is the critical angle that has impact on side branch (SB) occlusion during coronary intervention due to plaque shift. There have been few research studies especially in Pakistan on the role of BA in plaque shift.

Objective: To know the impact of bifurcation angle on the side branch occlusion during provisional stenting.

Methodology: A retrospective cohort study was conducted at Punjab Institute of Cardiology, Lahore on consecutively enrolled patients between July 2017 and June 2019. The subjects were split into two groups: high angle and low angle using the median BA. Binary logistic regression analysis was performed to identify BA as an independent predictor of occlusion of SB.

Results: Occurrence of side branch occlusion was found in 7.7% of the total of 600 bifurcation lesions. SB occlusion rate was found to be significantly higher in higher angle (HA) group compared to lower angle (LA) group i.e. (37/292, 12.7 %) and (9/308, 2.9 %) respectively, ($P < 0.001$). Binary logistic regression analysis demonstrated high angle to be an independent predictor for the occlusion of side branches (odds ratio [OR]: 1.026 per degree increment, 95% confidence intervals [CI]: 1.016 – 1.045, $P < 0.001$).

Conclusion: Higher branching angle was noted as the independent predictor of the occlusion of side branches following provisional stenting of main vessel.

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Keywords | Bifurcation angle, side branch occlusion, plaque shift, PCI, bifurcation lesion

Introduction

In coronary bifurcation lesions, provisional coronary artery stenting remains a challenge with risk of occlusion of SB.[1] SB occlusion incidence varies from 2.7 to 10% and can cause ischemia to infarction of the cardiac muscle.[2] BA is a major factor in prediction of SB occlusion. Therefore, we conducted this study as only limited data is available especially in Pakistan on the role of BA in SB occlusion.

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https://doi.org/10.21649/akemu.v29i2.5454

European Bifurcation Club defines the angle between centerlines of the proximal main vessel (PMV) and SB is as "take-off angle", and the angle between centerlines of the distal main vessel (DMV) and SB as "bifurcation angle" (BA). BA has impact on SB occlusion during coronary bifurcation intervention.[3]

Shear stress on vascular walls under normal physiological conditions has a role in initiation, progression, and destabilization of atherosclerotic plaques. At the bifurcation site the laminar blood flow usually gets disrupted and generates an athero-prone milieu. Therefore, vascular geometry has an impact on localization sites and the progression of atherosclerosis. That's why atherosclerotic plaques mostly form at the bifurcation of the vessels,[4] which causes stenosis of the vessels that is repaired by stent implantation. Provisional stenting (PS) is usually done while treating bifurcation lesion which is implanting stent to the main vessel (MV) only,[5] while insertion of a guide wire to the SB before stenting to reduce risk of SB occlusion causing major adverse cardiac events (MACE), myocardial infarction (MI), and target vessel revascularization (TVR).[6]

Methodology

Our study population included patients undergoing PCI that were presented with coronary bifurcation lesions, i.e., defined as the narrowing of the coronary artery taking place adjacent to or involving significant SB.

A retrospective cohort study was conducted at Punjab Institute of Cardiology, Lahore on consecutively enrolled patients between July 2017 to June 2019 after ethical approval. The inclusion criteria were as follows.

- Patients >18 years of age
- Patients with coronary artery disease (CAD) or myocardial infarction (MI)
- Patients with plaque near bifurcation angle that can get lodged in SB and cause occlusion as per angiogram.
- Patients with coronary bifurcation lesion involving significant SB going to have PCI. European Bifurcation Club Criteria[12] was used to define significant SB, i.e., a branch which operator would not want to lose (location of ischemia, symptoms, collateralizing vessel viability, left ventricular function, etc.)

The exclusion criteria were;

- Patients of age <18 years.
- Patients of CAD with lesions not involving side branch

Clinical data was obtained by reviewing medical records. An independent core laboratory reviewed and analyzed all the baseline and procedural cine-angiograms. Quantitative coronary angiography (QCA) was performed with a computerized bifurcation analysis system on angiograms at baseline and after pre-dilation of lesion. QCA of four segments of bifurcation lesion were obtained: (1) PMV segment (2) DMV segment (3) SB segment and (4) the bifurcation core segment (Bifurcation core is defined as the central part of the bifurcation, which begins where the common vessel starts to split into two branches and ends at the carinal point. BA (the angle between the distal MV and the SB) was obtained from the analysis system.

Presentation of the continuous data was done as mean ± SD and comparison was made by Student t-test. Summarization of the categorical variables was done as the counts as well as the percentages and their comparison were done using chi-square test as suited. Binary logistic regression analysis was carried out for the identification of the independent predictors for the SB occlusion. Presentation of the estimates of adjusted differences for the risks was done with having 95% confidence intervals (CI) of difference. P value < 0.05 was taken as statistically significant. SPSS v20 was utilized to perform all the analyses.

Results

Bifurcation angle distribution has been demonstrated in Fig. 1. In the whole cohort (n = 600), median of the BA was noted to be 54, that was in consensus with a study conducted previously by Zhang et al.[7] Interquartile range of the BA was noted to be 28 (67 – 39). In consonance with previously acquired reports,[7,8,9] division of the patients was carried out into two groups, one being HA group while other LA group following median BA: 308 patients were made part of the LA group (≤ 54°) whereas 292 patients were made part of HA group (>54°). The interquartile range and median of the BA were found to be 11 (46 – 35) and 39 for LA group whereas for the HA group interquartile range and median were noted to be 14 (77 – 63) and 68.

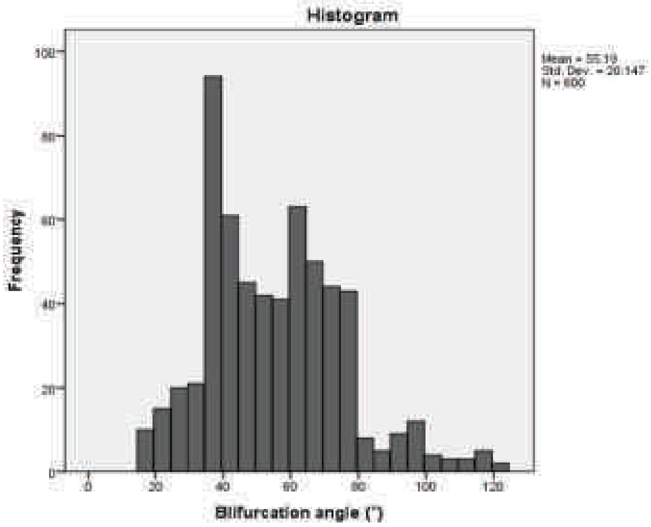

Figure 1 . *Distribution of Bifurcation Angle in all the Patients (n = 600).*

Characteristics of the patient are depicted in Table 1. All baseline characteristics were balanced among the

Table 1: *Baseline characteristics of the patients*

Variable	Low angle (n = 308)	High angle (n = 292)	p-value
Age	59.8 ± 6.1	59.1 ± 6.8	0.14
Gender (male)			
Male	238 (77.3 %)	226 (77.4 %)	0.9
Female	70 (22.7 %)	66 (22.6 %)	
BMI	27.0 ± 1.91	27.1 ± 1.98	0.87
Diabetes	84 (27.3 %)	76 (26 %)	0.71
Hypertension	196 (63.6 %)	194 (66.4 %)	0.47
Hyperlipidemia	245 (79.5 %)	237 (81.1 %)	0.62
Family history of CAD	54 (17.5 %)	57 (19.5 %)	0.52
Smoking	112 (36.4 %)	111 (38 %)	0.68
Prior MI	42 (13.6 %)	50 (17.1 %)	0.23
LVEF	63.26 ± 4.49	63.27 ± 4.45	0.98

two groups.

Table 2 depicts both procedural and lesion characteristics. Bifurcation locations with moderate to severe angulation in SB showed significant differences in the study groups. A greater number of subjects with distal left main bifurcation lesions, LCX lesions and RCA lesion were found in HA group (2.4 %, 27 % and 31.2 %, respectively). The most common bifurcation lesions in the LA group were LAD and diagonal lesions (68.8 % vs. 39.3 %, p > 0.001). The use of jailed wire in SB to prevent occlusion was significantly high in LA group (31.8%) in comparison with HA group (22.3%) (P = 0.009).

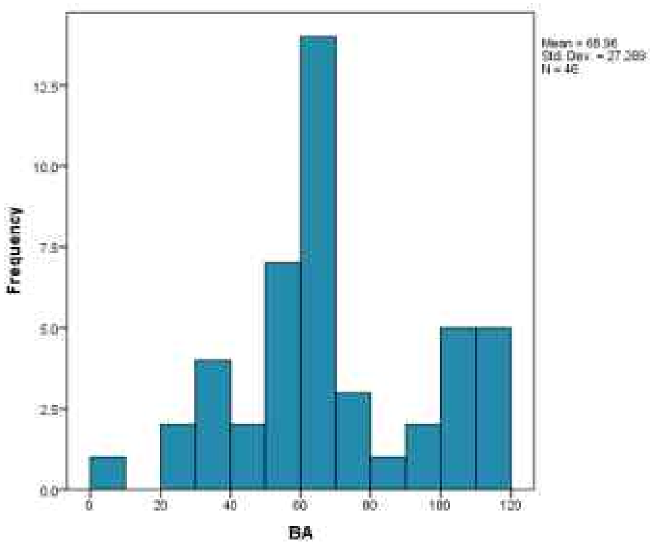

Figure 2. *Distribution of SB occlusion with respect to BA.*

Table 2: *Lesion and procedural characteristics of patients*

Variable	Low angle (n = 308)	High angle (n = 292)	p-value
Bifurcation location			<0.001
Left main bifurcation	3 (1 %)	7 (2.4 %)	
LAD/diagonal	212 (68.8 %)	115 (39.3 %)	
LCX	59 (19.2 %)	79 (27 %)	
RCA	34 (11 %)	91 (31.2 %)	
Medina Classification			0.32
Non-true bifurcation			
1,0,0	106 (34.4 %)	81 (27.7 %)	
0,1,0	92 (29.9 %)	85 (29.1 %)	
1,1,0	38 (12.3 %)	48 (16.4 %)	
0,0,1	3 (1 %)	1 (0.34 %)	
True bifurcation			
1,1,1	24 (7.8 %)	33 (11.3 %)	
1,0,1	27 (8.7 %)	28 (9.6 %)	
0,1,1	18 (5.8 %)	16 (5.5 %)	
Lesion and stent characteristics			
Main vessel (MV)			
Moderate – severe calcification	14 (4.5 %)	12 (4.1 %)	0.80
Moderate – severe angulation	166 (53.9 %)	167 (57.2 %)	0.41
Thrombosis	16 (5.2 %)	17 (5.82 %)	0.73
Total stent length (mm)	30.5 ± 12.7	31.2 ± 12.9	0.50
Maximal stent diameter (mm)	3.13 ± 0.34	3.11 ± 0.32	0.45
Side branch (SB)			
Moderate – severe calcification	0 (0 %)	2 (0.68 %)	0.14
Moderate – severe angulation	13 (4.2 %)	24 (8.21 %)	0.04*
Thrombosis	1 (0.32 %)	1 (0.34 %)	0.96
Total stent length (mm)	22.2 ± 9.4	21.6 ± 7.5	0.38
Maximal stent diameter (mm)	2.70 ± 0.31	2.73 ± 0.35	0.26
SB pre-dilation	55 (17.8 %)	39 (13.4 %)	0.13
Jailed wire in SB	98 (31.8 %)	65 (22.3 %)	0.009*

*Statistically significant

Table 3 demonstrates quantitative data for the coronary angiography. Significant differences among the two groups in terms of lesion length of the PMV and the SBs, stenosis diameter of the SBs prior to stenting of MV and stenosis diameter of the bifurcation core and DMV.

Occurrence of SB occlusion was found in 7.7% of the total of 600 bifurcation lesions which received treatment

Table 3: *QCA data of all the patients*

Variable	Low angle (n = 308)	High angle (n = 292)	p- value
Bifurcation angle	39.2 ± 8.8	72.0 ± 14.0	< 0.001*
Baseline			
Proximal Main vessel (MV)			
Lesion length, mm	14.1 ± 9.1	16.9 ± 8.9	<0.001*
Reference diameter, mm	2.99 ± 0.61	3.02 ± 0.57	0.53
Diameter stenosis (%)	55.3 ± 26.4	52.2 ± 28.7	0.16
Distal Main vessel (MV)			
Lesion length, mm	8.9 ± 7.8	9.2 ± 7.6	0.63
Reference diameter, mm	2.68 ± 0.5	2.73 ± 0.5	0.22
Diameter stenosis (%)	48.1 ± 25.7	55.6 ± 24.9	<0.001*
Side branch (SB)			
Lesion length, mm	4.3 ± 2.5	3.8 ± 2.6	0.01*
Reference diameter, mm	2.1 ± 0.2	2.09 ± 0.3	0.62
Diameter stenosis (%)	31.7 ± 19.3	33.7 ± 21.1	0.22
Bifurcation core			
Lesion length, mm	3.1 ± 1.9	3.3 ± 1.4	0.14
Reference diameter, mm	3.1 ± 0.9	3.0 ± 0.5	0.09
Diameter stenosis (%)	31.1 ± 25.3	39.2 ± 28.2	< 0.001*
Total lesion length of MV (mm)	19.9 ± 8.8	21.2 ± 9.2	0.07
Diameter stenosis of SB before MV stenting (%)	30.3 ± 17.6	33.9 ± 21.7	0.02*
Diameter stenosis of MV before MV stenting (%)	51.9 ± 16.0	52.3 ± 16.2	0.7

*Statistically significant

Table 4: *Regression analysis to identify BA as a predictor of SB occlusion.*

Independent predictor	OR	95% CI	P value
Bifurcation Angle (°)	1.031	1.016 – 1.045	< 0.001*

*Statistically significant

via single stent technique or the main vesicle stenting initial strategy. In 32 lesions (69.5%) blood flow was absent and decreased TIMI flow grade was recorded in 23 (26.1%) of the lesions.

SB occlusion rate was found to be significantly higher compared to LA group (37/292, 12.7 %) and (9/308, 2.9 %) respectively, (P < 0.001). The distribution of SB occlusion with respect to BA is presented in figure 2.

Using SB occlusion following stenting of the MV as variable state and taking BA as the test variable, receiver operating characteristic or ROC curve was created (Fig. 3). Area located under ROC curve was noted to be 0.67 (95% CI: 0.585– 0.757, P < 0.001), and cut-off value for the prediction of the SB was noted to be 53.5, with specificity being 51.8% and sensitivity being 78.3%.

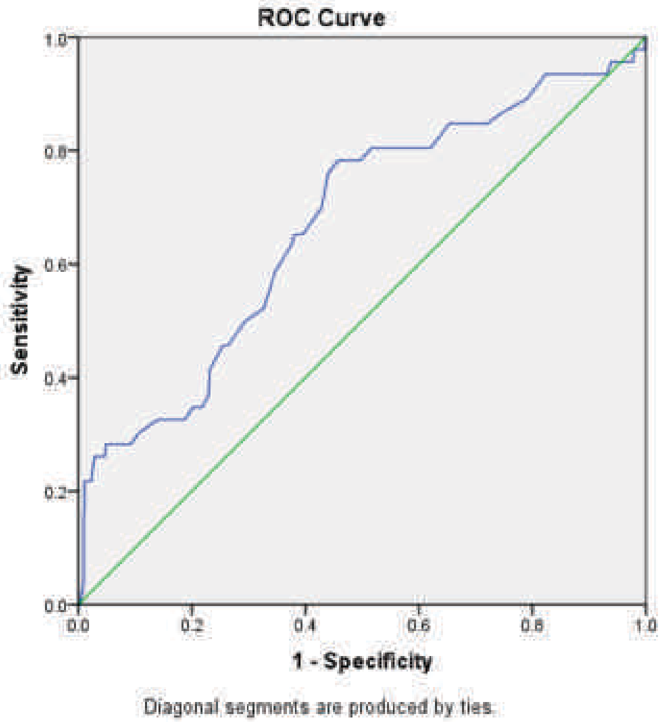

Figure 3. *ROC curve for BA.*

Binary logistic regression analysis demonstrated HA to be an independent predictor for the occlusion of SBs (odds ratio [OR]: 1.026 per degree increment, 95% confidence intervals [CI]: 1.016 – 1.045, P < 0.001). The incidence as well as the risk of SBs occlusion elevated consequently to the increase in the BA becoming larger.

Discussion

As of now, occurrence of bifurcation lesions is a common observation in cardiovascular intervention. Bifurcation stenting is crucially affected by BA.[10,11] Strategies for the stenting selection is affected by the BA and numerous controversies exist regarding the outcomes governed by angle effect and newer and improved strategies are still being proposed (Lassen et al. 2018).[12] In the current study, we looked at the potential impact BA has on SB occlusion for the first time in Pakistani population. Our study primarily reported that HA has a significant correlation with occlusion of SB, while LA had more patency in SB intervention (with use of jailed wire in SB).

Both carina and plaque shift were thought of being potential mechanisms that leads to SB compromise following PS.[13] Nonetheless, via combining different factors, such as hemodynamics, bifurcation anatomy and the geometric characteristics besides carina and plaque shift, BA can have major impact on the SB occlusion. To explain the effects of BA on the SB occlusion following PS, more studies taking relevant variables into consideration were required. 600 bifurcation lesions were analyzed by this study and reached the conclusion that SB occlusion risk amplifies with increasing BA, subsequently. The results of this study are in agreement with a study conducted by Zhang et al.[7], in which BA > 52° was significantly associated with SB occlusion. Another recent study also demonstrates that BA measuring over 80.5° (higher BA) has its correlation with the SB stenosis along with subsequently occurring hemodynamic changes if lesion was within first 5 millimeter from site of bifurcation.[4] In another study, evaluation of the 44 bifurcation lesions via intravascular ultrasound (IVUS) was done which showed insignificant association among SB compromise and angle.[14] One of the explanation furnished was bifurcations that smaller BA resulted in easing of flow diversion to the side branch, while larger BA resulted in dropping of the pressure and subsequently flow resistance[15,16] so, increasing risk of SB occlusion.

Another explanation was for SBs with the similar reference diameter that decrease in ostium lumen of the SBs was noted subsequent to BA becoming wider. The lumen area of SB ostium can be utilized for the prediction of SB compromise with increased sensitivity[17]; so, higher BA and relatively small lumen area of SB ostium played a role in SBs occlusion. Furthermore, higher volume of the plaque in the bifurcation core might play a part in higher risk of SB occlusion. In our study we noted lesions in HA a greater number of severe bifurcation core diameter stenosis prior to the procedure (39.2 % ± 28.2 % vs. 31.1 % ± 25.3 %, P < 0.001), in comparison with the lesions in the LA group. Occurrence of dense plaque burden in bifurcation core for HA group might serve as an explanation for high incidence of the SB occlusion.

Identification of predictors of the SB occlusion might aid in decreasing risk of the occlusion in SB. In current study, higher BA was indicated via the regression analysis to be an independent predictor of SB occlusion.

Jailed wire for SB was regarded as being potential factor to affect occlusion of the SB in the current study in line with the findings of Zhang et al.[7], however, they concluded that even though jailed wired for the SBs as well as the other factors related to the procedures might affect occlusion of the SBs as well as recovery of SB flow, none among such factors were taken as independent predictors of SB occlusion. More prospective clinical studies are needed to clarify the question.

Lastly, current study noted by using 54 degrees BA as the cut-off point permitted predicting occlusion of the SB with an acceptable specificity as well as good sensitivity.

Our study possessed some limitations. Firstly, the current study observed limitations in terms of being single center based and retrospective in design. Secondly, operators were given free choice in terms of choosing stent types, strategies for the treatment and the other instruments. Our results might thus be subjected to a selection bias. Thirdly, the mean of the SB reference diameter in the current study was found to be relatively small and different results might be obtained for the patients where SB are larger. This might as well present as a partial explanation of the BA effect on the occlusion of SB presented in the current study.

Conclusion

Higher branching angle was noted as the independent predictor of the occlusion of side branches following stenting of main vessel. The risk of occlusion of the side branches with higher branching angle must be given importance. There is need for the validation in the diverse population of the patients.

Ethical Approval: Given
Conflict of Interest: The authors declare no conflict of interest.
Funding Source: None

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