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Corrected Bifurcation Angle versus Distal Bifurcation Angle for Prediction of Side Branch Compromise after Provisional Bifurcation Coronary Intervention

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Abstract

Provisional bifurcation percutaneous coronary intervention (PCI) is recommended over two stent strategy but with the risk of side branch (SB) compromise. Prediction SB compromise is crucial for optimizing of the procedure outcome. Neglecting the proximal bifurcation angle (BA), the distal BA was presented as a reliable predictor of SB compromise supposing that the main vessel is always a straight vessel. However, its impact on the fate of side branch is debated. This study aims to compare between of the corrected BA, the sum of proximal and distal BAs, and the distal BA in terms of prediction of SB compromise. This prospective cohort study was conducted in Zagazig university hospitals in the duration between March 2019 and March 2020, and involved 185 patients who underwent provisional bifurcation PCI. Patients were divided according to the corrected BA into two groups; straight bifurcation model group which involved 73 patients with corrected BA = 180°, and wide bifurcation model group which involved 112 patients with corrected BA > 180°. Compared to the wide bifurcation model, the incidence of SB compromise was substantially higher in the straight bifurcation model (52.1% vs. 15.2%; P < 0.001). The corrected BA had a better area under the curve compared to the distal BA with statistically significant difference (0.711 vs. 0.580; P = 0.023). Multivariate analysis demonstrated that the corrected BA was among the independent predictors of SB compromise. The study concluded that the corrected BA could be a novel strong predictor of SB compromise after provisional bifurcation PCI for future verification.

Keywords: Bifurcation Coronary Artery Disease; Coronary Angiographic Predictors; Coronary Bifurcation Angle

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Introduction

Bifurcation coronary artery disease has a significant burden among coronary intervention cases [1]. Being one of the challenging complex procedures, ongoing studies aim to improve immediate and long term outcomes after bifurcational percutaneous coronary intervention (PCI) [2]. The provisional main vessel (MV) PCI is recommended over the two stent strategy but with the risk of side branch (SB) compromise [3].

Many studies had discussed different strategies to minimize the risk of SB compromise during bifurcational PCI such as; jailed wire and jailed balloon strategies [4,5]. Other studies had discussed the angiographic predictors of SB compromise after MV stenting for better selection of intervention strategy [6].

Among the predictors of SB compromise, distal bifurcation angle (BA), the angle between SB and distal MV, was presented as a reliable predictor [7]. However, studies results were contradicted. Some studies demonstrated that narrow distal BA had increased the risk of SB compromise [8]. More recent studies have concluded that the wider the distal BA the higher the risk of SB compromise [9].

This debate could be due to focusing on the distal BA and neglecting the proximal BA [6,10]. MV is not always a straight vessel. Based on three dimensions Quantitative coronary angiography studies, there are two models of coronary bifurcation; Y and T models [11]. Furthermore, a computed tomography (CT) coronary angiography study demonstrated that the MV could change its curvature at the origin of the SB [12].

Correction of the distal bifurcation angle could be achieved by adding proximal BA. Corrected BA, which is the sum of proximal and distal bifurcation angles, could be a potential predictor of SB compromise during provisional bifurcational PCI. This study aims to compare between corrected BA and distal BA in terms of prediction of SB compromise during provisional bifurcational PCI.

Patients and Methods

The institutional review board approved this study in Zagazig University Hospitals, Sharkia, Egypt.

Study Design, Setting, and Duration

This prospective cohort study was conducted in Zagazig university hospitals. The study started in March 2019 and ended in March 2020.

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Study Population

The study involved Patients with coronary bifurcation lesion and a SB diameter ≥ 1.5 mm who underwent provisional MV PCI.

According to the European Bifurcation Club guidelines, Coronary bifurcation disease was defined as SB involvement in MV lesion with absence of normal area between MV minimal luminal diameter and SB, true coronary bifurcation lesion was defined as involvement of SB ostium with SB diameter being ≥ 2 mm, and significant SB was defined as any SB you do not want to lose [13].

Patients with chronic total occlusions and in stent restenosis were excluded. Also, we excluded procedures that started with SB stenting.

Study Variables, Clinical Assessment

Clinical assessment of all patients included age, gender, cardiovascular risk factors, coronary angiography indication, pulse, blood pressure, and serum creatinine level.

In terms of an observational study, operators planned PCI procedures and peri-procedure medications according to current guidelines without our interference. Loading doses with 300 mg aspirin and 600 mg clopidogrel were given to stable coronary artery disease patients 12 hrs. before PCI. A loading dose with 180 mg ticagrelor replaced the clopidogrel in acute coronary syndrome (ACS) patients in absence of contraindications.

Two separate cardiologists analyzed coronary angiography films using RadiAnt DICOM Viewer 5.0.1 (64-bit) program. Bifurcation angles were defined as following (Figure 1):

- Distal BA was defined as the angle between distal MV and SB.
- Proximal BA was defined as the angle between proximal MV and SB.
- Corrected BA was defined as the sum of proximal and distal bifurcation angles.

We calculated of the bifurcation angles by two dimensions (2D) quantitative coronary analysis (QCA) in the view showing the widest angle. Horizontal left main bifurcation angles were calculated in the spider view. However, Vertical left main bifurcation angles were calculated in the left anterior oblique (LAO) view with cranial angulation. We calculated proximal left anterior descending (LAD) / diagonal (D) bifurcation angles in the spider view and the mid to distal LAD/D bifurcation angles in the LAO view with cranial angulation.

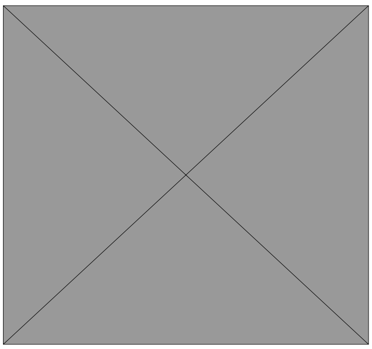

Figure 1: Shows definitions of bifurcation angles, (A): Proximal bifurcation angle which is the angle between side branch and distal main vessel, (B): Distal bifurcation angle which is the angle between side branch and proximal main vessel, Corrected bifurcation angle is the sum of proximal and distal bifurcation angles, PMV: Proximal main vessel, DMV: Distal main vessel, SB: Side branch.

We calculated left circumflex (LCX)/obtuse marginal (OM) bifurcation angles in either spider view or right anterior oblique (RAO) view with caudal angulation. The posterior descending artery (PDA) / postrolateral (PL) branch bifurcation angles were calculated in either postroanterior (PA) view with cranial angulation or LAO view with cranial angulation. If the bifurcation angle was foreshortened in the standard view, views were modified to get the widest angle.

We measured the bifurcation angle between the central axes of the two vessels to avoid the bias that could be made by plaque irregularity. In case of vessel tortuosity, the angle was measured at the level of bifurcation core.

We checked the coronary angiograms for other potential angiographic predictors of SB compromise that could be confounding factors as coronary dominance, site of bifurcation, Medina classification, angulation, calcification, Plaque irregularity, lesion thrombus, and both MV and SB TIMI flow grade. Guiding catheter diameters were used to correct vessels diameters as following; 2 mm for 6 French catheter and 2.3 mm for 7 French catheter. Radio-opaque length of coronary wires was used to correct the length of lesions. Stenosis percentage was calculated as following; ([reference diameter-minimal diameter]/ reference diameter) ×100.

Furthermore, PCI procedure was observed for potential steps that impact the risk of SB compromise as leaving jailed wire in SB, pre-dilatation of MV, pre-dilatation of SB, any observed dissections after pre-dilatation, stent diameter/distal MV diameter ratio, and proximal optimization technique (POT).

All patients were followed during PCI procedure case by case after completed analysis of coronary angiography film. The SB was considered compromised after the MV stent deployment when the SB TIMI flow grade decreased.

In order to minimize the risk of bias, we performed the following steps:

- Our study involved all patients with bifurcation coronary lesions who underwent provisional PCI during the study period to avoid selection bias.
- All clinical data were collected from each patient before PCI to avoid missed data in medical records.
- Two separate cardiologists analyzed the coronary angiography film before start of PCI to decrease observer bias. SB compromise was checked during PCI procedure as cine recordings could be lost.

Sample Size Calculation

Previous studies demonstrated that the area under the curve of the distal BA was 0.655 for prediction of SB compromise. Therefore, the minimum sample size required was estimated by SciStat online calculator to be 106 cases to achieve 80% power and 95% confidence interval.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 16.0 (SPSS for Windows 16.0, Inc., Chicago, IL, USA). Shapiro wilk test was used to test the quantitative variables for normal distribution. Non parametric Mann-Whitney test or student t-test was used to compare between the studies groups according to the type of data. A chi-square test was used to compare between groups as regarding qualitative variables.

We expressed continuous parameters as mean and standard deviation. Categorical data were presented as the absolute number and percentage within brackets. We used Receiver Operating Characteristic (ROC) curve to calculate area under the curve for both distal and corrected bifurcation angles. Multivariate analysis was used to test the predictive power of bifurcation angles taking other confounding factors in consideration. All P values were based on a 2-tailed distribution; P value ≥ 0.05 was considered non-significant, and P value < 0.05 was considered Significant.

Results

Characteristics of the Study Population

This study rolled in 185 patients who underwent provisional PCI for bifurcational coronary artery disease. Patients were divided according to corrected BA into two groups; straight bifurcation model group which involved 73 patients with corrected BA = 180°, and wide bifurcation model group which involved 112 patients with corrected BA > 180°.

As regarding the basic characteristics, the two-group comparison did not show a significant difference in most variables. However, Patents in the straight bifurcation model had more frequent dyslipidemia (*P* = 0.009) and prior coronary artery bypass graft (CABG) (*P* = 0.023).Most patients in both groups presented with stable angina. However, the wide bifurcation model involved more patients with non-ST segment elevation myocardial infarction (NSTEMI) and the straight bifurcation model involved more patients with ST segment elevation myocardial infarction (STEMI) (*P* = 0.037) (Table 1).

Bifurcation site analysis demonstrated that LAD/D bifurcations were more frequent in both groups. The straight bifurcation model involved more patients with LCX/OM and PDA/PL bifurcations. However, LM bifurcation was absent in the straight bifurcation model (*P* = 0.002). Other qualitative coronary angiography measures are presented in details in table 2.

As regarding quantitative parameters of coronary angiography, the corrected BA was 180° for the straight bifurcation model and the mean corrected BA was 195.3° ± 8.2° for the wide bifurcation model. Also, the mean distal BA was 53.5° ± 18.5° for the straight bifurcation model and 59.6° ± 19.4° for the wide bifurcation model. Furthermore, mean proximal BA was 126.2° ± 18.2° for the narrow bifurcation model and 134.8° ± 20.6° for the wide bifurcation model.

Difference between the Study Groups

The statistical analysis did not reveal any significant difference between two groups as regarding qualitative coronary angiography measures or PCI procedure parameters including SB wiring, pre-dilatation, stent diameter/distal MV diameter ratio, and POT. The only reported significant difference was at level of distal MV lesion length which was longer in the wide bifurcation model (*P* = 0.029). Details of quantitative coronary angiography parameters and PCI procedure parameters are presented in table 3 and table 4 respectively.

The Study Outcome

The incidence of SB compromise was substantially higher in the straight bifurcation model as compared to the wide bifurcation model group (52.1% *vs.* 15.2%; *P* < 0.001) (Figure 2). The frequency of total

Table 1: Baseline characteristics.

Characteristics		Straight bifurcation model N=73	Wide bifurcation model N=112	Test value	P value
Age (years)		59.1 ± 8.2	59.3 ± 8.9	3961.500*	0.722
Gender	**Male**	54 (74.0%)	83 (72.1%)	0.000**	0.984
	Female	19 (26.0%)	29 (25.9%)		
BMI (kg/m2)		26.5 ± 3.2	26.5 ± 3.5	3989.500*	0.782
History of diabetes mellitus		27 (37.0%)	35 (31.2%)	0.653**	0.419
History of Hypertension		33 (45.2%)	50 (44.6%)	0.006**	0.940
History of smoking		31 (42.5%)	44 (39.3%)	0.185**	0.667
History of prior STEMI		9 (12.3%)	14 (12.5%)	0.001**	0.972
History of prior NSE-ACS		11 (15.1%)	14 (12.5%)	0.249**	0.617
History of dyslipidemia		27 (37.0%)	22 (19.6%)	6.827**	0.009
History of stroke		4 (5.5%)	4 (3.6%)	0.389+	0.714
History of PAD		3(4.1%)	3 (2.7%)	0.288+	0.682
Family history of premature CAD		1 (1.4%)	4 (3.6%)	0.815+	0.650
History of chronic kidney disease		3(4.1%)	6 (5.4%)	0.149+	1.000
History of prior PCI		5 (6.8%)	10 (8.9%)	0.256**	0.613
History of prior CABG		4(5.5%)	0 (0.0%)	6.273+	0.023
LVEF (%)		61.4 ± 5.3	61.6 ± 5.8	3940.500*	0.678
Heart rate before PCI (BPM)		77 ± 7	78 ± 9	3772.500*	0.374
Systolic blood pressure (BPM)		126.7 ± 13.0	128.9 ± 16.7	3723.500*	0.303
Serum creatinine (mg/dl)		0.9 ± 0.2	0.9 ± 0.3	3521.000*	0.105
Indication of PCI	**Stable angina**	32 (43.8%)	61 (54.5%)	8.487**	0.037
	Unstable angina	18 (24.7%)	14 (12.5%)		
	NSTEMI	6 (8.2%)	19 (17.0%)		
	STEMI	17 (23.3%)	18 (16.1%)		
Anti-platelet used	**Clopidogril**	65 (89.0%)	100 (89.3%)	0.003**	0.958
	Ticagrelor	8 (11.0%)	12 (10.7%)		

Where: *: Mann Whitney test; **: chi-square test; +: Fisher exact test; NSTE-ACS: non ST elevation acute coronary syndrome; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft; BPM: beat per minute; NSTEMI: Non ST elevation myocardial infarction; STEMI: ST elevation myocardial infarction and the values are presented as n (%) or mean ± standard deviation.

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Table 2: Qualitative coronary angiography parameters.

Angiography parameters		Straight bifurcation model N=73	Wide bifurcation model N=112	Test value	P value
Coronary dominance	**Right dominance**	60 (82.2%)	102 (91.1%)	3.201**	0.074
	Left dominance	13 (17.8%)	10 (8.9%)		
Site of bifurcation lesion	**LM bifurcation**	0 (0.0%)	14 (12.5%)	14.874**	0.002
	LAD/D bifurcation	43 (58.9%)	73 (62.5%)		
	LCX/OM bifurcation	21 (28.8%)	16 (14.3%)		
	PDA/PL bifurcation	9 (12.3%)	9 (8.0%)		
True bifurcation lesion		39 (53.4%)	55 (49.1%)	0.330**	0.566
Medina Classification	**0.1.1**	9 (12.3%)	15 (13.4)	11.326**	0.045
	1.1.1	22 (30.1%)	34 (30.4%)		
	1.1.0	6 (8.2%)	22 (19.6%)		
	1.0.0	16 (21.9%)	15 (13.4%)		
	0.1.0	8 (11.0%)	19 (17.0%)		
	1.0.1	12 (16.4%)	7 (6.2%)		
Severe main vessel calcification		8 (11.0%)	6 (5.4%)	1.983+	0.169
Severe main vessel angulations		28 (38.4%)	40 (35.7%)	0.133**	0.716
Irregular plaque		15 (20.5%)	17 (15.2%)	0.891**	0.345
Thrombus containing lesion		18 (24.7%)	22 (19.6%)	0.656**	0.418
TIMI flow in main vessel before PCI	**TIMI 0**	4 (5.5%)	3 (2.7%)	2.865**	0.413
	TIMI 1	4 (5.5%)	3 (2.7%)		
	TIMI 2	5 (6.8%)	13 (11.6%)		
	TIMI 3	60(82.2%)	93 (83.0%)		
TIMI flow in side branch before PCI	**TIMI 1**	2 (2.7%)	1 (0.9%)	2.349**	0.309
	TIMI 2	8 (11.0%)	7 (6.3%)		
	TIMI 3	63 (86.3%)	104 (92.9%)		
Severe SB calcification		5 (6.8%)	2 (1.8%)	3.113+	0.115

Where: *: Mann Whitney test; **: chi-square test; +: Fisher exact test; TIMI: thrombolysis in myocardial infarction; LAD/D: left anterior descending artery/diagonal bifurcation; LCX/OM: left circumflex/obtuse marginal bifurcation; LM: left main bifurcation; PDA/PL: posterior descending artery/postrolateral artery bifurcation; PCI: percutaneous coronary intervention and the values are presented as n (%) or mean ± standard deviation.

Table 3: Quantitative coronary angiography parameters.

Angiography parameters		Straight bifurcation model N=73	Wide bifurcation model N=112	Test value	P value
Proximal main vessel	**Reference diameter (mm)**	3.4 ± 0.5	3.5 ±0.5	3864.500*	0.530
	Lesion length (mm)	9.0 ± 6.8	8.8 ± 7.4	3926.500*	0.647
	Stenosis degree (%)	61.7 ± 35.4	54.9 ± 38.3	3771.500*	0.368
Distal main vessel	**Reference diameter (mm)**	2.8 ± 0.4	2.9 ± 0.5	3730.000*	0.314
	Lesion length (mm)	9.6 ± 10.3	12.7 ± 9.9	3320.500*	0.029
	Stenosis degree (%)	50.0 ± 40.4	61.9 ± 33.3	3647.000*	0.210
Side branch	**Reference diameter (mm)**	2.3 ± 0.5	2.3 ± 0.5	4060.500*	0.938
	Lesion length (mm)	4.2 ± 4.6	4.4 ± 5.4	3978.000*	0.745
	Stenosis degree (%)	41.9 ± 36.7	33.4 ± 34.7	3489.000*	0.076
Distal bifurcation angle		53.5 ± 18.5	59.6 ± 19.4	3349.500*	0.038
Proximal bifurcation angle		126.2 ± 18.2	134.8 ± 20.6	3119.500*	0.007

Where: *: Mann Whitney test; mm: Millimetre; Values are presented as mean ± standard deviation.

occlusion of the SB with TIMI flow grade 0 was higher in the straight bifurcation model (11% *vs.* 3.6%; P <0.001).

Comparison between the Distal and the Corrected BAs

ROC curve was constructed for both the distal and the corrected BA as predictors of the SB compromise (Figure 3).

As regarding the distal BA, the area under the curve was 0.580 with 95% CI 0.495-0.666 ($P = 0.084$). The best cut off value of the distal BA was ≤ 64° with sensitivity 70.3% (95% CI 58.5%-80.3%), specificity 52.7% (95% CI 43.0%-62.2%), positive predictive value 49.5% (95% CI 43.4%-55.6%), negative predictive value 72.8% (95% CI 64.4%-79.9%), and accuracy 59.7% (95% CI 52.3%-66.8%).

On the other hand, the area under the curve for the corrected BA was 0.711 with 95% CI 0.623-0.800 ($P < 0.001$). For prediction of the

Table 4: PCI procedure and outcome parameters.

PCI parameters		Straight bifurcation model N=73	Wide bifurcation model N=112	Test value	P value
Jailed Wire in side branch		26 (35.6%)	49 (43.8%)	1.213**	0.271
Main vessel pre-dilatation		37 (50.7%)	66 (58.9%)	1.217**	0.270
Side branch pre-dilatation		3 (4.1%)	8 (7.1)	0.727+	0.531
Main vessel dissection		1 (1.4%)	6 (5.4%)	1.930+	0.165
Side branch dissection		1 (1.4%)	2 (1.8%)	0.048+	1.000
Stent diameter/distal main vessel diameter ratio more than 1		24 (32.9%)	41 (36.6%)	0.270**	0.603
Proximal optimization technique		37 (50.7%)	66 (59.5%)	1.376**	0.241
TIMI flow in side branch after PCI	**TIMI 0**	8 (11.0%)	4 (3.6%)	29.131**	<0.001
	TIMI 1	11 (15.1%)	5 (4.5%)		
	TIMI 2	21 (28.8%)	10 (8.9%)		
	TIMI 3	33 (45.2%)	93 (83.0%)		
Percentage of ostial side branch stenosis after PCI (%)		67.1 ± 34.6	48.3 ± 31.6	116.500*	<0.001
Side branch compromise after MV stent deployment		38 (52.1%)	17 (15.2%)	28.767*	<0.001

Where: *: Mann Whitney test; **: chi-square test; +: Fisher exact test; TIMI: thrombolysis in myocardial infarction; PCI: percutaneous coronary intervention and the values are presented as n (%) or mean ± standard deviation.

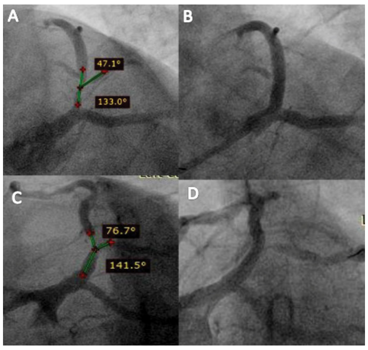

Figure 2: Case presentation of the two bifurcation models. A: Spider view showing pre-procedure LAD/D bifurcation angles in the straight bifurcation model where the distal bifurcation angle was 47° the proximal bifurcation angle was 133°, and the corrected bifurcation angle was 180°. B: Total occlusion of the diagonal branch after LAD stenting. C: Spider view showing pre-procedure LAD/D bifurcation angles in the wide bifurcation model where the distal bifurcation angle was 77° the proximal bifurcation angle was 141°, and the corrected bifurcation angle was 218°. D: Diagonal branch was preserved after LAD stenting. LAD: Left anterior descending artery, D: Diagonal artery.

SB compromise, the corrected BA (180) had a sensitivity of 71.6% (95% CI 59.9%-81.5%), specificity of 73.2% (95% CI 64.0%-81.1%), positive predictive value of 63.9% (95% CI 55.8%-71.2%), negative predictive value of 79.6% (95% CI 72.8%-85.1%), and accuracy of 72.6% (95% CI 65.6%-78.9).

Comparison between the two ROC curves was performed revealing that the area under the curve of the corrected BA was significantly higher than that of the distal BA (*P* = 0.023). Furthermore, the diagnostic accuracy of the corrected BA was better than that of the distal BA.

Multivariate Analysis

Step wise approach logistic regression analysis revealed that the corrected BA was among the independent predictors of SB compromise after MV stent deployment. The independent predictors were corrected BA, Ostial SB stenosis percentage before PCI, stent diameter/distal MV diameter ratio, jailed wire in SB, and lesion thrombus. The distal BA was not identified among the best predictors of SB compromise (Table 5).

Discussion

Importance of the Study

In clinical practice, Coronary bifurcation coronary artery disease

Table 5: Multivariate analysis using step wise approach logistic regression analysis to pick up independent predictors of side branch compromise.

Independent Predictors	Odds Ratio	95% CI of Odds Ratio	P value
1- Corrected bifurcation angle	0.906	(0.863-0.951)	<0.001
2- Pre-procedure ostial side branch stenosis percentage	1.036	(1.022-1.051)	<0.001
3- Stent diameter/distal main vessel reference diameter > 1	7.755	(3.136-19.178)	<0.001
4- Jailed wire in side branch	0.149	(0.056-0.396)	<0.001
5- Lesion thrombus	3.506	(1.301-9.445)	0.013

Where: CI: Confidence interval.

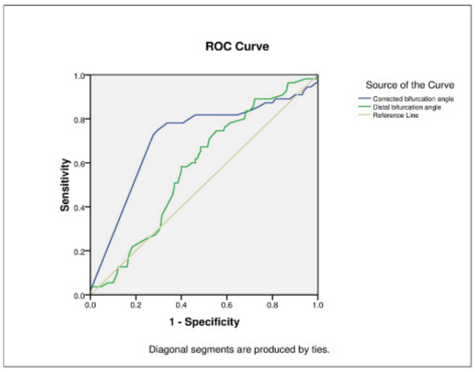

Figure 3: ROC curve analysis of the distal and the corrected bifurcation angles for prediction of side branch compromise after provisional bifurcation coronary intervention.

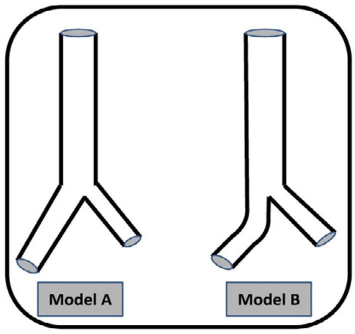

Figure 4: Models of corrected bifurcation angle which is the sum of proximal and distal bifurcation angles. Model A means wide bifurcation model with corrected bifurcation angle >180°. Model B means straight bifurcation model with corrected bifurcation angle = 180°.

is frequent scenario requiring PCI [1]. Current guidelines recommend provisional MV PCI over two stent strategy in terms of reduction of target lesion failure and cardiovascular mortality [3,14,15]. Therefore, it is better to predict the risk of SB compromise before proceeding with provisional PCI. The relation between BA and fate of SB during provisional PCI is a current hot debate.

Summary of Key Findings

Our study demonstrated that bifurcation lesions in the straight bifurcation model had a higher incidence of SB compromise in comparison with lesions in the wide bifurcation model ($P < 0.001$). The corrected BA was better than the distal BA in prediction of SB compromise after provisional PCI with statistically significant difference ($P = 023$). Furthermore, the corrected BA was among the best independent predictors of SB compromise in association with high SB ostial stenosis percentage prior to PCI, stent diameter/distal MV diameter ratio > 1, absence of jailed wire in SB, and presence of lesion thrombus.

Previous Research

Previous studies demonstrated that the risk of SB compromise had increased with narrow distal BA [8,10,16,17]. Our study was concordant with these studies and the risk of carina shift or plaque shift with narrow distal BA could explain such finding [18]. Other equivocal studies, including intravascular ultrasound (IVUS) guided studies, did not demonstrate any association between the distal BA and the incidence of SB compromise [19-21].

On the other hand, more recent studies concluded that the risk of SB compromise had increased with wider distal BAs [6,7,9]. They explained such finding with the Pressure drop in SB with wider distal BA [22], the circular shape of SB ostium in the wide distal BA with subsequent small ostium circular area which was believed to be a sensitive predictor of SB compromise [2,23], and the increase in bifurcation core plaque burden with the wide distal BA due to decrease in the wall shear stress [24-27].

The impact of corrected BA on the risk of SB compromise during provisional PCI is not studied yet. Our study demonstrated that corrected BA was among the independent predictors of SB compromise. Previous research studied only the distal BA considering that the MV is always a straight vessel [6,7]. However, MV could change its angle at site of bifurcation. In real life, we have two models of coronary bifurcation; model A that involves wide corrected BA when the sum of distal and proximal bifurcation angles is more than 180°, and model B that involves straight bifurcation model with corrected BA ≤ 180° (Figure 4). In our study, the risk of SB compromise was significantly high in patients with straight bifurcation model. We could explain such new result with the direction of stent strata opening. Theoretically, the direction of stent strata opening could open the SB otium in model A and could occlude it in model B.

To the best of our knowledge, we are the first study to compare between the corrected BA and the distal BA regarding the risk of SB compromise. The area under the curve of the corrected BA was better than that of the distal BA with statistically significant difference.

Many studies confirmed that stent oversize in the distal MV could increase the risk of carina shift and SB compromise which is concordant to our study [28]. However, Zhang et al. study reported that stent diameter/distal MV reference diameter did not affect the fate of SB [6]. The importance of Jailed wire was demonstrated by many studies to decrease the risk of carina shift, to decrease the risk of SB compromise, and to be a marker for the re-cross if SB was compromised [3,29,30]. Our study was concordant with such finding as non-wiring of the SB was among the best predictors of SB compromise. However, our study was discordant with many studies that reported that jailed wire in SB did not impact the fate of SB [6,20].

In our study, the increased pre-procedure ostial SB stenosis percentage was one of the predictors of SB compromise which is concordant with many studies that proposed bifurcation core stenosis and SB stenosis as independent predictors of SB compromise [9,20].

Many studies had recommended ACS as a strong predictor of SB compromise [20]. Furthermore, IVUS guided studies concluded that unstable plaques at bifurcation lesions are more liable for SB compromise [31]. This is concordant with our study that demonstrated that presence of lesion thrombus was one of the best predictors of SB compromise.

Our study has several strength points:

- The study was a prospective cohort study.
- Bifurcation angles were checked by two separate cardiologists to minimize observing bias.
- Bifurcation angles were measured between the central axes of the vessels to minimize the impact of plaque irregularity on the measurement accuracy.
- Follow up was performed for all cases during the PCI procedure to avoid missing recordings. However, the study was observation in nature with small sample size. Furthermore, a dedicated bifurcation quantitative coronary angiography was not available.

We are in unmet need for future study with a larger sample size and longer follow up duration in order to test the impact of the corrected BA on immediate and long term angiographic and clinical outcomes.

Conclusion

Straight bifurcation model with corrected BA = 180° is one of the independent predictors of SB compromise after provisional bifurcational intervention. Compared to the distal BA, the corrected BA presented a better predictive accuracy with statistically significant difference. We recommend a future study with a larger sample size and longer follow up duration in order to test the impact of the corrected BA on the immediate and the long term angiographic and clinical outcomes.

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