Int J Clin Exp Med 2017;10(11):15724-15729
www.ijcem.com /ISSN:1940-5901/IJCEM0065377

Original Article

Cutting balloon versus common balloon in coronary bifurcation lesions patients with diabetes

Shoudong Wang, Zhiming Ge, Beian You, Sen Zhang, Xuanlong Li, Hefeng Wang, Qingfeng Meng

Department of Cardiology, Qilu Hospital of Shandong University (Qingdao), Qingdao City, Shandong Province, China

Received September 11, 2017; Accepted October 20, 2017; Epub November 15, 2017; Published November 30, 2017

Abstract: Objective: To investigate the efficacy of cutting balloon (CB) versus plain balloon (PB) in percutaneous coronary intervention (PCI) in the management of coronary artery bifurcation lesions patients complicated with diabetes mellitus (DM). Methods: From May 2015 to May 2016, 88 coronary artery bifurcation lesions patients with DM admitted to our hospital were recruited in this study. The participants were assigned to undergo pre-dilation of bifurcation lesions with CB alone (the CB group) or with PB alone (the PB group). Stents were implanted into the main coronary artery lesions after pre-dilation among all the patients in the two groups. The clinical data at baseline and the characteristics of bifurcation lesions were compared between the two study groups. The primary outcome measures included minimal lumen diameter (MLD) of the main vessels and the side branches, side branch extrusion and occlusion, while the secondary outcome was perioperative complications. Results: No striking differences in gender, age, comorbidities of hyperlipidemia and hypertension, the left ventricular ejection fraction and the number of diseased arteries, bifurcation site, lesion classification, DM stage, fasting blood glucose, fasting insulin and glycosylated hemoglobin were observed between the two groups ($P>0.05$). Before PCI, the differences in MLD of main vessels and side branches were insignificant among the patients in the two groups ($P>0.05$); but after the procedure, MLD of main vessels and side branches increased markedly, with a greater magnitude of increase in the MLD of side branches among the patients in the CB group ($P<0.05$). According to the results of immediate postoperative angiography, the rates of side branch extrusion and occlusion were smaller but the number of unaffected side branches was larger in the CB group than in the PB group ($P<0.05$). All the patients in the two groups had no perioperative death, arrhythmia, heart failure or other complications, but the episodes of perioperative myocardial infarction in the CB group were fewer than those in the PB group ($P<0.05$). Conclusion: CB pre-dilation of bifurcation lesions applied in PCI for artery bifurcation lesions patients with DM is associated with better protection of side branches, reduction in side branch occlusion and perioperative complications. Thus, CB is of greater significance in clinical practice than PB.

Keywords: Cutting balloon, common balloon, diabetes mellitus, coronary artery bifurcation lesion, percutaneous coronary intervention

Introduction

Percutaneous coronary intervention (PCI) has become one of the most effective surgical techniques for treating coronary bifurcation lesions, but it often comes along with complex procedure, high risk and postoperative restenosis [1]. Treatment of coronary bifurcation lesions with PCI is difficult and at high risk because the release of stents to the main branches extrudes stenotic side branches, resulting in further stenosis of side-branch ostium, or even occlusion, which has become one of the decisive causes for the occurrence of major adverse cardiovascular events in the patients undergoing PCI [2]. The main purpose of PCI for treating coronary bifurcation lesions is to ensure the patency of the main coronary arteries and side branches, reducing the occurrence of postoperative restenosis in the side branches. Clinically, the kissing balloon technique is a preferred technique for protecting the side branches of coronary arteries. For the rich and smaller target branches, however, it is difficult to achieve dilation of the stenotic segments by using plain balloon (PB), with low rate of procedural success [3]. The above dilemma has allowed the development of cutting balloon (CB). With metal blades

evenly distributing on the surface of the balloon, the CB can cut, separate and displace the plaque, preventing displaced plaque from occluding the vascular branches [4]. Compared with PB, CB can make the stenotic segments of coronary artery regular in shape, minimize the damages to the intima and media in the process of stent expansion, so as to protect the side branches and diminish the incidence of perioperative complications. As a result, CB is particularly suitable for the treatment of the rich and small side branches [5]. In addition, for coronary artery disease patients complicated with DM, which is a common coexisting disease, coronary artery disease often manifests as multiple vessels, diffuse stenosis at many sites, and poor vascular compliance. Such patients are at higher risk in the case of PCI with PB. Nevertheless, few reports have concerned with CB use. Therefore, in the current study, we compared the efficacy of CB and PB for PCI in the management of coronary artery bifurcation lesions patients complicated with DM.

Materials and methods

General data

From May 2015 through May 2016, a total of 88 coronary artery bifurcation lesions patients with diabetic mellitus undergoing PCI, who were admitted to the Department of Cardiovascular Medicine in our hospital, were selected as subjects in this study. A total of 96 coronary bifurcation lesions of Stage D or F on Duke's classification were identified. The patients were randomly divided into the CB group and the PB group. The patients were eligible for inclusion if they had coronary artery bifurcation lesions on coronary angiography, branch vessel diameter of 2-3 mm, with stenosis higher than 75%, side branches in need of protection as a result of extrusion of side branch ostium from stenting release. They were also requied to have DM at the intermediate or advanced stage, without severe complications including diabetic nephropathy, ocular complications or diabetic foot, with the blood glucose levels which could be stabilized after hypoglycemic therapy. In addition, the study obtained approval from the Hospital Ethics Committee, and each patient and (or) their families supplied us with written informed consent. The patients were excluded from the study if they had target lesions which were restenosis lesions or graft lesions with serious calcification, angulation and flexure, ST-segment elevation acute myocardial infarction, previous PCI procedures or contraindications to antiplatelet drugs.

Study method

All the patients underwent coronary angiography via the transfemoral or transradial approach. The angiograms with regard to the left and right main coronary arteries at different sites of the patients were acquired. Before and after the PCI procedure, they received quantitative measurements of the main and side branch arteries in size. Before the PCI procedure, they were given aspirin, plavix, statins lipid-lowering agents, and hypoglycemic therapy to stabilize blood glucose and pressure. During the PCI procedure, they received intravenous infusion of the above drugs at 100 U/kg, and heparin was added when the PCI procedure was longer than 2 h. Stenting was performed for the main artery bifurcation lesions, and stenting was also applicable for the side and main coronary artery if necessary. Appropriate balloons were selected based on lesion length and the ratio of balloon diameter to reference diameter (1.0-1.1:1.0). The patients in the CB group received pre-dilation of artery coronary bifurcation lesions with CB alone whereas those in the PB group received pre-dilation of the lesions with PB alone. After full pre-dilation of bifurcation lesions with balloons, stents were implanted into the main vessels. The treatment regimen decision, primarily kissing-balloon dilatation technique or stent implantation, was made on the basis of the degree of extrusion to the side branch from the implanted stent at the main artery. When the side branches showed beneficial hemodynamics and stenosis diameter of less than 50%, the patient needed close observation but no treatment. In case of evident abnormal hemodynamics in the side branch, with thrombolysis in myocardial infarction (TIMI) flow lower than Grade 2, and stenosis dimeter no less than 50%, kissing-balloon dilatation or stent implantation was performed based on the dissection and occlusion profiles. In the process of pre-dilation with CB, CB was sure to maintain in a negative pressure state, without containing any gas or liquid and with the blades uniformly distributing on the surface of the balloon. To ensure a good support, the CB was delivered by appropriate catheters or

Table 1. Clinical and baseline data of patients

Variable	CB (n=44, 47 bifurcation lesions)	PB (n=44, 49 bifurcation lesions)	Statistic value	*P* value
Male (%)	26 (59.09)	25 (56.82)	0.745	0.586
Age (year)	58.9±0.35	59.2±0.41	0.415	0.745
Hyperlipidemia (%)	13 (29.55)	14 (31.82)	0.625	0.632
Hypertension (%)	24 (54.55)	22 (50.00)	0.952	0.452
LVEF (%)	0.584±0.084	0.592±0.091	1.044	0.145
Diseased vessels				
One-vessel	12	13		
Two-vessel	25	23	1.239	0.095
Three-vessel	7	8		
Bifurcation site				
ADR/FDB (%)	31	30	0.145	0.984
LCA/FOMB (%)	5	6		
RCA/PLVB or PDA (%)	11	13		
Lesion classification				
Duke D (%)	35	34	0.412	0.824
Duke F (%)	12	15		
DM stage (n)				
Intermediate	18	20	0.624	0.541
Advanced	26	24		
FBG (mmol/L)	5.81±0.022	5.68±0.019	1.065	0.241
FI (mU/L)	24.9±0.016	25.3±0.014	1.159	0.124
GH (%)	6.21±0.023	5.96±0.015	0.965	0.136

Note: With the use of a t-test, a chi-square test and a rank sum test. LVEF denotes left ventricular ejection fraction, ADR, anterior descending artery, FDB, first diagonal branch, LCA, left circumflex artery, FOMB, first obtuse marginal branch, RCA, right coronary artery, PLVB, posterior left ventricular branch, PDA, posterior descending artery, FBG, fasting blood glucose, FI, fasting insulin, GH, glycosylated hemoglobin.

guide wires. Pressure in the course of CB predilation should be gradually increased, then released and removed.

Outcome measures and outcomes-related criteria

The primary outcomes included the minimal lumen diameter (MLD) of the main vessels and the side branches, side branch extrusion and occlusion and perioperative complications. Coronary angiography was performed before and after stent implantation; the software specified for quantitative analysis was applied for measurement of the MLD of the main vessels and the side branches; whether there was extrusion or occlusion at the side branch ostium was observed. In the first 48 h after PCI, regular monitoring of myocardial predictors was made among all the patients, and perioperative complications including death, arrhythmia, heart failure, and myocardial infarction were also observed [6, 7].

Statistical analysis

Experimental data were processed using the SPSS software, version 18.0. Measurement data with normal distribution and homogeneity of variance were represented as mean ± standard deviation, and a t-test was utilized for between-group comparisons, whereas measurement data without normal distribution were expressed as M (Q1, Q3), and a Mann-Whitney U test was applied for between-group comparisons. Enumeration data was assessed with the chi-square test. Ordinal data was measured with the rank sum test. P<0.05 indicated significant differences in data between groups.

Results

Clinical data of patients at baseline

The clinical data including sex, age, comorbidities of hyperlipidemia and hypertension, left ventricular ejection fraction, the number of diseased vessels, bifurcation site, lesion classification, DM stage, fasting blood glucose, fasting insulin and glycosylated hemoglobin were compared between the two groups, indicating no striking differences (P>0.05, **Table 1**).

MLD of the main vessels and side branches

The MLD of the main vessels and side branches among all the patients after PCI increased significantly than those before PCI, with a markedly greater increase in the CB group instead of in the PB group (P<0.05, **Table 2**).

Immediate postoperative angiography

The immediate postoperative angiography of the CB group showed that the rates of side branch extrusion and occlusion were substan-

Table 2. Minimal lumen diameter of the main vessels and side branches before and after PCI (mm)

	Case	MLD of main vessel			MLD of side branch		
		Pre-PCI	Post-PCI	Difference	Pre-PCI	Post-PCI	Difference
CB	44	2.22±0.19	3.39±0.15	1.25±0.09	1.41±0.09	1.94±0.14	0.59±0.05
PB	44	2.19±0.23	2.91±0.26	0.71±0.08	1.39±0.11	1.76±0.08	0.31±0.07
t		0.716	1.514	1.623	0.698	1.842	6.845
P		0.095	0.074	0.071	0.098	0.062	0.024

Note: With the use of a t-test.

Table 3. Immediate postoperative angiographic results (%)

Variable	Case	Extrusion of SB (%)	Occlusion of SB (%)	Unaffected SB (%)
CB	44	9.09 (4/44)	2.27 (1/44)	88.64 (39/44)
PB	44	27.27 (12/44)	11.36 (5/44)	61.36 (27/44)
χ^2		12.045	15.845	11.045
P		0.041	0.026	0.048

Note: With the use of a chi-square test.

Table 4. Perioperative complications in the two groups (%)

Variable	Case	Perioperative myocardial infarction (%)
CB	44	4.55 (2/44)
PB	44	11.36 (5/44)
χ^2		11.465
P		0.045

Note: With the use of a chi-square test.

tially lower, but the rate of unaffected side branches was markedly higher compared to the PB group (P<0.05, **Table 3**).

Perioperative complications

As for complications, no death, arrhythmia and heart failure occurred among the all patients in the perioperative period, but fewer episodes of perioperative myocardial infarction occurred in the CB group versus the PB group (P<0.05, **Table 4**).

Discussion

In the treatment of patients with coronary bifurcation lesions complicated with DM by PCI, the dilation mode with CB is different from that with PB. Dilation with PB only leads to plaque extrusion, which is prone to rupture or dissection in the vascular walls, thereby damaging the endocardium and promoting thrombosis. In such case, stent implantation may give rise to distal vascular no-reflow and restenosis [8]. Moreover, plaque displacement may damage the side branch ostium, and even result in severe stenosis and occlusion in side branches. In a study conducted by Zhao et al., among 89 patients with coronary artery bifurcation lesions receiving CB or PB, a greater number of patients with CB had successful bifurcation operations and their incidence of postoperative restenosis was significantly lower than those with PB [9]. It is generally believed that the effect of dilation with CB or PB is similar in large bifurcation lesions. When it comes to lesions in rich and small side branches, especially for diffuse bifurcation lesions patients with DM, however, the use of CB for pre-dilation can effectively reduce the chance of occlusion in small side branches [10-12]. Xiong et al., also found that CB dilation used in patients with diffuse coronary artery bifurcation lesions could significantly reduce the rates of side branch restenosis and occlusion [13]. Zimarino and colleagues argued that the use of CB in PCI for patients with coronary artery bifurcation lesions had better effect of revascularization in the patients after 6 months of follow-up. According to Xu et al., in a study with regard to 87 patients with coronary artery bifurcation lesions undergoing PCI with CB or PB, a higher rate of procedural success but a lower rate of restenosis were present in patients with CB as compared to those with PB [15]. In the current study, a total of 88 coronary artery bifurcation lesions patients with DM were treated with PCI. All the patients had lesions in the side branch ostia and received CB or PB pre-dilation. Among them, the patients receiving pre-dilation of the main vessels and the side branches with CB greatly improved protection of side branches, side branch extrusion and blood flow and perioperative complications.

In the present study, we found that all the patients in the two groups had significantly larger MLD of the main arteries and side branches after PCI. The magnitude of increase in MLD of side branches was substantially greater among the patients in the CB group than those in the PB group. What's more, the immediate postoperative angiography demonstrated lower rates of extrusion and occlusion in the side branches but a higher rate of unaffected side branches in the CB group. This might be attributable to the afore-mentioned mechanism of action of CB. A study conducted by Sakamoto et al., has also confirmed the mechanisms of CB [16]. Unlike PB, CB mainly cuts and extrudes plaques, rather than dilates the vessel walls mechanically, which is related to the structure of CB. A great number of metal blades distribute on the surface of CB. In the process of CB dilation, the metal blades accordingly cut longitudinally to separate the plaque; metal blades diminishes gradually in size with the full dilation of CB and then evenly extrudes the vascular walls to reduce vascular adventitial injury; after repeated cutting (with each cutting at different location), the plaque is segmented, which can preclude displaced plaque from blocking the side branch ostia in the process of stent release. Moreover, the reason why CB dilation can reduce restenosis and occlusion of side branches is that CB can segment the plaques and reduce the chance of vascular elastic retraction. In previous PCI, it was believed that repair of the main vessels could guarantee the myocardial blood supply, so no attention was paid to repair of side branches, especially the rich and small side branches. In recent years, however, multiple studies have indicated that it is of great clinical value to ensure the patency of small branches in the course of PCI [17-19]. Given that coronary artery bifurcation lesions patients with DM tend to have multi-vessel, multi-location and diffuse pathologic characteristics, compared with those with coronary artery lesions alone, their vascular compliance was significantly reduced, CB in them thereby can realize its unique value as PB dilation is more prone to coronary artery dissection, rupture, and even acute occlusion [20]. For coronary artery bifurcation lesions patients complicated with DM, PCI following CB pre-dilation can largely protect side branches and reduce stenosis or occlusion in the side branch ostia while reducing the occurrence of perioperative myocardial infarction, which may be due to the mechanisms of CB. The latest research shows that after PCI, a large number of patients with coronary bifurcation lesions were complicated with stenosis or occlusion in the small side branches, and secondary to symptoms of chest pain, with strikingly higher levels of myocardial predictors, which might be due to the unprotected side branches in the process of PCI. In the present study, no perioperative death, arrhythmia, heart failure and other complications occurred in all the patients in the two groups, but significantly lower rate of perioperative myocardial infarction was observed in the CB group ($P< 0.05$), which is consistent with the above theory. This fully demonstrates that the use of CB for pre-dilation of bifurcation lesions in PCI for treating patients with coronary artery bifurcation lesions and DM has good prognosis and significantly reduces the occurrence of perioperative myocardial infarction than PB.

The results of our current study indicates that pre-dilation of bifurcation lesions with CB in PCI for treatment of coronary artery bifurcation lesions patients with DM is effective in protecting side branches, reducing the incidences of side branch occlusion and perioperative complications. As a result, it is of greater value in clinical practice compared with PB. Surely, there were several inevitable limitations in this study due to the small sample size and a paucity of data on long-term follow-up and intravascular angiography. In addition, with diverse sites of the lesions and differences in individual patients, it is difficult to come to an accurate conclusion. Whether CB would cause plaque rupture and lead to side branch restenosis or occlusion remains controversial. Therefore, it is necessary for us to further increase the sample size and prolong the follow-up time to validate the efficacy and safety of CB pre-dilation in PCI, so as to provide more evidence for the improvement in the efficacy of PCI in the treatment of patients with coronary bifurcation lesions.

Disclosure of conflict of interest

None.

Address correspondences to: Qingfeng Meng, Department of Cardiology, Qilu Hospital of Shandong University (Qingdao), No. 758 Hefei Road, Qingdao City, Shandong Province, 266035, China. Tel: +86-0532-66850660; E-mail: qingfengmeng6@126.com

References

[1] Zhang HW, Chen YD, Sun ZJ, Wang JD, Chen S, Li CW, Liu JX, Zhang J and Lu L. Protective effects of cutting balloon on coronary artery branches during interventional therapy. Chinese Journal of Evidence-Bases Cardiovascular Medicine 2017; 9: 297-300.

[2] Kubo S, Kadota K, Sabbah M, Otsuru S, Hasegawa D, Habara S, Tada T, Tanaka H, Fuku Y, Katoh H, Goto T and Mitsudo K. Clinical and angiographic outcomes after drug-eluting stent implantation with triple-kissing-balloon technique for left main trifurcation lesion: comparison of single-stent and multi-stent procedures. J Invasive Cardiol 2014; 26: 571-578.

[3] Yumoto K, Sasaki H, Aoki H and Kato K. Successful treatment of spontaneous coronary artery dissection with cutting balloon angioplasty as evaluated with optical coherence tomography. JACC Cardiovasc Interv 2014; 7: 817-819.

[4] Ma YL, Wang WM, Liu J, Zhao H, Lu MY and Li Qi. Branched cutting balloon dilation combined with branched balloon protection technique in bifurcation lesions. Chinese Journal of Interventional Cardiology 2017; 25: 92-95.

[5] Watanabe M, Uemura S, Sugawara Y, Ueda T, Soeda T, Takeda Y, Kawata H, Kawakami R and Saito Y. Side branch complication after a single-stent crossover technique: prediction with frequency domain optical coherence tomography. Coron Artery Dis 2014; 25: 321-329.

[6] Liu J, Jun J, Zhang TL, Dai YH and Huang J. Cutting balloon angioplasty for coronary artery in-stent restenosis in elderly patients. Chinese Journal of Gerontology 2016; 36: 6109-6111.

[7] Ferenc M, Ayoub M, Buttner HJ, Gick M, Comberg T, Rothe J, Valina CM, Hochholzer W and Neumann FJ. Long-term outcomes of routine versus provisional T-stenting for de novo coronary bifurcation lesions: five-year results of the Bifurcations Bad Krozingen I study. EuroIntervention 2015; 11: 856-859.

[8] Lassen JF, Holm NR, Stankovic G, Lefevre T, Chieffo A, Hildick-Smith D, Pan M, Darremont O, Albiero R, Ferenc M and Louvard Y. Percutaneous coronary intervention for coronary bifurcation disease: consensus from the first 10 years of the European bifurcation club meetings. EuroIntervention 2014; 10: 545-560.

[9] Zhao J, Wu YJ, Qian J, Yu MY, Teng SY, Luo T, Song GY and Sun ZW. Clinical observation of cutting balloon combining single stent crossover technique for treating the patients with coronary bifurcation lesions. Chinese Circulation Journal 2016; 31: 546-549.

[10] Tang Z, Bai J, Su SP, Wang Y, Liu MH, Bai QC, Tian JW, Xue Q, Gao L, An CX and Liu XJ. Cutting-balloon angioplasty before drug-eluting stent implantation for the treatment of severely calcified coronary lesions. J Geriatr Cardiol 2014; 11: 44-49.

[11] Peng J, Lin XM, Zhang YY and Li TF. Application of cutting balloon in the treatment of diabetes mellitus complicated with coronary artery disease with slight calcification. Hainan Medical Journal 2015; 1123-1125.

[12] Nishino M, Lee Y, Nakamura D, Yoshimura T, Taniike M, Makino N, Kato H, Egami Y, Shutta R, Tanouchi J and Yamada Y. Differences in optical coherence tomographic findings and clinical outcomes between excimer laser and cutting balloon angioplasty for focal in-stent restenosis lesions. J Invasive Cardiol 2012; 24: 478-483.

[13] Xiong R, Liu WX, Chen LY, Ning SQ, Kang TD and Li J. Safety and effectiveness of cutting balloon versus plain balloon in bifurcation lesions. Journal of Cardiovascular and Pulmonary Diseases 2015; 34: 15-18.

[14] Zimarino M, Corazzini A, Ricci F, Di Nicola M and De Caterina R. Late thrombosis after double versus single drug-eluting stent in the treatment of coronary bifurcations: a meta-analysis of randomized and observational Studies. JACC Cardiovasc Interv 2013; 6: 687-695.

[15] Xu B, Zhao L and Zhang XY. Meta-analysis on the efficacy and safety of the cutting balloon and plain balloon treatment of coronary in-stent restenosis. Chinese Journal of Arteriosclerosis 2014; 22: 298-303.

[16] Sakamoto N, Hoshino Y, Mizukami H, Sugimoto K, Yamaki T, Kunii H, Nakazato K, Suzuki H, Saitoh S and Takeishi Y. Intravascular ultrasound predictors of acute side branch occlusion in coronary artery bifurcation lesions just after single stent crossover. Catheter Cardiovasc Interv 2016; 87: 243-250.

[17] Huang ZY, Qian JY and Ge JB. Very late stent thrombosis due to multiple stent fracture and stent malapposition. Chin Med J (Engl) 2013; 126: 186-189.

[18] Tang Z, Bai J, Wang Y, Su SP, Ma QH, Liu MH, Tian JW, Gao L, Song KX and Li YH. Efficacy and safety evaluation on cutting balloon angioplasty for treating the patients with severe coronary calcification lesions under intravascular ultrasound guidance. Chinese Circulation Journal 2014; 29: 12-15.

[19] Li Q, He Y, Jiang R and Huang D. Using sheathless standard guiding catheters for transradial percutaneous coronary intervention to treat bifurcation lesions. Exp Clin Cardiol 2013; 18: 73-76.

[20] Li MZ, Wu Q, Zhao AM, Li ZY and Li XD. Efficacy and safety of the main stenting and side branch embedded balloon in treatment of coronary bifurcation lesions. South China Journal of Cardiovascular Diseases 2014; 20: 567-570.