Original article

Hemodynamic changes of fractional flow reserve after double kissing crush and provisional stenting technique for true bifurcation lesions

YE Fei, CHEN Shao-liang, ZHANG Jun-jie, ZHU Zhong-sheng, KAN Jing, TIAN Nai-liang, LIN Song, LIU Zhi-zhong, YOU Wei, XU Hai-mei and XU Jing

Keywords: *double kissing crush; bifurcation; provisional; fractional flow reserve*

Background Fractional flow reserve (FFR)-guided percutaneous coronary intervention (PCI) is associated with fewer unfavorable events. However, the hemodynamic change in FFR after different stenting approaches for bifurcation lesions is still not fully studied. The aim of this study was to analyze the hemodynamic changes in FFR after double kissing (DK) crush and provisional side branch (SB) stenting (PS) for true coronary bifurcation lesions.

Methods Seventy-five patients with true bifurcated lesions were randomly divided into DK (*n*=38) and PS (*n*=37) groups. Additional SB stenting in the PS group was required if there was any pinched SB ostium >70% stenosis, or ≥ type B dissection, or TIMI flow <grade 3. FFR at hyperemia in the main vessel (MV) and SB was measured prior- and post-stenting, and at 8 months follow-up.

Results Baseline clinical, angiographic and lesion characteristics were matched well between the two groups, with the exception of the final kissing balloon inflation (FKBI, 100.0% in the DK vs. 83.8% in the PS group, *P* <0.001). Baseline FFR was comparable between the DK and the PS groups, however, the acute gain and late loss of SB FFR at 8-month follow-up in the DK group were 0.18±0.15 and –0.06±0.11, compared to 0.12±0.18 (*P*=0.044) and –0.002±0.07 (*P*=0.037) in the PS group, respectively. MV FFR post-stenting >0.94 was seen in about 40% of patients. There was no significant difference in the clinical events at 1-year follow-up between the two groups.

Conclusions DK crush was associated with improved acute gain and late loss of SB FFR. The lower rate of FFR >0.94 after stenting underscored the further improvement of stenting quality.

Chin Med J 2012;125(15):2658-2662

Fractional flow reserve (FFR) is an invaluable index well correlated with noninvasive testing to evaluate hemodynamic significance of coronary artery stenosis in the cath lab.[1,2] It can guide cardiologists in making decisions about percutaneous coronary intervention (PCI) for intermediate lesions, left main disease, multivessel disease, and bifurcation lesions.[3-7] Compared with angio-guided PCI, FFR-guided PCI can get more favorable long-term results.[8] Previous studies have confirmed the role of FFR-guided stenting strategy for ostial or pinched SB. However, the hemodynamic changes to FFR after stenting bifurcation lesions have not been completely studied.[9] Different strategies (1-stent or 2-stent strategy) for bifurcation lesions have comparable major adverse cardiac event (MACE) rates.[10] Our study previously reported that double kissing (DK) crush stenting had a higher post-stenting FFR value when compared with provisional stenting (PS),[11] however, the hemodynamic change of FFR has not yet been systematically studied. Therefore, the present pilot study aimed to evaluate the dynamic changes and functional significance of FFR after DK and PS strategies for true bifurcation lesions.

METHODS

Study population

Seventy-five patients with single *de novo* true bifurcation lesion by Medina classification (type 1, 1, 1 or 1, 0, 1 or 0, 1, 1) underwent PCI between October 2008 and January 2011. They were randomly assigned to DK crush (*n*=38) or PS (*n*=37) techniques at a 1:1 ratio. FFRs at both the main vessel (MV) and side branch (SB) were successfully calculated in 68 patients. The inclusion criteria were: (1) age 18–75 years, with left ventricular ejection fraction (LVEF) >30%, (2) SB diameter were ≥2.25 mm by visual estimation, (3) each lesion in the MB and SB could be completely covered by two rapamycin eluting stents. The exclusion criteria were: (1) life expectancy <1 year, (2) women who were pregnant, (3) severe diffuse or calcified lesions in the MV or SB, (4) plasma platelet count $<10\times10^9$/L or S-creatinine >3 mg/dl, (5) cerebrovascular events within 6 months, (6) allergy to aspirin, clopidogrel, or sirolimus, (7) ST elevation myocardial infarction (STEAMI) or other condition with refractory low blood pressure, (8) intolerance to injection of adenosine.

DOI: 10.3760/cma.j.issn.0366-6999.2012.15.003

Department of Cardiology, Nanjing First Hospital of Nanjing Medical University, Nanjing, Jiangsu 210006, China (Ye F, Chen SL, Zhang JJ, Zhu ZS, Kan J, Tian NL, Lin S, Liu ZZ, You W, Xu HM and Xu J)

Correspondence to: Dr. CHEN Shao-liang, Department of Cardiology, Nanjing First Hospital of Nanjing Medical University, Nanjing, Jiangsu 210006, China (Tel: 86-25-52271351. Fax: 86-25-52208048. Email: chmengx@126.com)

Medication

All enrolled patients were pretreated with 300 mg of aspirin and 300 mg of clopidogrel as a loading dose 6–12 hours before the PCI procedure, then 300 mg of aspirin daily for one month followed by 100 mg of aspirin daily for life with 75 mg/d of clopidogrel for at least for one year. Unfractionated heparin was immediately administered by bolus injection (100 U/kg) to maintain an activated clotting time (ACT) >280 seconds during the whole procedure period. Repeat ACT checking was not mandatory. Glycoprotein receptor antagonists could be used at the discretion of the operator.

Percutaneous coronary interventional procedure

The PS technique was performed as usual, after wiring the MV and SB, stenting the MV with jailed wire in the SB. Treatment criteria for the SB were as follows: diameter of the residual stenosis >70% by visual estimation, >type B dissection, and thrombolysis in myocardial infarction (TIMI) <grade 2. If kissing balloon inflation with a smaller size balloon (about a quarter of the size of SB reference diameter) used in the SB did not succeed, a T stent technique with a little protrusion (TAP) was performed and followed by final kissing balloon inflation (FKBI).

The DK crush technique was described previously.[12] After wiring both the MV and SB, stenting the SB followed by balloon crush, the first kissing balloon was inflated after rewiring the SB, stenting the MV, and then FKBI (same size noncompliant balloon kissing at high pressure ≥1418.55 kPa). Intravascular ultrasound (IVUS) and the administration of glycoprotein IIb/IIIa inhibitors were left to operator's discretion.

Drug eluting stents selection

Sirolimus-eluting stents (SES), CYPHER select plus (Cordis, Johnson & Johnson, Miami Lakes, USA) or FIREBIRD-2 (a durable polymer-based SES, MicroPort, Shanghai, China), were used in the current study. Operators could deploy additional drug-eluting stents (DES) to completely cover the whole lesion or dissections occurring at the edge of the stents.

Fractional flow reserve measurement

A 6F or 7F guiding catheter without side hole was used to engage the coronary ostium avoiding deep seating. FFR was measured by a 0.3556 mm sensor-tipped high-fidelity pressure guide wire (Combo^{TM}, Volcano Corporation, Rancho Cordova, USA) after adequate calibrating and normalizing. Before and after the PCI procedure measurement of FFR for both the SB and MB at maximum hyperaemia were performed after remaining contrast material was flushed out from the guiding catheter with saline. Hyperaemia was induced by intravenous infusion of adenosine (140 $\mu g \cdot kg^{-1} \cdot min^{-1}$),[13] after positioning the pressure sensor at least 5 mm distal to the lesions of both branches. The FFR value was recorded as the ratio of the mean distal intra-coronary pressure to mean aortic pressure at the time point of the maximum trans-stenotic pressure gradient. Gain of FFR was defined as FFR post-PCI – FFR pre-PCI, loss of FFR was defined as FFR at follow-up – FFR post-PCI.

Quantitative coronary angiographic (QCA) analysis

QCA analysis was done at baseline, post-stenting procedure, and at 8-month follow-up in a core laboratory (Nanjing Heart Center, Nanjing, China) using a computer-based dedicated bifurcation analysis (CAAS II 5.0, Netherlands).[14] Bifurcation lesions were divided into four segments: proximal MV, distal MV, SB, and polygon of confluence (POC). QCA variables included reference vessel diameter (RVD), minimal luminal diameter (MLD), acute gain (defined as MLD post-PCI – MLD pre-PCI), late loss (defined as MLD at follow-up – MLD post-PCI).

Clinical follow-up

Clinical follow-up was conducted by telephone contact or office visit for all patients. Angiography and FFR follow-up was scheduled at 8 months after the procedure unless clinically indicated earlier. MACE was defined as cardiac death, myocardial infarction (MI), clinical-driven target vessel revascularization (TVR), or target lesion revascularization (TLR). All deaths were regarded as being of cardiac origin unless otherwise documented. A non-Q wave myocardial infarction was defined as a creatine kinase (CK)-MB concentration increase three times the upper limit of the normal value in the absence of pathological Q waves. TLR was defined as a repeated revascularization with a stenosis >50% in the target lesion in either the MV or SB, and TVR was defined as any repeat revascularization within the treated vessel, in the setting of symptomatic chest pain.

Study end points and definitions

The primary end point was loss of FFR at 8-month follow-up. The secondary end point was QCA analysis of RVD, MLD, acute gain, late loss of diameter and binary restenosis, occurrence of MACE at 12 months including TVR, stent thrombosis (ST), cardiac death, or MI. ST was defined according to the Academic Research Consortium (ARC) definitions.[15]

Statistical analysis

Data are expressed as mean ± standard deviation (SD) for continuous variables and as frequency for categorical variables. Comparisons of continuous variables were performed using the Student's or paired *t*-test. Analyses of discrete variables were performed using the chi-square test or Fisher's exact test where appropriate. Statistical analyses were performed using SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). All tests were two-sided and a P value <0.05 was considered statistically significant.

RESULTS

FFR measurements were performed in 100.0% of the DK group but in only 81.1% of the PS group because of

failing to cross the SB with pressure wires. Baseline clinical characteristics are presented in Table 1. Age, gender, history of hypertension, hyperlipidemia, diabetes, old myocardial infarction (OMI) and LVEF were comparable between the two groups.

Table 2 shows the lesions and procedural variables in the two groups. There were no significant differences in lesion length, stent length and diameter in MV, RVD, MLD, and type of bifurcation lesions by Medina classification between the two groups. But the FKBI rate (100.0% vs 86.7%, P <0.0001) and SB lesion length ((16.87±8.17) mm vs. (10.24±8.40) mm, P=0.028) in the DK group were significantly different from the PS group (P <0.0001). SB stents were implanted in 13 patients in the PS group.

About 80% of the bifurcation lesions in the two groups were 1, 1, 1 by Medina classification and only one fifth were 0, 1, 1. Nearly 78% of the lesions were located at the left anterior descending diagonal (LAD-D), 15% of the lesions at the left circumflex-obtuse marginal (LCX-OM), and other lesions at the posterior descending branch-posterior branch of left ventricle (PD-PL) of the right coronary artery (RCA). There was no significant difference of distribution and bifurcation classification between the two groups.

QCA analysis before and after the PCI procedure and at 8-month follow-up

Clinical follow-up at 12 months was available in all 68 patients (Table 3). Repeated angiography and FFR measurements at 8 months were available in 58 (85.3%) patients. Data showed that there were no significant differences in acute gain and late loss in either the MV or the SB MLD between the two groups (Table 4).

FFR changes after PCI and at follow-up

FFR measurements were completed in 68 patients during the PCI procedure; baseline FFR characteristics were similar between the two groups (Table 5). Post-PCI FFR >0.94 in the MV were less than 40%, but for the SB the FFR gain in the DK group was higher than that in the PS group.

At the 8-month follow-up the FFR value and changes after PCI were similar in the MV in the two groups. But the FFR of the SB was lower in the PS group than in the DK group. The loss of FFR in the SB was higher in the PS group than in the DK group (Table 6).

Figures 1 and 2 show that both the MV and the SB FFR increased after PCI. At the 8-month follow-up the MV FFR had nearly the same value, but the SB FFR decreased significantly in the PS group compared to the DK group which had nearly the same value.

By Person correlation analysis, the FFR value in the SB was positively correlated with the MLD at the SB ostium (P=0.019, r=0.325). This may indicate that the more SB ostium stenosis there is during the mid- or long-term follow-up, the more significant will be the loss of FFR at the SB, especially for the PS strategy.

Table 1. Baseline clinical characteristics in the two groups

Variables	DK (n=38)	PS (n=30)	P values
Age (years, mean ± SD)	63.5 ± 10.5	61.7 ± 9.4	0.472
Male (n (%))	24(63.2)	23(76.7)	0.295
OMI (n (%))	4 (10.5)	2 (6.7)	0.687
Unstable angina (n (%))	27 (71.1)	19 (63.3)	0.604
Diabetes (n (%))	7 (18.4)	4 (13.3)	0.743
Hypertension (n (%))	29 (76.3)	20 (66.7)	0.424
Hyperlipidemia (n (%))	7 (18.4)	6 (20.0)	1.000
LVEF (%)	61.5 ± 9.8	64.4 ± 5.8	0.498

OMI: old myocardial infarction; LVEF: left ventricular ejection fraction.

Table 2. Lesions and procedural baseline characteristics in the two groups

Variables	DK group (n=38)	PS group (n=30)	P values
MV			
Lesion length (mm)	28.9 ± 11.1	25.5 ± 10.1	0.194
Stent length (mm)	33.5 ± 12.4	30.7 ± 16.3	0.378
Proximal RVD (mm)	2.89 ± 0.49	2.83 ± 0.48	0.726
DS (%)	64.5 ± 7.50	64.8 ± 8.70	0.867
MLD (mm)	0.97 ± 0.33	0.95 ± 0.35	0.731
Stent diameter (mm)	3.08 ± 0.36	3.18 ± 0.37	0.236
No. stent per patient (n)	1.21 ± 0.41	1.17 ± 0.46	0.681
SB			
Lesion length (mm)	16.87 ± 8.17	10.24 ± 8.40	0.028
Stent length (mm)	20.7 ± 7.40	18.0 ± 8.20	0.259
RVD (mm)	2.27 ± 0.34	2.39 ± 0.50	0.295
DS (%)	69.9 ± 7.20	61.0 ± 8.30	0.701
MLD (mm)	0.97 ± 0.34	1.01 ± 0.30	0.957
Stent diameter (mm)	2.65 ± 0.25	2.76 ± 0.32	0.192
FKBI (n (%))	38 (100.0)	26 (86.7)	<0.0001

MV: main vessel; SB: side branch; RVD: reference vessel diameter; MLD: minimal luminal diameter; DS: diameter stenosis; FKBI: final kissing balloon inflation.

Table 3. Outcomes of clinical follow-up at 12-month (n (%))

Outcomes	DK group	PS group	P values
Cardiac death	0 (0)	0 (0)	
MI	0 (0)	2 (6.7)	0.191
TLR/TVR	1 (2.6)	3 (10.0)	0.314
MACE	1 (2.6)	5 (16.7)	0.080
ST (definite)	0 (0)	0 (0)	

MI: myocardial infarction; TLR: target lesion revascularization; TVR: target vessel revascularization; MACE: major adverse cardiac events; ST: stent thrombosis.

Table 4. QCA analysis after PCI procedure and at 8-month follow-up

Variables	DK group	PS group	P values
MV diameter (mm)			
Proximal-MV			
Acute gain (n=68)	0.98 ± 0.34	0.88 ± 0.31	0.541
Late loss (n=58)	–0.11 ± 0.21	–0.16 ± 0.23	0.516
Distal-MV			
Acute gain (n=68)	0.89 ± 0.36	0.96 ± 0.36	0.574
Late loss (n=58)	–0.08 ± 0.14	–0.10 ± 0.15	0.677
SB diameter (mm)			
Acute gain (n=68)	0.55 ± 0.37	0.42 ± 0.52	0.295
Late loss (n=58)	–0.014 ± 0.17	0.056 ± 0.27	0.490

MV: main vessel; SB: side branch.

DISCUSSION

Some previous studies in the bare metal stent (BMS) era

Table 5. FFR changes between two groups after PCI

FFR changes	DK (*n*=38)	PS (*n*=30)	*P* values
MV (at hyperemia)			
FFR before-PCI	0.76±0.16	0.82±0.13	0.077
<0.80 (*n* (%))	16 (42.1)	20 (66.7)	0.054
FFR post-PCI	0.92±0.04	0.93±0.04	0.516
>0.94 (*n* (%))	11 (29.7)	11 (36.7)	0.607
FFR gain	0.16±0.16	0.12±0.13	0.123
SB (at hyperemia)			
FFR before-PCI	0.76±0.17	0.79±0.18	0.339
<0.80	19 (50.0)	20 (66.7)	0.219
FFR post-PCI	0.93±0.04	0.91±0.08	0.159
>0.94 (*n* (%))	17 (45.9)	12 (40.0)	0.804
≥0.90 (*n* (%))	30 (81.1)	22 (73.3)	0.559
FFR gain	0.18±0.15	0.12±0.18	0.044

MV: main vessel; SB: side branch; FFR: fractional flow reserve; PCI: percutaneous coronary interventional therapy.

Table 6. FFR changes between two groups at 8-month follow-up

FFR changes	DK (*n*=29)	PS (*n*=23)	*P* values
MV FFR	0.92±0.05	0.90±0.05	0.297
>0.94 (*n* (%))	11 (37.9)	7 (30.4)	0.585
Loss	0.003±0.07	–0.03±0.06	0.086
SB FFR	0.93±0.05	0.87±0.04	0.007
≥0.90 (*n* (%))	23(79.3)	13(56.5)	0.032
Loss	–0.002±0.07	–0.06±0.11	0.037

MV: main vessel; SB: side branch; FFR: fractional flow reserve.

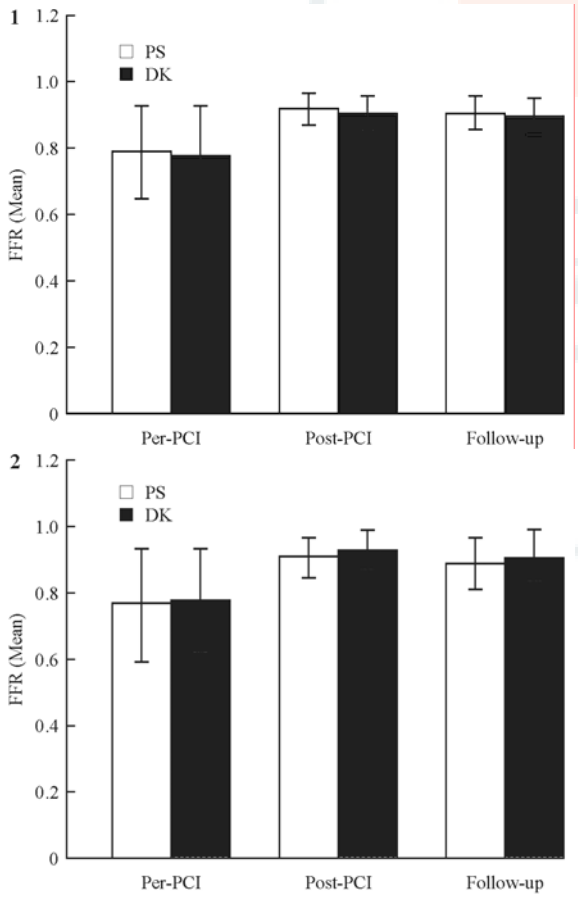

Figure 1. MV FFR pre-, post-PCI and at follow-up.
Figure 2. SB FFR pre, post-PCI and at follow-up.

had shown that FFR represented a very useful tool to combine anatomical and functional information for non-bifurcated lesions in the catheterization lab. The reason was that the FFR value has a good relationship with non-invasive tests. A FFR successful criteria post-PCI is a FFR >0.94 after BMS implantation or FFR >0.90 after balloon inflation, which indicates good mid-term and long-term outcomes. Theoretically, it could be used for bifurcation lesions of both the MV and SB, but some reports of bifurcation lesions showed a correlation between the SB FFR >0.75 or 0.80 (in stead of >0.90) after kissing balloon inflation and a lower MACE at 9 months or at long-term clinical follow-up using the PS technique.[16,17] However, comprehensive data comparing the differences of FFR after different strategies for patients with true bifurcation lesions are still needed. In order to obtain some information about FFR for bifurcation lesions treated with various stenting techniques, we designed this pilot study to compare the functional significance of FFR at both the MV and SB after DK and PS techniques for true bifurcation lesions.

High pressure postdilation in the stent and FKBI were performed in most cases in our study, the ratio of MV FFR >0.94 after stenting is less than 40% in our two groups, the TLR/TVRs were lower in the DK group compared to the PS group. The average MV FFR was 0.92±0.04 in the DK group and 0.93±0.04 in the PS group, which were less than previous FFR successful criteria in the era of BMS. MACE at 12 month follow-up was very low in both two groups and FFR values were nearly the same at 8-month angiogram follow-up. That indicates two points: (1) FFR successful criteria in the DES era are lower than before which may be due to the use of anti-restenosis DES. If FFR post stenting is >0.92, mid-term outcome in our study is as good as FFR >0.94 in the BMS era. (2) No matter what kind of strategy (DK or PS) was used, MV FFR effect in the acute phase after PCI and at 8-month follow-up showed no significant difference. In a previous study comparing the DK with PS technique, the DK technique can produce a significantly higher acute SB FFR after PCI,[4] just because the DK crush technique could achieve almost 100% FKBI with higher kissing pressure (>1418.55 kPa) compared to the PS technique (we always use a smaller size balloon in the SB to perform FKBI with a lower pressure <607.95 kPa in order to avoid dissection occurring). The carina and plaque shifting after MV stenting were less in the DK group, and more SB recoiling was seen after kissing balloon inflation in the PS group, or endothelial dysfunction. The ratio of SB FFR >0.90 after MV stenting is about 81.1% in the DK group vs. 73.3% in the PS group, without a significant difference. In our study, a significant reduction of the SB FFR had been seen combined with more loss of the SB FFR in the PS group than in the DK group at 8-month follow-up, which may be the reason why the DK crush technique is associated with a significant reduction of TLR/TVR compared with the PS technique.[18]

There are several limitations in this study. First, the number of patients was relatively small and the rate of cases transferring to the "TAP" technique was a little

higher than previous trials,[18] which might influence the final SB FFR results in the PS group. Second, pre-PCI SB FFRs might not reflect the true SB lesion severity due to nearly 80% of patients having had MV proximal lesions (Medina type 1, 1, 1 or 1, 0, 1). Third, FFR is correlated with not only fixed stenosis but also endothelial dysfunction especially for the SB in the PS group; we did not check endothelial data, such as high sensitivity C-reactive protein (hsCRP) levels, in the study. Finally, the follow-up observation time was relatively short. If we want to get the relation between FFR and MACE after PCI, a large-scale randomized trial should be designed to compare the clinical outcomes and the FFR post-PCI and at follow-up.

In conclusion, the FFR value can provide hemodynamic performance in the MV and SB which QCA and IVUS cannot provide after PCI for true bifurcation lesions. The DK crush technique can produce a good functional outcome in the SB post-intervention compared with a "provisional" technique at mid-term follow-up, but for the MV functional index, the DK crush technique is as good as the PS technique.

REFERENCES

1. Tonino PA, De Bruyne B, Pijls NH, Siebert U, Ikeno F, van't Veer M, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. N Eng J Med 2009; 360: 213-224.
2. Lockle T, Ishida M, Perera D, Chiribiri A, De Silva K, Kozerke S, et al. High-resolution magnetic resonance myocardial perfusion imaging at 3.0-Tesla to detect hemodynamically significant coronary stenoses as determined by fractional flow reserve. J Am Coll Cardiol 2011; 57: 70-75.
3. Pijls NH, van Schaardenburgh P, Manoharan G, Boersma E, Bech JW, van't Veer M, et al. Percutaneous coronary intervention of functionally nonsignificant stenosis: 5-year follow-up of the DEFER Study. J Am Coll Cardiol 2007; 49: 2105-2111.
4. Hamilos M, Muller O, Cuisset T, Ntalianis A, Chlouverakis G, Sarno G, et al. Long-term clinical outcome after fractional flow reserve-guided treatment in patients with angiographically equivocal left main coronary artery stenosis. Circulation 2009; 120: 1505-1512.
5. Iwasaki K, Matsumoto T. Coronary pressure measurement identifies patients with diffuse coronary artery disease who benefit from coronary revascularization. Coron Artery Dis 2011; 22: 81-86.
6. Pijls NH, Fearon WF, Tonino PA, Siebert U, Ikeno F, Bornschein B, et al; FAME Study investigators. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel coronary artery disease: 2-year follow-up of the FAME (Fractional Flow Reserve Versus Angiography for Multivessel Evaluation) study. J Am Coll Cardiol 2010; 56: 177-184.
7. Applegate RJ. Fractional flow reserve-guided stent therapy for multivessel disease: taking a closer look. J Am Coll Cardiol 2010; 55: 2822-2824.
8. Tonino PA, Fearon WF, De Bruyne B, Oldroyd KG, Leesar MA, Ver Lee PN, et al. Angiographic versus functional severity of coronary artery stenoses in the FAME study fractional flow reserve versus angiography in multivessel evaluation. J Am Coll Cardiol 2010; 55: 2816-2821.
9. Sarno G, Garg S, Onuma Y, Girasis C, Tonino P, Morel MA, et al. Bifurcation lesions: functional assessment by fractional flow reserve vs. anatomical assessment using conventional and dedicated bifurcation quantitative coronary angiogram. Catheter Cardiovasc Interv 2010; 76: 817-823.
10. Chen SL, Zhang JJ, Ye F, Chen YD, Patel T, Kawajiri K, et al. Study comparing the double kissing (DK) crush with classical crush for the treatment of coronary bifurcation lesions: The DKCRUSH-1 bifurcation study with drug-eluting stents. Eur J Clin Invest 2008; 38: 361-371.
11. Ye F, Zhang JJ, Tian NL, Lin S, Liu ZZ, Kan J, et al. The acute changes of fractional flow reserve in DK (double kissing), crush, and 1-stent technique for true bifurcation lesions. J Interv Cardiol 2010; 23: 341-345.
12. Chen SL, Ye F, Zhang JJ, Zhu ZS, Lin S, Shan SJ, et al. DK crush technique: modified treatment of bifurcation lesions in coronary artery. Chin Med J 2005; 118: 1746-1750.
13. Pijls NHJ. Optimum guidance of complex PCI by coronary pressure measurement. Heart 2004; 90: 1085-1093.
14. Goktekin O, Kaplan S, Dimopoulos K, Barlis P, Tanigawa J, Vatankulu MA, et al. A new quantitative analysis system for the evaluation of coronary bifurcation lesions: comparison with current conventional methods. Catheter Cardiovasc Interv 2007; 69: 172-180.
15. Mauri L, Hsieh WH, Massaro JM, Ho KK, D'Agostino R, Cutlip DE. Stent thrombosis in randomized clinical trials of drug-eluting stents. N Eng J Med 2007; 356: 1020-1029.
16. Bon-Kwon Koo, Kyung-Woo Park, Hyun-Jae Kang, Cho YS, Chung WY, Youn TJ, et al. Physiological evaluation of the provisional side-branch intervention strategy for bifurcation lesions using fractional flow reserve. Eur Heart J 2008; 29: 726-732.
17. Koo BK, Kang HJ, Youn TJ, Chae IH, Choi DJ, Kim HS, et al. Physiologic assessment of jailed side branch lesions using fractional flow reserve. J Am Coll Cardiol 2005; 46: 633-637.
18. Chen SL, Santoso T, Zhang JJ, Ye F, Xu YW, Fu Q, et al. A randomized clinical study comparing double kissing crush with provisional stenting for treatment of coronary bifurcation lesions: results from the DKCRUSH-II (double kissing crush versus provisional stenting technique for treatment of coronary bifurcation lesions) trial. J Am Coll Cardiol 2011; 57: 914-920.

(Received August 22, 2011)
Edited by WANG Mou-yue and LIU Huan