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STATE-OF-THE-ART PAPER

Kissing Balloon Inflation in Percutaneous Coronary Interventions

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Bifurcation lesions are the most frequently approached complex coronary lesions in everyday interventional practice. Bifurcations complexity relies essentially on their very specific anatomy that is imperfectly handled by current coronary devices and, despite dedicated techniques and drug-eluting stents, percutaneous coronary interventions directed toward the treatment of bifurcations are technically demanding and require proper execution. Kissing balloon (KB) inflation was the first specific bifurcation technique to have been developed for percutaneous bifurcation interventions and continues to currently play an important role. Indeed, KB has been proposed to optimize stent apposition, improve side branch access while correcting stent deformation or distortion. Over the years, the KB technique has been deeply investigated by many different methods, from bench testing and computer simulations to in vivo intravascular imaging and clinical studies, producing a large amount of data pointing out the benefits and limitations of the technique. We sought to provide here a comprehensive overview of all those aspects. (J Am Coll Cardiol Intv 2012;5:803–11) © 2012 by the American College of Cardiology Foundation

Among complex coronary lesions, bifurcations are those most frequently encountered by every interventional cardiologist. Bifurcation complexity essentially relies on their specific anatomic configuration, which is imperfectly handled by current coronary devices.

Until the advent of drug–eluting stents (DES) and dedicated techniques, percutaneous bifurcation interventions were associated with very high rates of unfavorable outcomes (1,2). Nevertheless, procedures directed to bifurcation treatment are often technically demanding and require proper execution. When implementing dedicated percutaneous bifurcation approaches, kissing balloon (KB) has been variably recommended to optimize stent apposition, correct stent deformation or distortion, and improve side branch (SB) access. Over the years, KB has been deeply investigated by many different methods, from bench testing and computer simulations to in vivo intravascular imaging and clinical studies that have produced a large amount of data.

We review the rationale of KB and findings from dedicated studies, aiming to provide an updated and comprehensive overview of this technique.

Anatomy of Bifurcation Lesions

A coronary bifurcation is a branching artery constituted by a main vessel (MV) and a SB. The segment before the origin of the SB is referred as proximal MV, whereas the one that is distal to it is referred as distal MV (Fig. 1). The tissue membrane separating the origins of the 2 bifurcation arms is called the flow divider or carina.

Operative definitions of bifurcation lesions have been based on the SB diameter, either arbitrarily or in relation to potential blood supply. Actually, a bifurcation stenosis is defined as a coronary artery narrowing occurring adjacent to and/or involving the origin of a significant SB (3). To be significant,

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the SB has to be considered important in the individual patient according to symptoms, location of ischemia, vitality, collateral vessels, and left ventricular function.

Morphology classification is mainly based on plaque distribution. Indeed, plaque distribution can variably involve the proximal MV, the distal MV, or the SB. This has engendered at least 6 different classification schemes (4–9). Sometimes, branching arteries are called "true" rather than "false" bifurcations according to the mere presence or absence of significant SB stenosis. Pathological examination of coronary arteries reveals that the atherosclerotic plaques are mainly located in areas of low shear stress, such as the lateral walls of the MV and SB, whereas they are less common at the carina level, which is characterized by high shear stress.

The spatial relation between the 2 arms of the bifurcation can be defined by 3 angles (Fig. 1) that have been recently named A (the angle between the proximal MV and the SB), B (the angle between the SB and the distal MV), and C (the angle between the proximal and distal segment of the MV). At times, bifurcations are defined as V- or T-type according to angle B being <70° or >70°, respectively. Moreover, the proximal and distal branches of a bifurcation often do not lie on a single plane, thus posing significant challenges to quantitative coronary angiography software.

A recent ex vivo study of polymer casts of human coronary arteries has revealed a complex curvilinear transition zone between MV and SB, mainly characterized by an elliptical and asymmetrical configuration of the SB ostium and brief tapering of the SB origin (10). Moreover, it has been previously pointed out that SB ostium asymmetry increases with increasing bifurcation angles (11). In bifurcations, there is also an asymmetrical geometric reduction according to the law of conservation of energy (12).

The complex interaction among different factors makes every bifurcation lesion quite unique (Fig. 1), although certain lesion characteristics have been associated with treatment success when using currently accepted techniques and DES platforms (13).

Abbreviations and Acronyms

CI = confidence interval

DES = drug-eluting stent(s)

FFR = fractional flow reserve

IVUS = intravascular ultrasound

KB = kissing balloon(s)

MV = main vessel

OCT = optical coherence tomography

SB = side branch(es)

TIMI = Thrombolysis In Myocardial Infarction

TLR = target lesion revascularization

The Need for KB

Bifurcation lesions, by their anatomy, expose the patient to the risk of SB damage, defined as worsening of percent stenosis, and in some cases, SB occlusion (14). Different mechanisms have been suggested to explain SB damage, such as plaque or carina shift, refractory spasm, or dissection of the ostium. In the case of SB occlusion, myocardial necrosis could ensue, being associated with a worse short- and long-term clinical outcome with elevation of both creatine kinase–myocardial band isoform and cardiac troponin levels (15–17). Despite the fact that most acutely occluded SBs undergo late spontaneous reperfusion (18), temporary occlusion causes myocardial enzyme elevation.

In the case of SB stenosis, myocardial ischemia might ensue with persistence of symptoms or mechanical dysfunction. In a recent prospective study of patients with bifurcation lesions successfully treated by DES implantation according to the provisional approach, significant SB stenosis was present in about 20% of patients as assessed by 3-dimensional quantitative coronary angiography. These patients had a significantly increased rate of late inducible ischemia and minor adverse coronary events (19). Angiographic (20) and intravascular ultrasound (IVUS) (21) predictors of SB damage have been described, with further insights recently provided by 3-dimensional optical coherence tomography (OCT) (22).

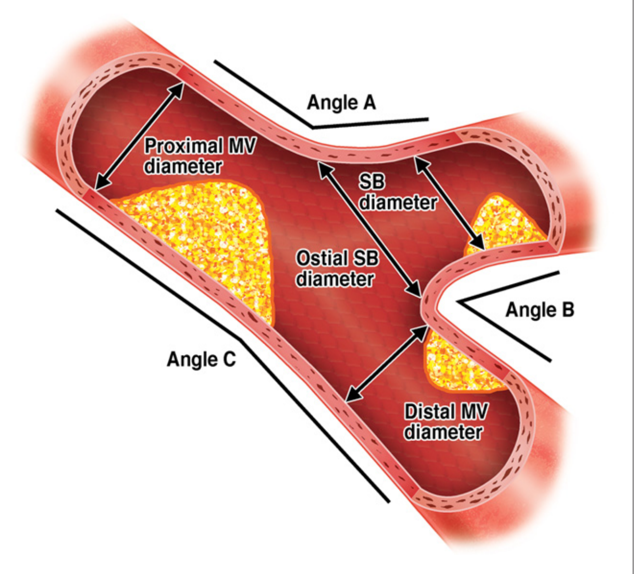

Figure 1. The Complexity of Bifurcation Lesions

Main aspects of anatomic complexity of bifurcation lesions include variable distribution of atherosclerosis, variable spatial relation between the branches defined by angles A, B, and C, the tapered nature of the side branch as reflected by a bigger ostial diameter, and the asymmetrical geometric reduction of the vessel diameter at the bifurcation site. MV = main vessel; SB = side branch.

History of KB

The term *kissing balloon* was first used by Gruentzig to describe the percutaneous treatment of an iliac bifurcation stenosis (23). In 1980, Velasquez et al. (24) published the first report of this technique for distal aorta angioplasty in a patient with Leriche syndrome. One year later, Gruentzig applied the KB technique to percutaneous coronary revascularization (25). At that time, 2 guiding catheters were required, each inserted through a single vascular access, and despite the name of the technique, the simultaneous inflation of the 2 balloons was not the routine: rather, repeated sequential inflation of the MV and SB balloons was deemed safer in regard to the risk of vessel dissection (26,27). Pioneering experiences were positively reported by Meier (25), Zack et al. (26), and Pinkerton et al. (28) in 3, 8, and 13 patients, respectively. In 1986, George et al. (29) reported their experience with KB through a brachiofemoral approach in 52 selected patients, with a procedural success obtained in 98% of them. To avoid a dual guiding catheter system, a single-guide, two-wire technique, sometimes called kissing wire, has been advocated as a simpler, but equally effective, approach to SB preservation (30). Advancing technology has rapidly made KB possible through a single guiding catheter using either 2 balloons with fixed wires (31), a balloon with a fixed wire and a balloon over the wire (23), 2 balloons over the wire (32), or 2 rapid exchange balloons (33). In 1996, Krikorian et al. (34) proposed a simplification of the technique with a single inflation device connected to the 2 balloons through a 3-way stopcock, allowing for single-operator interventions.

Following the introduction of coronary stents and refinement of the technology, the rate of KB progressively increased (6). Actually, KB can be performed with noncompliant balloons (35) and drug-eluting balloons (36) in a 6-F guiding catheter and with special equipment in a 5-F guiding catheter (37).

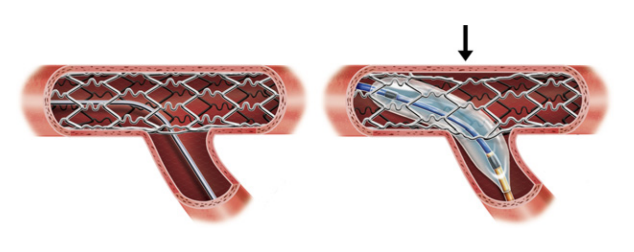

Figure 2. Main Vessel Stent Distortion Without Kissing Balloon

Bench testing has shown that balloon dilation through the side of the main vessel stent to open a cell toward the side branch determines marked distortion of the stent itself **(arrow)**.

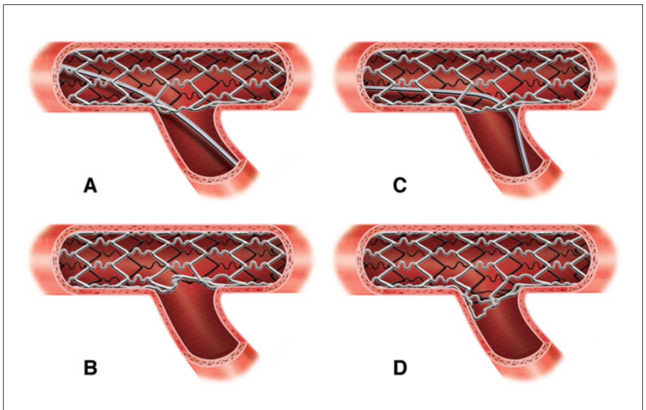

Figure 3. Influence of Main Vessel Stent Cell Rewiring on Stent Deformation Following Kissing Balloon

Access to the side branch through the strut of a stent is usually possible through 2 or 3 different cells. The cell choice affects stent deformation. Bench testing has shown that wire crossing through the strut closest to the carina **(C and D)** provides better scaffolding of the origin of the side branch than proximal crossing that pushes the struts inward towards the main vessel lumen **(A and B)**.

Gaining Insight Into KB

KB modifies the geometry of the implanted stent depending on many factors, including balloon size, inflation pressure, and deflation sequence.

Bench testing. One of the most important contributions of bench testing to the better understanding of bifurcation stenting is the demonstration by Ormiston et al. (38,39) that balloon dilation through the side of the MV stent to open a cell toward the SB results in marked distortion of the stent itself (Fig. 2). This important issue has been shown to be either prevented or corrected by KB. Accordingly, if the balloons chosen for the kissing inflation are too small, the MV stent will be distorted. Moreover, this finding underscores that the SB balloon should be deflated at the same time as the MV balloon to avoid MV stent deformation. However, the sensitivity to SB dilation in terms of MV stent distortion might vary according to specific designs (40,41).

KB can also provide optimal scaffolding of the SB ostium when care is taken to properly rewire the SB. In the provisional technique, bench testing has shown that wire crossing through the cell closest to the carina provides better scaffolding than proximal crossing (Fig. 3).

By contrast, when implementing the crush technique, it is highly advisable to cross the proximal cell. Indeed, bench tests have shown that when stents are crushed, there is a trough between the MV and SB stents on the side opposite to the crushed portion (42–45). If a wire recrosses the MV stent through a distal strut, it may pass outside the stents through the trough before entering the SB stent. If inflated, a post-dilation balloon would push the struts aside, producing a gap in coverage between the stents at the level of the carina. Moreover, a 2-step post-dilation involving a high-

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pressure post-dilation in the SB followed by final KB significantly reduced the ostial stenosis as compared with a 1-step post-dilation by KB. This is especially true for sharp SB angles (42–44).

Bench tests have also provided evidence on the limitations linked to a specific stent design (40) and to the KB technique itself. Indeed, it has been shown that KB determines coating damage to first-generation DES and elliptical deformation of the stent proximally to the SB (46) and that is corrected by final post-dilation of the proximal part of the MV stent (47). Overlapping configuration of the KB has also been shown to influence the stent deformation (45).

Finally, bench testing has recently been used to gain insight into the influence of flow patterns in stented coronary bifurcations with a silicone bifurcation model positioned within a closed-flow loop system mimicking the flow conditions of human arterial circulation (48). In this model, KB corrected the systolic flow disturbance induced by stent implantation.

Finite element analysis. Computer simulation allows assessment of physical structures through the building of geometric models incorporating realistic material behavior. Finite element analysis has recently provided valuable inside into percutaneous bifurcation interventions. Indeed, it has been shown that the relative position of the deployed MV stent strongly affects the occurring strut deformations, with optimal SB access being obtained only if a cell was centrally placed with respect to the SB ostium (49,50). Moreover, the stent cell design significantly affects strut apposition after SB dilation, pointing toward mandatory KB when dilating an open-cell stent (49).

Recently, a very elegant simulation by Mortier et al. (51) has highlighted that KB induces elliptical deformation of the proximal segment of the MV stent with consequent high vessel wall stress and possible direct vessel wall injury at the entry of the SB. However, KB simulations with a tapered balloon for the SB have shown a significant decrease in the MV stent overexpansion (52). Finally, it has been found that despite KB, a high proportion of struts at the proximal MV stent edge remained incompletely apposed as compared with simple MV stenting without opening the cell toward the SB (53).

Computational flow dynamics. Computers can also apply numerical methods and algorithms to analyze the interaction of fluid with definite surfaces.

In a computed model of a 90° bifurcation treated by T-stenting, flow features were characterized by flow stasis and recirculation areas downstream from the bifurcation, depending on the way the cell facing the SB was opened according to its variable position with respect to the SB itself. In absence of final KB, the stent struts protruding into the lumen of the MV induced high values of shear stress at the stent wall (54).

Recently, an innovative approach consisting in the development of a sequential model in which the structural simulations are used to build the fluid domains highlighted the advantages of final KB in terms of better flow pattern (52). Indeed, by removing the stent struts from the blood flow, final KB freed the access to the SB and lowered the hemodynamic disturbance that were present after the mere implantation of a stent on the MV. Of note, flow alteration in stented bifurcations has been shown to significantly influence the interaction between the eluted drug and the vessel wall (55).

Success and Safety of KB

The BBC ONE study (British Bifurcation Coronary Study: Old, New and Evolving Strategies) randomized 500 patients to either a simple stenting procedure with optional KB or a complex procedure (either crush or culotte) with mandatory KB (56). The reported rate of attempted and successful final KB is 31% and 29% in the provisional group and 90% and 76% in the crush group, respectively. Overall, KB success was 95% in the simple approach and 85% in the complex approach ($p = 0.01$).

So far, only 1 complication possibly related to the KB procedure has been described in the published reports. Indeed, an intramural hematoma was reported in a patient on warfarin therapy (international normalized ratio: 3.3) treated by KB after a stent implantation on the left main coronary artery across the left circumflex artery (57).

Imaging Assessment of KB

One-stent strategy. In a serial IVUS study on 23 patients treated by a 1-stent strategy followed by SB dilation and then final KB, dilation of the SB introduced geometric distortion of the distal MV stent and a 12% loss in stent area (58). After KB, stent geometry was not fully restored, and complete recovery of the stent area did not occur.

In the CORPAL (Cordoba & Las Palmas) Kiss trial, IVUS findings were assessed in 101 patients treated by a 1-stent technique for coronary bifurcation disease (59). Patients randomized to KB showed a larger proximal stent cross-sectional area than did the patients from the non-KB group, suggesting overexpansion of the proximal MV stent.

Recently, OCT has been used to point out the importance of KB after MV stenting (60) and to confirm in vivo the importance of recrossing the MV stent through the cell closest to the carina (61). Importantly, OCT has recently underlined a high rate of uncovered struts across the SB ostium when simple MV stenting is performed without final KB (62).

2-stent strategy. Twenty-five patients treated by crushing technique underwent IVUS analysis, and in 23 of them, final KB was performed. At IVUS, most SB lesions showed angiographically unsuspected stent underexpansion, with the smallest minimal stent area found at the SB ostium and frequent incomplete stent apposition in the crush area (63).

Another serial IVUS study compared the results of classical crush and double-crush technique at the end of the procedure and at 8-month follow-up (64). Incomplete crush was observed in 81.3% of the patients in the classical crush group compared with 38.5% in the double-crush group ($p = 0.004$). The post-procedure symmetry index was higher in the double-crush technique than in classical crush, both at the level of the MV stent and at the SB ostium.

A recent IVUS study has shown that the quality of the KB technique, in addition to its simple performance, significantly impacts the clinical outcome following crush stenting (65). Indeed, rewiring proximal rather than distal to the carina significantly predicted SB restenosis (hazard ratio: 2.34, 95% confidence interval [CI]: 1.78 to 4.32, $p < 0.001$).

Functional Assessment of KB

In patients treated by a 1-stent technique, fractional flow reserve (FFR) measured in the jailed SB was compared with quantitative coronary angiography results showing a negative correlation between percent stenosis and FFR ($r = -0.41$, $p < 0.001$). However, there was a wide variation of functional significance even among lesions with angiographically significant stenosis, with only 27% of lesions with ≥75% stenosis being functionally significant (66). In a subsequent study, KB has been performed in 26 lesions with FFR <0.75 showing achievement of FFR ≥0.75 in 92% of them (67). Notably, this functional gain was maintained at 6-month follow-up.

In a study of 60 patients treated by provisional stenting, lack of KB inflation was the only technical factor associated at univariate analysis with post-procedural inducible ischemia as assessed by exercise stress test (19).

Very recently, a FFR substudy of the Nordic-Baltic Bifurcation Study III showed that among 75 participating patients, FFR measured in the SB at the end of the procedure showed a significantly higher mean value in the final KB group as compared with the non-final KB group (0.92 vs. 0.85, respectively, $p = 0.011$) (68). Interestingly, the absence of final KB was a strong predictor of post-procedural FFR <0.75 ($p = 0.006$).

Clinical Assessment of KB

One-stent strategy. In the bare-metal stent era, KB has been shown to be associated with improved outcomes following provisional stenting (6). Moreover, in a small study on 59 patients undergoing MV stenting, SB compromise defined as Thrombolysis In Myocardial Infraction (TIMI) flow grade <3 was significantly higher using sequential balloon inflation than after KB (33% vs. 0%, respectively, $p = 0.003$), although the rate of target lesion revascularization (TLR) at 6-month follow-up was not different between the 2 groups (69).

THUEBIS (Thueringer Bifurcation Study) compared a strategy of percutaneous bifurcation intervention by provisional stenting and final KB with an approach consisting of provisional stenting, with SB dilation only in case of TIMI flow grade ≤2 in 110 patients (70). Paclitaxel-eluting stents were implanted in all patients, and dual antiplatelet therapy was prescribed for at least 6 months. At 6-month follow-up, no significant differences in the incidence of major adverse cardiac events was observed between the 2 groups (Table 1). Notably, in 10 patients randomized to final KB per protocol, SB could not be rewired, and in 7 of 54 patients randomized to final KB, balloon inflation was actually sequential rather than simultaneous. Overall, 31% of patients randomized to KB did not receive this treatment, thus impairing results interpretation.

In the Nordic-Baltic Bifurcation Study III, 477 patients with a bifurcation lesion were randomized to KB ($n = 238$) or non-KB ($n = 239$) after MV stenting with sirolimus-eluting stent (71). At 6-month follow-up, the rates of major adverse cardiac events were 2.1% and 2.5% ($p = 1.00$) in the KB and non-KB groups, respectively (Table 1). At 8-month angiographic follow-up in 326 patients, a trend was ob-

Table 1. Summary of Clinical Trials Assessing the Clinical Utility of KB Inflation in PCI

First Author/Study (Ref. #)	Stenting Strategy	n	Follow-Up Length	Cardiac Death (KB vs. Non-KB)	Myocardial Infarction (KB vs. Non-KB)	Target Lesion Revascularization (KB vs. Non-KB)	MACE (KB vs. Non-KB)	Definite/Probable Stent Thrombosis (KB vs. Non-KB)
Ge et al. (75)	Complex	KB (n = 116) vs. non-KB (n = 65)	9 months	1.7% vs. 0%	10.3% vs. 13.9%	9.5% vs. 24.6%*	19.8% vs. 38.5%*	2.6% vs. 3.1%
THUEBIS (70)	Simple	KB (n = 56) vs. non-KB (n = 54)	6 months	0% vs. 3.7%	3.6% vs. 1.9%	17.9% vs. 14.8%	23.2% vs. 24.1%	3.6% vs. 1.9%
Nordic III (71)	Simple	KB (n = 238) vs. non-KB (n = 239)	6 months	0.8% vs. 0%	0.4% vs. 1.3%	1.3% vs. 1.7%	2.1% vs. 2.5%	0.4% vs. 0.4%†
CORPAL Kiss (59)	Simple	KB (n = 124) vs. non-KB (n = 120)	12 months	0.8% vs. 1.7%	3.2% vs. 1.7%	4.0% vs. 1.7%	9% vs. 6%	0.8% vs. 0.8%

*p = 0.008; ††definite stent thrombosis.
KB = kissing balloon; MACE = major adverse cardiac events; PCI = percutaneous coronary intervention.

served toward a lower rate of binary restenosis in the KB group (11% vs. 17.3% in the non-KB group, p = 0.11). Of note, KB significantly reduced angiographic SB restenosis (7.9% vs. 15.4%, p = 0.039), especially in true bifurcation lesions (7.6% vs. 20.0%, p = 0.024).

In a real-world registry assessing the incidence of target bifurcation failure in 187 patients treated by main mTOR inhibitor-eluting stents according to the provisional T-stenting and small protrusion (TAP) technique, lack of final KB was associated with a worse outcome (p = 0.045) at 12-month follow-up, with significant divergence of the Kaplan-Meier curves for event-free survival starting at the 6-month follow-up (72).

However, in the CORPAL Kiss Trial, patients with bifurcation lesions treated by a simple approach with sirolimus- or everolimus-eluting stents (50% each) were randomized to KB (n = 124) and non-KB (n = 120) with the MV stent cell opened toward the SB with single-balloon dilation in all patients of the non-KB group (59). The incidence of major adverse cardiac events was similar in both groups at 1-year follow-up (Table 1).

In the retrospective multicenter COBIS (COronary BIfurcation Stent) registry, among 1,065 patients treated by a 1-stent technique, 329 were treated by KB whereas 736 were not. At a median follow-up of 22 months, most TLRs were observed to occur in the MV rather than in the SB, whereas no significant differences were observed between groups in rates of cardiac death, myocardial infarction, or stent thrombosis (73).

In a recent meta-analysis, an increasing rate of final KB in the simple-strategy group significantly reduced the risk of SB restenosis (74).

2-stent strategy. Ge et al. (75) compared the 9-month outcome of 181 patients treated according to the crush technique, showing that the lack of final KB was a predictor of TLR at 9 months (hazard ratio: 1.79, 95% CI: 1.14 to 2.80, p = 0.01) (Table 1). In the SB, both late lumen loss and binary restenosis were lower among patients treated by final KB.

In 231 patients treated by crush technique with either sirolimus-eluting stents (n = 131) or paclitaxel-eluting stents (n = 101), final KB significantly improved angiographic results, leading to a larger post-procedural minimal lumen diameter in the MV and in the SB, which was maintained at follow-up (76).

In a study by Dzavik et al. (13), final KB was performed in 98 of 133 (74%) patients who were treated according to the crush technique. At a median follow-up of 386 days, major adverse cardiac event-free survival was higher in the KB group compared with the non-KB group (p = 0.009).

Double kissing showed good immediate- and short-term clinical outcomes (77). In the DKCRUSH-1 study, the double-kissing crush technique was associated with a higher success rate of final KB as compared with classical crush (78). At 8-month follow-up, the rate of major adverse cardiac events was significantly lower in patients treated by double-kissing crush rather than classical crush.

In a study on 132 patients treated by the culotte technique (79), final KB showed a trend toward a protective effect against binary restenosis as assessed by a dedicated bifurcation quantitative coronary angiography system at 6 to 8 months follow-up (odds ratio: 0.37, 95% CI: 0.13 to 1.10, p = 0.07).

Special KB Applications

Recently, kissing inflation with drug-eluting balloons after provisional MV stenting with a bare-metal stent has been reported as a promising treatment in patients with low compliance to prolonged dual antiplatelet therapy (36). This technique has been shown to be feasible through a 6-F guiding catheter with all drug-eluting balloons available and has also been successfully applied to the treatment of several kinds of DES restenosis (80). Clinical and preliminary angiographic and OCT results of this approach appear encouraging (36,81).

Kissing 2 drug-perfusion balloon catheters has been reported to be feasible and effective in the treatment of 3 patients with bifurcation restenosis (82).

Technical Notes

Rewiring the SB. In the provisional technique, both in vitro bench tests (38,39) and in vivo OCT imaging (61) have underscored that rewiring through the cell closest to the carina provides a better scaffolding than proximal crossing. Also, balloon trackability into the SB is found to be easier when effectively recrossing through the distal cell. Accordingly, SB pre-dilation is discouraged to avoid possible dissection of the SB ostium and to take advantage of the carina shift ensuing from MV stenting so the wire could cross the stent exactly at the carina level (83). To increase the chance of crossing through the distal strut, pullback rewiring is advised. The wire should be shaped manually, and after the tip is engaged within the struts at the origin of the SB, a careful steering allows crossing into the SB. Hydrophilic-coated wire might encounter less friction in crossing the struts, but the risk of dissecting the SB increases. Advanced techniques to ensure difficult SB rewiring have been recently reviewed (84).

Balloon diameters. Bench tests have pointed out the importance of the KB diameters (38,39), and several rules have been proposed to appropriately select the diameters of the balloons to be inflated simultaneously during the KB procedure (Fig. 4), with 1 rule being recently validated in an IVUS study (85).

Tracking sequence. Because of the more complex pathway leading to the SB, the balloon that is directed to this branch

Figure 4. Rules Guiding the Choice of the Balloon Diameters for Kissing Inflation

Among the several rules that have been proposed to select the diameters of the balloons to inflate simultaneously during the kissing balloon procedure, these reported in the figure are the most frequently applied. PROX = proximal; RVD = reference vessel diameter; other abbreviations as in Figure 1.

should be tracked at first. Indeed, in a simple stenting strategy, easy navigability of the balloon to the SB is often a marker of optimal rewiring. Sequential removal starting from the last balloon tracked is advised.

Inflation duration. A recent study has demonstrated that prolonged inflation times up to 60 s result in optimal stent expansion (86). Therefore, a 2-step strategy consisting of 30-s delivery balloon inflation followed by another 30-s KB inflation should be recommended.

Deflation sequence. Bench-testing results suggest that the SB balloon should be deflated at the same time as the MV balloon to avoid MV stent deformation (38,39). A useful method to ensure simultaneous deflation of both balloons is the use of a 3-way stopcock by which the 2 balloons are connected to a single inflation device.

Final Remarks

Owing to its important role in most approaches to percutaneous bifurcation intervention, KB has been deeply investigated by several different methods. However, despite the amount of data favoring KB, clinical studies have supported the value of this technique only in patients undergoing percutaneous bifurcation intervention by a complex 2-stent strategy (75–79). In patients treated by a 1-stent technique, published trials to date do not allow the endorsement of systematic KB owing to the lack of significant advantage or penalty (59,70,71). Surely, KB is a complex procedure influenced by a number of parameters that can be modified by the operator. Bench tests in coronary models and computer simulations have shown how small differences in these parameters could translate into significantly different results (38–41,49–54), leading toward the endeavor of optimal procedural performance in vivo. Although whether such an attempt might be effective and could provide better clinical outcomes has not been explored. More importantly, in the assessment of the value of KB in the simple 1-stent technique, follow-up data extending over 1 year are actually lacking. Since 1 year corresponds to the typical length of dual antiplatelet therapy after DES implantation, this is an especially critical issue because bifurcation lesions are significantly predictive of very late stent thrombosis after DES implantation (87). Notably, recent OCT data have pointed out the lack of coverage of stent struts facing the SB ostium when KB is not performed (62), thus suggesting an increased risk of very late stent thrombosis (88). Moreover, the finding that bifurcation stent thrombosis is associated with a higher in-hospital and long-term mortality than stent thrombosis occurring at non-bifurcation lesions (89) urges one to ascertain the possible impact of KB on the long-term safety of percutaneous coronary interventions.

Therefore, if the advantage of KB in 2-stent bifurcation techniques is undoubtful, its role in a simple bifurcation approach cannot be definitely ruled out until longer clinical follow-up data are available.

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