Tips and Tricks for Stenting of Bifurcation Coronary Lesions

ABSTRACT: Although the provisional stenting technique to treat coronary bifurcation lesions is the preferred method, many bifurcation lesions still require a two-stent technique to optimize the result and clinical outcome. This manuscript summarizes the tips and tricks of bifurcation stenting with cases illustrations. As interventionists are encountering more complex and difficult cases, one may find the tips and tricks in this manuscript helpful in daily practice.

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Even though the provisional approach of implanting one stent in the main branch (MB) is currently the default strategy for stenting most bifurcation lesions, the two-stent approach of stenting both the MB and the side branch (SB) is required in approximately 20–35% of cases.[1–5] It is inevitable, for example, when the diameter and territory of distribution of the side branch are relatively large, in true bifurcation lesions where there is significant stenosis of both the MB and SB, especially beyond the ostium. The two-stent technique is also necessary in lesions where there is a relatively large amount of plaque burden or in cases of flow-limiting dissection of the SB ostium during angioplasty. Therefore, it is prudent for any interventional cardiologist to have proficient knowledge of the tips and tricks of bifurcation stenting. In a recent meta-analysis by Katritsis et al[6] of six randomized trials, 1,642 patients with coronary bifurcation lesions were randomized to undergo percutaneous coronary intervention (PCI) by either single stenting of the MB only (n = 821) or placement of two stents in both the MB and SB using any technique (n = 821).[3–6] All patients received drug-eluting stents (DES), and the rates of usage of glycoprotein IIb/IIIa inhibitors were not significantly different. The conclusions of this meta-analysis were that there was no significant difference in the clinical outcome endpoints of stent thrombosis, death and target vessel revascularization (TVR) rates between the one-stent and two-stent approaches, while the only significant difference was an increased incidence of myocardial infarction (MI) in the group that received routine stenting of both branches compared to the provisional one-stent approach. Thus, the authors suggest using the two-stent technique for both branches only when necessary (Table 1), such as in cases of a very large bifurcation branch with a diameter almost as large as that of the main branch. On the other hand, in the CACTUS trial, Colombo et al[4] found no significant difference in their primary clinical endpoint, the occurrence of major adverse cardiac events (MACE), defined as a composite of cardiac death, Q-wave or non-Q-wave MI or TVR at 6 months, among 350 patients randomized to provisional SB T-stenting or routine two-stent “crush” stenting. The authors of the CACTUS trial subsequently suggest that there is no additional harm in the two-stent approach compared to provisional stenting if it is performed by experienced operators. This begs the question: Are all two-stent techniques equal? In a nonrandomized cohort trial of 45 patients with 52 bifurcation lesions, the mini-crush technique was found to be slightly better than historical results of the T-stenting technique, provisional stenting or crush stenting using DES in terms of reducing restenosis rates.[7] However, there have been only two randomized, controlled trials (RCTs) addressing this important issue. The Nordic II study[8]evaluated the differences in outcomes between the culotte (n = 215) and crush (n = 209) stenting techniques in 424 patients with 426 bifurcation lesions. The primary endpoint of MACE including cardiac death, MI, TVR or stent thrombosis at 6 months, procedure and fluoroscopy times, contrast volumes and procedure-related increase in biomarkers of myocardial injury were all very similar between the two groups. The only difference was a trend toward less in-segment restenosis and significantly less in-stent restenosis in the culotte stenting group. Finally, the study by Chen et al[8]comparing the double kissing double-crush (DK) crush and the classic crush-stenting techniques found that the DK crush-stenting technique, with 100% final kissing balloon inflation rates, resulted in better clinical outcomes such as reduced stent thrombosis, target lesion revascularization (TLR) and MACE than the classic crush-stenting technique.[9] However, overall, the data suggest that all the two-stent techniques are similar except for small differences in restenosis rates. Further RCTs are necessary and underway to address these differences. Still, the challenges of directly comparing multiple highly variable and highly technical strategies in the conventional randomized, controlled format are significant. Our goal is to review the most important techniques of bifurcation lesion stenting, various scenarios that may favor one technique over another and helpful tips and tricks to make each of these techniques maximally successful, garnered from the experience of high-volume operators.

Tips and Tricks of Various Techniques

The following are the most frequently used two-stent techniques for bifurcation lesions: 1) T-stenting; 2) crush stenting; 3) culotte stenting; 4) simultaneous kissing stenting (SKS). The selection of a particular stenting technique often depends on the preference and experience of the individual operator. The priority of any two-stent technique is to protect or maintain SB patency so as to minimize SB restenosis.

Jailing of the Side Branch

Case 1. A 72-year-old male with a past medical history of hypertension and dyslipidemia is referred for coronary angiography for progressive, typical angina and abnormal noninvasive myocardial perfusion imaging. Coronary angiography revealed a Medina[10] classification (1,1,1) bifurcation lesion involving the mid left anterior descending artery (LAD) with a 95% lesion at the bifurcation of the first diagonal branch (D1), which had a 60% lesion and was a 1.5 mm diameter vessel. This was a case appropriate for jailing using the SB technique. Jailing the SB is the strategy of first wiring both branches, which should be employed in most bifurcation lesion interventions and then allowing the SB wire to be "jailed" after deployment of the stent in the MB. This technique provides near-perfect protection of the SB.1,[11] This method has distinct advantage, including maintenance of patency during main-vessel stenting in cases of plaque and carina shifting or from the stent struts themselves. In addition, in the event of massive plaque shifting that results in total occlusions, re-wiring using a third guidewire will not be very difficult because the "jailed" wire widens the angle between the MB and SB, acts as a marker for the SB ostium and changes the angle of the SB take-off.[1] The "jailed-wire" technique is most suitable when the SB is too small for stenting or is clinically irrelevant and has ostial or diffuse disease but where the need to maintain patency is important. It can be used alone or as part of a provisional approach. It is a generally accepted concept to avoid using hydrophilic wires in the SB when it is jailed by the MB stent, as the hydrophilic coating may slough off during the removal. Also, one should also avoid jailing a guidewire between the metal of the stents during crush stenting, as fracturing of the guidewire may occur.

Crush or DK (Double-Kissing) Crush Stenting

Case 2. A 58-year-old male with a past medical history of dyslipidemia and coronary artery disease (CAD) status post prior PCI was referred for cardiac catheterization for angina and anterior ischemia on noninvasive myocardial perfusion imaging. Coronary angiography revealed a Medina[10] Classification (1,1,1) bifurcation lesion involving a mid-LAD lesion with 80% stenosis and a D1 lesion with 70% stenosis. The bifurcation angle was 30 degrees and both branches were 3 mm in diameter. To fully cover the SB ostium, the crush-stenting technique was performed. The classic crush technique consists of wiring both branches, predilatation where needed, stenting the SB first with a balloon or stent in the MB and partial deployment of the SB stent in the proximal MB. Next, the undeployed stent in the MB is deployed after removal of the SB wire.11 A consensus of the European Bifurcation Club stated that either mini-crush or DK crush variants should be used when this technique is chosen.[11] The DK crush technique differs in that part of the SB stent protruding into the MB is first crushed with a balloon in the MB, then kissing balloon inflations are performed, followed by stenting of the MB and final kissing inflations. These techniques are suited for patients with a low bifurcation angle (9 Thus, the problems lie in the facilitated guidewire rewiring, balloon re-entry and performance of successful kissing balloon inflations. In DK crush stenting, most cases require removal of the guidewire and stent balloon from the SB after the SB stent is deployed, so when the balloon crush is performed, the wire will not be jailed in the first crush. The guidewire is then inserted into the crushed stent strut. Attempts should be made to insert the guidewire into a proximal- or middle-stent strut to avoid a distal gap of the SB stent (Figure 1). Frequently, a hydrophilic guidewire is needed, and if that also fails, then a stiff tapered guidewire should be used (Figure 2). Sometimes a deflected tip catheter can fulfill this purpose by directing the tip to the origin of the SB and then a guidewire can be inserted through the catheter. If one cannot pass a balloon, then one must ensure that the guidewire is not under the stent strut (Figure 3). A criss-cross guidewire technique can frequently be used to successfully rewire the SB guidewire into the MB and then to insert the MB guidewire into the SB (Figure 4). This ensures that the SB guidewire is not underneath the stent strut. The operator can then attempt to pass the lowest-profile balloon available through the crushed stent strut. However, if the balloon cannot enter the SB, a third guidewire can be inserted into the SB, which changes the geometry of the SB vessel (Figure 5). The purpose of using these techniques and tricks is to allow a low-profile balloon to then be passed through. In select cases, the balloon or stent can be dipped into a lubricant (Rotoglide) solution to facilitate its delivery.[12] A very practical question that is often asked is how much of the SB stent should protrude into the MB. Currently, the best practice is to have as minimal metal overlapping as possible. In the DKCRUSH-1 study, the protrusion was about 3–5 mm. Now, however, it is recommended to incorporate the mini-crush theory into the DK crush-stenting by pulling the SB stent into the main vessel so that it is just in contact with the main vessel balloon or the proximal marker of the SB stent is positioned in the MB at a distance of 1–2 mm proximal to the carina and beginning deployment there (Figure 6).[7,11] The quality of the kissing-balloon inflations is also very important. Today, the two-step kiss is the most popular method. As pointed out by Ormiston et al, a two-step kiss can achieve a larger SB lumen as compared to regular kissing inflation.[13,14] The balloon should be a noncompliant one with high inflation in the SB first to achieve a large minimum luminal area, stent apposition and expansion. Then kissing-balloon inflations with medium pressure are performed to correct any stent malformation.

T-Stenting

Case 3. 69-year-old male with a past medical history of hypertension and diabetes mellitus (DM) presented for cardiac catheterization for angina and abnormal nuclear perfusion imaging. Coronary angiography revealed a Medina[10] Classification (1,1,1) bifurcation lesion involving a 70% mid-LAD stenosis and a 70% D1 stenosis with a bifurcation angle of 90 degrees. In this case, T-stenting was done to minimize the ostium gap between the stents. The classic T-stent technique involves advancing a stent to the ostium of the SB after stenting the MB without protrusion into the MB, but minimizing any gap between the ostium of the SB and the stent. In bifurcation angles close to 90 degrees, T-stenting provides complete coverage of the SB ostium.[10] This group includes T-stenting, modified T-stenting, provisional T-stenting, protrusion T-stenting (TAP) and the proximal optimization technique (POT).[15] In regular T-stenting, the MB is stented first. In the modified T-stenting, the SB is stented first. In provisional T-stenting, the SB is stented only when there is a significant residual lesion or a flow-limiting dissection. With TAP, the MB is stented first then the SB is stented with a slight protrusion into the main vessel. In the POT, a short balloon is inflated in the main vessel proximal to the SB in order to optimize the SB ostium stent-strut coverage. Final kissing-balloon inflations should be performed in all T-stenting techniques. It is generally accepted that T-stenting is usually associated with some degree of incomplete SB ostial coverage. The gap increases for angles that are less severe (16 Our preference is to follow the suggestion of Louvard et al to re-enter the side branch using a distal stent-strut approach, which provides more stent cells in the SB ostium11 (Figure 7). With provisional stenting, even when the angle is not 90 degrees, there will be enough stent struts to cover the ostium, and overlapping the SB ostium with another stent in the SB should not be a problem. We also recommend inserting a noncompliant balloon in the main vessel stent for positioning. The SB stent can then be accurately positioned at the ostium without protrusion. After the SB stenting, both balloons should be pulled back to the proximal part of the main vessel, and final kissing inflations should be performed.

Culotte Stenting

Case 4. A 69-year-old female with a past medical history of dyslipidemia and smoking was referred for cardiac catheterization after being admitted for symptoms of unstable angina and elevated biomarkers diagnostic for a non-ST-elevation myocardial infarction (NSTEMI). Coronary angiography revealed a Medina[10]Classification (1,1,1) bifurcation lesion involving a proximal left circumflex artery lesion (LCx) with 90% stenosis and an obtuse marginal lesion with 80% stenosis. The bifurcation angle was Y-shaped and both branches were 3 mm in diameter. In this case, an excellent result was achieved with culotte stenting. This two-stent culotte stenting method is designed to provide total SB ostial coverage.[17] This technique involves wiring both branches, stenting the more angulated branch, which is usually the SB, and then stenting the unstented branch, the MB, followed by final kissing inflation. It is best suited for Y-shaped bifurcation angles, but it is more technically demanding, leads to excess metal covering the proximal end and requires re-wiring of the MB and SB. In cases with steeper angles, full expansion of the SB ostium is more difficult. It is recommended to stent the SB of the steepest angle first. Again, minimal metal overlap is recommended.

Simultaneous Kissing Stent (SKS) Technique

Case 5. A 70-year-old male with a past medical history of smoking and hypertension presented with NSTEMI. Coronary angiography showed a severe distal left main artery with 99% stenosis at the bifurcation of the LAD and LCX. The left main diameter was approximately 6 mm, while the diameter of the LAD and LCX were approximately 3.5 mm each. The SKS technique was chosen in this case because of the large proximal vessel. The SKS technique involves wiring both branches, positioning two parallel stents covering both branches and extending into the MB with a double barrel in the MB, deploying both stents sequentially or simultaneously, and then final kissing inflations. In some cases, especially in patients with a large proximal main vessel, SKS can provide an excellent angiographic result. It is less time consuming when compared to other two-stent techniques and advantages include no loss of access to either branch and no need to re-cross any stent. Thus, for emergency situations, there is a need to learn this technique. However, the disadvantages are as follows: 1) a large guide catheter is needed; 2) a metallic carina is created with a large overlap of metal in the main vessel; 3) a gap forms beneath the crossing point of the two stents; 4) creation of a double barrel makes endothelialization more unlikely, and the patient may require lifelong dual antiplatelet therapy; and 5) if proximal dissection occurs, converting to crush stenting or placing another stent is very difficult. One must pay attention to carefully align the proximal stents. Sequential inflation of stents should start gently with the SB first, which should then be deflated before inflation of the main vessel stent. Final kissing-balloon inflations are the essential last step. If one needs to re-wire during the SKS procedure, the guidewire must be manipulated very carefully to enter the double barrel.[18]

Role of Intravascular Ultrasound (IVUS)

IVUS is an important tool for bifurcation stenting. The minimum luminal diameter (MLD) of the SB ostium is a predictor of restenosis. IVUS can also detect the SB ostium stent expansion or stent malapposition, but it is recommended to pull back the IVUS catheter from the SB to fully assess the SB ostium.[19]

Antiplatelet Therapy

Due to the extra metal, an increased risk of stent thrombosis may be a concern for two-stent techniques. However, according to the aforementioned meta-analysis,[6] the stent thrombosis rates were not statistically significantly different for the one-stent and two-stent groups. Yet a suitable approach is to recommend dual antiplatelet therapy for more than 1 year, while tailoring the duration and regimen to the individual clinical situation.

Summary

In recent years, bifurcation coronary artery stenting has attracted tremendous attention in the literature as interventionists have attempted to overcome this important obstacle in PCI. Before the dawn of any dedicated bifurcation stents, interventionists have multiple two-stent techniques from which to choose for a given bifurcation lesion. The tips and tricks described above are presented to help the interventionist make the most of these techniques and maximize his/her success in coronary bifurcation stenting.

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