Bifurcation Coronary Lesions – Approaches to Bifurcation Management

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Abstract

The most important question in bifurcation percutaneous coronary intervention (PCI) is selecting the appropriate strategy for an individual bifurcation and optimising the performance of this technique. Provisional T-stenting remains the gold-standard technique for most bifurcations as routine two-vessel stenting does not improve either angiographic or clinical outcomes for most patients with coronary bifurcation lesions. However, further studies are required to determine which bifurcation lesions may particularly benefit from a two-stent strategy as an intention to treat. In this article, we highlight what we know about the treatment of bifurcation lesions and, based on this knowledge, offer our recommendations and a practical approach to bifurcation intervention.

Keywords

Bifurcation lesion, percutaneous coronary intervention, kissing balloon, provisional stenting, two-stent technique

Approaches to Bifurcation Treatment

The Provisional Approach

Several major randomised trials comparing one or two stents in the treatment of coronary bifurcations have been completed, demonstrating that the implantation of a stent only in the MB (the ‘provisional’ SB stenting strategy) remains the preferred strategy. This strategy is quick, safe and easy to perform and has been shown to be associated with similar results to a more complex approach. The consensus from randomised trial data was that routine two-vessel stenting did not improve either angiographic or clinical outcomes for most patients with coronary bifurcation lesions. Depending on one’s view of the importance of peri-procedural creatinine kinase (CK) elevation, it could also be argued that routine dual-vessel stenting did not involve a significant penalty either. The provisional SB stenting strategy starts with stenting of the MB across the ostium of the SB. This may be the first and last step of the procedure, but may also be followed by the opening of a stent cell towards the SB with or without final kissing balloon inflation. If necessary, a second stent can be implanted in the SB using a T-stent, T-stenting with protrusion technique (TAP) stenting (T and small protrusion), culotte stenting or a reverse/internal crush technique.

A 6Fr guide catheter is generally used. The exception is when, owing to lesion characteristics, the operator decides from the very beginning to implant two stents (which requires a 7Fr guiding catheter). After wiring both branches, the MB is pre-dilated if required. There is a general consensus that SBs should be pre-dilated only if severely calcified or diffusely diseased (>5mm) or if there is an unfavourable extreme angulation of the SB take-off.
Bifurcation Stenting

Since previous pathological studies and in vivo IVUS evaluation demonstrated that atherosclerosis occurs predominantly at lateral walls of bifurcation while carina (flow divider) involvement by atherosclerosis is extremely unusual, MB stenting results in carina displacement/shift. For that reason, if the SB is not pre-dilated, the guidewire will cross the stent strut exactly at the carina level (carina cell) after MB stenting. On the other hand, the SB pre-dilation can cause dissection and increases the risk of re-crossing a more proximal strut through a dissection plane, and therefore increases the chance of SB stenting.

The next step after MB pre-dilatation is stent implantation across the SB, leaving the SB wire in place (jailed wire). If the angiographic results in the MB and SB are satisfactory, the procedure is complete and the jailed wire can be removed. Different criteria have been used in randomised trials to obtain acceptable results in the SB following MB stenting.

There has been significant debate in terms of the use of routine kissing inflations, with general agreement that in the absence of an angiographically tight lesion at the ostium of the SB, kissing balloon inflations may not be routinely required. However, when a tight lesion (>75%) is present in the SB after main vessel (MV) stenting, it is known that a kissing balloon inflation will reduce its functional significance.18 Therefore, two appropriate strategies are either to use a pressure wire to interrogate the significance of the SB lesion, or simply to perform kissing balloon inflations on all angiographically significant ostial SB lesions in the knowledge that this reduces the proportion that remains physiologically significant, coupled with the information from NORDIC III that there appears to be no penalty for doing so. If the result at the SB ostium is not satisfactory or if final kissing balloon inflation is performed systematically, the SB is re-wired with the MV wire (wire exchange) or a third wire is used for SB wiring before removing the jailed wire. In the provisional technique, it is strongly recommended to cross-wire through the distal strut following MB stenting because it creates better SB scaffolding than proximal crossing. In order to optimise SB access through the ‘carina strut’, the proximal optimisation technique (POT) has been proposed, and relates to a method of expanding the stent at the carina using a short oversized balloon.

The jailed wire in the SB should always be left in place as a marker until complete re-crossing has been carried out. In addition, the jailed wire favourably modifies the angle between both branches and keeps the SB open. Stent selection for treating the MB of bifurcation lesions is crucial and the primary stent should be sized according to the distal MV diameter.

After re-crossing the SB, balloon dilation of the SB ostium and final kissing inflation (FKI) should be performed. FKI is proposed if the SB is dilated through the MB stent struts to correct MB stent distortion and expansion, provide better scaffolding of the SB ostium and facilitate future access to the SB. Equally, kissing balloon inflations appear to be neither beneficial nor harmful, but could justifiably be undertaken at the operator’s discretion.

A Second Stent in the Side Branch Following the Provisional Approach

If the result remains unsatisfactory after FKI (>75% residual stenosis, dissection, Thrombolysis in Myocardial Infarction [TIMI] flow grade <3 in an SB ≥2.5mm or fractional flow reserve [FFR] <0.75),19 SB stenting should be performed. According to randomised trials, a second stent in the SB may be required in between 2 and 51% of cases.18,20,22 FFR or new imaging techniques, such as optical coherence tomography (OCT), could be of value in the evaluation of SB results after balloon dilation.

When SB stenting is performed, the T technique is most frequently used.21 It usually consists of positioning a stent at the ostium of the SB, while being careful not to have the stent protruding into the MB. Some operators leave a balloon in the MB to aid in precise positioning and sometimes inflate the balloon at a low pressure in order to help SB stent positioning. The TAP technique is a modification of the T-stenting technique and is based on an intentional minimal protrusion of the SB stent within the MB.22 FKI is performed to complete the procedure. In bifurcations with angles close to 90º, T-stenting provides complete coverage of the SB ostium.

Some operators prefer using the culotte technique in order to be sure that SB ostial scaffolding is obtained. The culotte technique leads to full coverage of the bifurcation at the expense of an excess of metal covering of the proximal end. The procedure starts with MB stenting as in the original description,23 although the first stent can be deployed across the most angulated branch – usually the SB (inverted culotte technique, described below as a two-stent technique as intention-to-treat).24 The SB is then re-wired through the struts of the stent and dilated. A second stent is advanced and, after removal of the guidewire from the MB, the stent is expanded into the SB. The next step is re-wiring and dilatation of the MB through the struts of the SB stent. FKI is then performed.

Another technique that was developed with the intention of minimising any possible stent gap between the MB and SB stents is reverse or internal crush. In this technique, the stent is first implanted in the MB and balloon dilatation with kissing inflation towards the SB is performed. Subsequently, the stent is inserted in the SB and pulled back to protrude a few millimetres inside the MB stent. The reverse crush can be performed utilising a 6Fr guiding catheter as the protruding segment of the SB stent is crushed with the balloon in the MB. The SB is then re-wired and high-pressure balloon inflation is performed in order to open access to the SB. The procedure is completed by FKI. Our proposed approach to bifurcation lesion treatment is summarised in Table 1 and an example of the provisional stenting technique is presented in Figure 1.

Two Stents as Intention to Treat

Controversy continues to surround this most basic and yet most complex of matters in terms of bifurcation vessel stenting. Large-calibre true bifurcations with significant ostial SB length disease are considered by most experts to require a systematic two-stent strategy, but evidence to support this approach is lacking.

Two important elements that guide our decision to use a two-stent strategy are the size and territory of distribution of the SB and the angle between the MB and the SB. SBs with ostial disease extending >5mm from the carina, which are as important as the MB in terms of both the size and territory of distribution, are likely to require a two-stent strategy, and SBs whose access is particularly challenging should also be secured by stenting once accessed. Importantly, wider-angle bifurcations are unfavourable for two-stent strategies.
because of the relative inability of stents to conform uniformly to the vessel wall in regions of acute angulation, even with optimal techniques. The most frequently applied two-stent techniques are culotte, mini-crush and V and simultaneous kissing stent (SKS).

Inverted Culotte Technique
The procedure starts with pre-dilatation of both branches and stent implantation across the most angulated branch, usually the SB. The MB is then re-wried through the struts of the SB stent and dilated. A second stent is advanced and expanded into the MB. The procedure is completed by FKI. An important limitation of the culotte technique is its dependence on maximal stent cell diameter. For this reason, open-cell stents are preferable when the culotte technique is performed in order to allow full opening of the struts towards both branches. Another disadvantage of this technique is that re-wiring both branches through the stent struts can be difficult and time-consuming.

This technique is suitable for all angles of bifurcations and provides near-perfect coverage of the SB ostium, although the ideal bifurcation for this technique is a narrow-angle bifurcation with both branches being a similar size. The disadvantages are that, similar to the crush technique, the culotte technique leads to a high concentration of metal with a double-stent layer at the carina and in the proximal part of the bifurcation. An example of the culotte stenting technique is presented in Figure 2.

The Mini-crush Technique
The classic crush technique consists of partial deployment of the SB stent in the MB, which is crushed by the MB stent after removal of the SB wire. The main disadvantage of this technique is that it requires at least a 7Fr guiding catheter. After pre-dilatation of the MB and SB, two stents are inserted and the stents are positioned by pulling the SB stent about 2–3mm into the MB. This step is verified in at least two projections. The stent in the SB is deployed and the balloon is removed into the guiding catheter. An angiogram is taken to verify that the stent is fully expanded and the SB has normal flow and no distal dissection or residual lesions. An additional stent can be implanted in the SB if necessary. Following this verification, the wire is removed from the SB and the stent in the MB is fully deployed at high pressure. SB is then re-wired and dilatation of the stent towards the SM is performed with a balloon appropriately sized to the diameter of this branch and inflated at high pressure. The procedure is completed by FKI.

The clinical outcome of the crush technique is improved by FKI, which is now strongly recommended, and some operators prefer to inflate a high-pressure balloon towards the SB before performing kissing balloon inflation. The main disadvantage of the crush technique is that the performance of the FKI makes the procedure more laborious due to the need to re-cross multiple struts with a wire and a balloon. Even in the most experienced centres, complete success rates with SB kissing balloon inflations in crush stenting are ~90%, and are lower than for culotte stenting.

Recent addition of the word ‘mini’ to crush stenting highlights the need to reduce as much as possible the amount of stent overlap between the SB and MB, as described by Galassi et al. (compared with modified T-stenting as described by Kobayashi et al.). Compared with the original description, the mini-crush approach includes a minor retraction of the SB stent into the MB so that the proximal marker of the SB stent is positioned in the MB at a distance of 1–2mm proximally to the carina of the bifurcation.

When there is the need to perform a two-stent technique as intention to treat and a 6Fr-guiding catheter is the only available approach (radial approach), the ‘step crush’ or ‘the modified balloon crush’ techniques can be used. The techniques termed ‘double kissing

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**Table 1: Proposed Approach to Stenting Bifurcation Lesions**

<table>
<thead>
<tr>
<th>Type of Bifurcation</th>
<th>Proposed Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMCA/LAD: Cypher 3.5×18mm</td>
<td></td>
</tr>
<tr>
<td>LMCA/LAD: Durastar 3.5×15mm</td>
<td></td>
</tr>
<tr>
<td>LAD: Durastar 3.5×15mm</td>
<td></td>
</tr>
<tr>
<td>LCx: Durastar 3.5×15mm</td>
<td></td>
</tr>
</tbody>
</table>

A: Baseline angiogram shows tight lesion of distal left main artery. After wiring of the left anterior descending (LAD) and left circumflex artery (LCx) and pre-dilatation of the left main lesion, a drug-eluting stent was implanted from the left main artery towards the LAD SB. Kissing balloon inflation was performed with two non-compliant balloons sized according to LAD and LCx diameters (Q). The final result is presented in panel D. LMCA = left main coronary artery.

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**Figure 1: Baseline Angiogram**
Bifurcation Stenting

Figure 2: Baseline Angiogram

A: Baseline angiogram presents diffuse disease of the left anterior descending (LAD) artery and the ostial/proximal segment of the diagonal branch. Following pre-dilatation of the LAD and the diagonal branch, the first stent is implanted towards the diagonal as more angulated branch (arrows in panel B). The LAD is then re-wired through the struts of the stent and dilated. C: A second stent is advanced and expanded into the LAD. D: The procedure is completed by kissing balloon inflation; the final result can be seen in panel E.

LAD: Cypher 3.0x18mm
LAD/diagonal: Cypher 3.0x18mm

Table 2: Main Characteristics of Two-stent Techniques

<table>
<thead>
<tr>
<th></th>
<th>T/TAP</th>
<th>Culotte</th>
<th>SKS</th>
<th>Mini-crush</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guiding catheter (Fr)</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7*</td>
</tr>
<tr>
<td>Provisional SB stenting</td>
<td>Yes</td>
<td>Possible</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Number of steps</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>3 (6 if DKC)</td>
</tr>
<tr>
<td>Bifurcation angle &lt;70º</td>
<td>Not ideal</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Ideal</td>
</tr>
<tr>
<td>Bifurcation angle &gt;70º</td>
<td>Ideal</td>
<td>Not ideal</td>
<td>Not ideal</td>
<td>Not ideal</td>
</tr>
<tr>
<td>Similar diameters MB and SB</td>
<td>Suitable</td>
<td>Ideal</td>
<td>Ideal</td>
<td>Suitable</td>
</tr>
<tr>
<td>Small SB</td>
<td>Suitable</td>
<td>Not ideal</td>
<td>Not ideal</td>
<td>Ideal</td>
</tr>
</tbody>
</table>

*6Fr could be used for balloon step-crush. DKC = double kissing crush; MB = main branch; SB = side branch; SKS = single kissing crush; TAP = T and protrusion.

Technique because the part of the SB stent protruding into the MB is first crushed with a balloon in the MB, then FKI is performed, the MB is stented and second kissing inflation is performed. The main advantage of the crush technique is that immediate patency of both branches is assured. This is especially important when the SB is large or difficult to wire. The main disadvantage is that the performance of the FKI makes the procedure more laborious due to the need to re-cross multiple struts with a wire and a balloon.

The V and the Simultaneous Kissing Stent Techniques

The V-stenting and the SKS techniques are performed by delivering and implanting two stents together. Both branches are wired and fully pre-dilated. One stent is advanced in the SB and the other in the MB. Both stents are pulled back and, once the positions of the stents are confirmed and the proximal stent markers are overlapping, the stents are deployed with simultaneous inflation and deflation. The size of the balloon and the stents is chosen according to the diameter of the daughter vessels (1:1). The stent length is selected visualy to cover the entire length of the diseased segments (balloon for length). The main advantage of the V and SKS techniques is that the operator will never lose access to either of the two branches. In addition, when a FKI is performed there is no need to re-cross any stent. The main disadvantage of these two techniques is metallic neocarina, which is caused within the vessel proximal to the bifurcation. Theoretical concerns about the risk of thrombosis related to this new carina have not been confirmed in the literature. The types of lesion most suitable for this technique are proximal lesions, such as bifurcation of a short left main coronary artery (LMCA) free of disease. Ideally, the angle between the two branches should be <90º. The V-stenting technique is also suitable for other bifurcations, provided the portion of the vessel proximal to the bifurcation is free of disease and there is no need to deploy a stent more proximally.

While no definitive statement can be made in terms of the best strategy to use when there is the need to implant two stents in a bifurcation, Table 2 shows the main characteristics of the most frequently used two-stent techniques.

Dedicated Bifurcation Stents

Dedicated bifurcation stents may potentially overcome the limitations of conventional stents in bifurcations (SB protection, multiple layers, distortion, SB access, crossing through the side of the stent, gaps in scaffolding). However, although efforts to produce dedicated delivery systems for bifurcation stents are strongly encouraged, none of the currently available systems can challenge the results offered by the provisional T-stent strategy in the majority of bifurcation lesions.

Conclusions

The most important question in bifurcation PCI is selecting the appropriate strategy for an individual bifurcation and optimising the performance of this technique. Provisional T-stenting remains the gold-standard technique for most bifurcations because routine two-vessel stenting does not improve either angiographic or clinical outcomes for most patients with coronary bifurcation lesions. However, further studies are required to determine which bifurcation lesions may particularly benefit from the two-stent strategy as an intention to treat. Currently, dedicated bifurcation stent systems remain limited but are likely ultimately to prevail.


