EDITORIAL COMMENT

The 5 Ts of Bifurcation Intervention: Type, Technique, Two Stents, T-Stenting, Trials*

Ron Waksman, MD, FACC, Laurent Bonello, MD
Washington, DC

Bifurcation, the division of an artery into 2 branches, is a common anatomy feature of the human coronary tree and is recognized as a common site for atherosclerotic plaque buildup due to the differences in coronary flow, turbulence, and shear stress at the site of the bifurcation. The prevalence of bifurcation stenosis in the human coronary tree is reported to be between 15% to 20% of all interventions and is considered complex and challenging for percutaneous intervention.

See page 358

Numerous techniques and devices have been proposed to address the treatment of bifurcation lesions: balloon angioplasty, metallic stents, drug-eluting stents (DES), newly designed stents with dedicated access to the side branch, and full bifurcated stents. Clearly, the interest in the treatment of bifurcation stenting has increased with the availability to significantly reduce the recurrence rate, but this was associated with the increasing fear of stent thrombosis. Despite this extensive body of work and the latest innovations of 2008, there is not a “one size fits all” solution to the bifurcation puzzle, while the optimal percutaneous coronary intervention technique remains undetermined.

In this issue of JACC: Cardiovascular Interventions, Routledge et al. (1) present 2-year outcome data of 477 patients treated for bifurcation coronary disease with provisional side branch T-stenting using DES, and claim a systematic approach feasible for 90% of the patients, with acceptable efficacy and safety profiles. This editorial is written in response to this provocative study and will cover the 5 Ts of bifurcation stenting: Type of bifurcation, Techniques, Two stents versus one, T-stenting, and Trial design.

Types of Bifurcation

Part of the complexity in treating bifurcation lesions and applying technique standardization is in regard to the numerous anatomic patterns of bifurcation stenosis and the lack of consistent, reliable methodology. Further, the variations in anatomy, angulations, and location of the disease within the bifurcation have led to the development of numerous classifications of bifurcation lesions, with differentiation between “true” bifurcation (both the main and the branch are diseased) and “false” bifurcation (either the main or the branch is disease) based on angiography. The most popular and intuitive classification is that of Medina et al. (2), which identifies at least 7 types of bifurcation involving the proximal main branch, the distal main branch, and the side branch, with different variations. If we add this to the classification of the various potential angulations between the main and the side branches, the sizes of the parent vessel and the side branch, and the different potential morphologies of the diseased segment (calcification, fibrosis, and so on), we can identify nearly endless anatomic and morphologic configurations of bifurcations types (3).

Technique

2 stents versus 1. Numerous techniques have been proposed for the treatment of bifurcation lesions. The first decision that the operator must make is whether the procedure will involve 1 or 2 stents. The most important information relates to the size of the side branch and the degree of the disease in this branch. Or do we really care about the side branch? Initially, the thought of using 2 stents for all bifurcated lesions was appealing because this approach usually resulted in an optimal angiographic success rate. Among the most popular techniques that employed the use of 2 stents are the culotte, crush, V-stenting, T-stenting, and simultaneous kissing stents (4). However, after numerous reports of high rates of late complications, including an increase in stent thrombosis and restenosis frequency, systematical use of 2 stents did not live up to expectations (5–8). These poor outcomes were observed regardless of the technique used and thus discouraged the liberal use of 2 stents. Therefore, the provisional strategy gained ground: try 1 stent first, and, if the result is not acceptable (dissection, impaired lumen, or flow of the other branch), use a second stent for the side branch. The superiority of such a provisional approach over a 2-stent technique was confirmed by the Nordic Bifurcation study (9). The results of this study had operators favoring the provisional rather than the 2-stent approach. However, many questions still remain regarding this approach: can we predict which bifurcation will require 2, rather than 1 stent? In how many patients is the provisional approach feasible? If a second stent is required, what then is the optimal technique for implantation of the second stent? Is provisional stenting still superior...
to the 2-stent approach with the new generation of stents available? And lastly, are the latest technique modifications, including pre- and post-kissing, clinically beneficial?

The present study demonstrated that provisional stenting is feasible in 90% of all patients, and those who received a second stent in the side branch, 28%, had similar long-term outcomes as those treated with 1 stent. The outcome of this study is similar to that of the Nordic Bifurcation study, which observed no difference in outcomes at 6 months’ follow-up between 1 and 2 stents (9). Finally, the latest Nordic Bifurcation Stent Technique study, comparing the culotte and crush techniques, reported low rates of angiographic restenosis and major adverse cardiac events for both techniques (10), with similar angiographic and clinical outcomes as the provisional approach with T-stenting reported in the Routledge et al. study (1). This leaves us with the question of whether, in 2008, provisional stenting is still superior to 2 stents when an improved technique is applied and new-generation stents are used?

**T-stenting.** Use of the provisional T-stenting technique is gaining interest because of its simplicity and subsequent reports of good mid-term outcomes (11–13). As illustrated in the present report by Routledge et al. (1), it is feasible in a large majority of patients and is associated with low rates of recurrent events during long-term follow-up. In the past, the technique was described to resolve dissections of a side branch (8) or as a new technique for the use of 2 stents for the treatment of bifurcation lesions (11). In the present study, the authors used provisional T-stenting as the default technique. From a technical point of view, provisional T-stenting offers several advantages compared with other bifurcation techniques: it is simple to perform in most cases, and it limits the need for a second stent, as illustrated by the low rate of stenting in the side branch in the present study. One technical aspect of the procedure remains in question: is kissing post-procedure mandatory in the provisional T-stenting approach with 1 or 2 stents? Bench testing observed that the final kissing balloon may have several interesting advantages: it opens the stent cells to the side branch, it allows the side branch ostium to be at least partially covered by stent struts, and it prevents the main branch stent from becoming deformed by side branch dilation. Further, in previous studies involving crush stenting, kissing balloon was shown to be critical in preventing restenosis (14). Nevertheless, the clinical impact of a final kissing balloon in provisional T-stenting must be established in future trials. Several limitations should be considered with T-stenting: it is not applicable for all lesions, it is dependent on the bifurcation angle and cannot be applied to angles <40°; the second stent, if needed, may not be able to fully cover the ostium, which will result in switching to a mini-crush technique, and like other techniques, there is a learning curve. Nevertheless, among today’s available options, the provisional T-stenting technique seems to be the simplest and is associated with favorable long-term outcomes.

**Trials**

Perhaps the most challenging component in bifurcation stenting is how to design a clinical trial that will determine the optimal treatment strategy. The variability in anatomy, morphology, technique, and learning curve makes it almost impossible to have a reproducible and reliable trial free of deviation that can detect the preferred strategy. Even when the same strategy is performed by the same operator, we find it is hard to draw definitive conclusions perhaps due to bias in case selection. In the Nordic Bifurcation study, provisional stenting was superior to the 2-stent strategy, but in the Nordic Bifurcation Stent Technique study, either of the 2-stent techniques—crush or culotte—demonstrated excellent results when compared with the historical provisional group. A challenge in trial design is extending it for the evaluation of dedicated bifurcated stents. Which should be the control method—provisional stenting or the 2-stent technique?

Since in bifurcation stenting one size does not fit all, it is possible that several strategies will result in a similar outcome. We propose revisiting this to test these new techniques and dedicated bifurcated stents against objective performance criteria (OPC) that is set based on existing data derived from techniques and devices already used for bifurcation stenting (15–20) (Table 1). We recognize that testing a device or a strategy against OPC is subjected to potential bias in case selection and will have to apply to broad inclusion exclusion criteria as was performed in the study of Routledge et al. (1). A cautionary note and critical appraisal should be applied to single-center studies that may not be generalized for the rest of the interventional community and should not be sufficient to serve as a sole reference for OPC trials. Another difficulty is to determine the end points of such as study; clinical end points, including late stent thrombosis, will require large sample sizes, and angiographic thrombosis such as late loss can be done only against the parent vessel and not to the side branch when the provisional stent control group is chosen. Perhaps it would be better to choose a composite of clinical event end points, including both the parent and the branch vessel failure, to be used for the OPC. This approach could have been used in the present manuscript to assess the feasibility and safety of provisional T-stenting.

Bifurcation stenting continues to challenge the interventional cardiologist in 2008. Despite the recent literature, including the present manuscript, there is a lack of consensus on an array of important issues, such as: Which branches deserve protection? Should provisional stenting be the default strategy of bifurcation stenting? Should we always pre-dilate the side branch? And if 2 stents are required, which technique would be the best? Is kissing always mandatory for both branches? Are DES more thrombogenic? And finally, how will the special dedicated bifurcated stents be integrated into current practice? With further trials
and perhaps the sixth T in bifurcation stenting (Time), the answers to these important questions will be answered.

Reprint requests and correspondence: Dr. Ron Waksman, Washington Hospital Center, 110 Irving Street, NW, Suite 4B-1, Washington, DC 20010. E-mail: ron.waksman@medstar.net.

REFERENCES


Key Words: angioplasty • bifurcation lesions • drug-eluting stents • stent thrombosis.

Table 1. Comparison of Bifurcation Studies in the DES Era

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>181</td>
<td>141</td>
<td>120</td>
<td>150</td>
<td>324</td>
<td>205</td>
<td>200</td>
<td>413</td>
<td>281</td>
<td>424</td>
<td>477</td>
</tr>
<tr>
<td>Stent type</td>
<td>SES/SES</td>
<td>SES</td>
<td>SES</td>
<td>SES/SES</td>
<td>SES/SES</td>
<td>SES</td>
<td>SES/SES</td>
<td>SES/SES</td>
<td>SES/SES</td>
<td>SES/SES</td>
<td>SES/SES</td>
</tr>
<tr>
<td>Number of stents/lesions</td>
<td>2 1 + provisional</td>
<td>2 1 vs. 2</td>
<td>n/a</td>
<td>1 + provisional</td>
<td>2 1 vs. 2</td>
<td>2</td>
<td>2 1 + provisional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td>Crush</td>
<td>n/a</td>
<td>Crush</td>
<td>All</td>
<td>n/a</td>
<td>T-stenting</td>
<td>SKS</td>
<td>n/a</td>
<td>Crush</td>
<td>Culotte Crush</td>
<td>Provisional T-stenting</td>
</tr>
<tr>
<td>Final kissing balloon (%)</td>
<td>64.1</td>
<td>53.4</td>
<td>87.5</td>
<td>74 n/a</td>
<td>46 n/a</td>
<td>53 50.6</td>
<td>Crush 88.8</td>
<td>Culotte 93.9</td>
<td>95.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of follow-up, months</td>
<td>9 6 + 2</td>
<td>6 12</td>
<td>12 24</td>
<td>9 ± 2</td>
<td>6 9</td>
<td>8 24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLR (%)</td>
<td>14.9</td>
<td>2</td>
<td>11.3</td>
<td>15.3</td>
<td>n/a</td>
<td>8.3</td>
<td>4</td>
<td>1.5</td>
<td>9.7</td>
<td>n/a</td>
<td>5.2</td>
</tr>
<tr>
<td>TVR (%)</td>
<td>17.1</td>
<td>0</td>
<td>12.2</td>
<td>18.6</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>2 11</td>
<td>n/a</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Stent thrombosis (%)</td>
<td>4.4</td>
<td>0</td>
<td>1.7</td>
<td>2.7</td>
<td>1.5</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>4.3</td>
<td>n/a</td>
<td>3.6</td>
</tr>
<tr>
<td>Death</td>
<td>1.1</td>
<td>0</td>
<td>0.9</td>
<td>2.1</td>
<td>0.9</td>
<td>1.5</td>
<td>2</td>
<td>1.2</td>
<td>1.3</td>
<td>n/a</td>
<td>5.4</td>
</tr>
<tr>
<td>MI</td>
<td>11.6</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
<td>5.9</td>
<td>2.4</td>
<td>4</td>
<td>0.2</td>
<td>9.2</td>
<td>n/a</td>
<td>1.8</td>
</tr>
<tr>
<td>MACE</td>
<td>26.5</td>
<td>2</td>
<td>3</td>
<td>21.3</td>
<td>13.3</td>
<td>17.6</td>
<td>9</td>
<td>3.1</td>
<td>16.5</td>
<td>Crush 4.3</td>
<td>Culotte 3.7</td>
</tr>
</tbody>
</table>

*Cardiac death.

DES = drug-eluting stent(s); MACE = major adverse cardiac events; MI = myocardial infarction; PES = paclitaxel-eluting stent(s); SES = sirolimus-eluting stent(s); SKS = simultaneous kissing stents; TLR = target lesion revascularization; TVR = target vessel revascularization.