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EDITORIAL COMMENT

The Relentless Attempt to Perfect the 2-Stent Technique*

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A provisional, single-stent strategy is currently regarded as the default strategy for the treatment of bifurcation lesions, because of beneficial outcomes associated with this technique (1,2). However, this approach cannot be applied broadly across all bifurcation lesions because of the likelihood of side branch (SB) compromise in the presence of high-risk features (e.g. significant SB ostial disease) or because the SB has significant disease extending beyond its ostium requiring treatment (3). In such circumstances, the high risk of SB occlusion (and resultant periprocedural myocardial infarction) or residual critical stenosis on the SB demand the implementation of a 2-stent strategy in a bid to maintain optimal vessel patency and blood flow in both the main branch (MB) and the SB.

The ostium of the SB is the weakest segment in bifurcation lesions, being the most common location of restenosis (4). A number of different 2-stent techniques have been described, including T-stenting (5), T and protrusion, crush (6), and culotte stenting (7), in addition to the development of dedicated bifurcation devices (8), in an attempt to optimize the immediate and long-term results of the SB following treatment. However, each of these strategies has limitations, including stent distortion, inadequate ostial coverage, and multiple stent layers that contribute to restenosis.

Once the decision has been made to perform a 2-stent strategy, the ideal technique should satisfy the following properties:

- Optimal coverage of the SB ostium with no gaps between the MB and SB stent.
- Minimal distortion of the SB stent at the ostium of the SB.
- Minimal overlap between the MB and SB stents.
- Short procedural time.
- Minimal requirement of additional guidewires and balloons.
- The ability to maintain control of both the MB and the SB so that there is little risk of comprised blood flow in either branch.
- The technique should be relatively easy, reproducible, and predictably performed as described.
- A guiding catheter no greater than 6-F should be required.
- Immediate and long-term clinical results (e.g., target lesion revascularization) should be at least noninferior, if not superior, to existing techniques.

To date, no single approach is able to deliver all of the desired attributes as described. Therefore, the relentless effort to develop a better solution is laudable.

In this issue of *JACC: Cardiovascular Interventions*, Toth et al. (9) present both in vitro evaluation and limited clinical validation of a novel bifurcation technique: the “single string technique” that was originally proposed by Kawasaki et al. (10). To better understand the technical aspects of this treatment approach, we believe that the single string has many similarities to the mini-culotte technique.

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The authors elegantly demonstrate the feasibility of this bifurcation technique in an in vitro model in which it was successfully completed in all 20 experiments with only 1 case requiring a change of

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guidewire. Post-implantation imaging by optical coherence tomography and micro computed tomography confirmed only the proximal-most cell was crossed and dilated in all cases, and resulted in perfect or acceptable stent strut apposition in ≥90% to 95% of the stented segment including the high-risk bifurcation area. In the human pilot registry, the procedure was successfully carried out in all 11 patients, with good angiographic and short-term outcomes. Unfortunately, more detailed analysis by intravascular imaging was not conducted to confirm and validate the promising *in vitro* findings specifically with regard to stent strut apposition at the site of the bifurcation and the extent of coverage of the SB ostium, both of which are risk factors for future restenosis.

Referring back to the ideal attributes of a 2-stent strategy, we believe that the single string technique satisfies many of the requirements except the following:

- There is some inevitable distortion of the SB stent at the ostium of the SB (where maximal radial strength and luminal gain is required)—the only strategy that is least compromised by ostial stent distortion is the T and protrusion technique.
- There are as yet insufficient clinical data (e.g., acute performance and clinical outcomes) to compare the proposed approach with other currently established bifurcation techniques.

In addition, there are some specific concerns regarding the utilization of this technique:

- The average time required to perform the whole procedure in patients was reported as 110 ± 21 min minimum, and the time (1:16 min minimum and 5:57 min maximum, respectively) needed to cross the protruding struts was not trivial. However, this may be justified by the operator learning curve in these early cases.
- The ability of the operator to precisely position the SB stent to ensure sufficient protrusion to allow for re-wiring through the most proximal cell of the stent, while not “missing” the ostium or having excessive protrusion into the MB, and thus converting the proposed technique into a mini-culotte, may not be consistently reproduced. The risk of malpositioning increases and becomes almost inevitable as the bifurcation angle gets closer to 90°.
- The wire used to cross the protruding stent strut into the MB may cross outside the SB strut resulting in a mini-crush.

Despite these limitations and concerns that are unavoidable with most bifurcation techniques, we believe that the single string option appears attractive and warrants further evaluation in a larger number of lesions. Specifically, it would be important to gain a better understanding as to which stent designs are most (and least) suitable to employing this approach and what anatomy would be most appropriately treated with this approach as opposed to other existing techniques. It is also important to note, that because of specific anatomic considerations and different clinical contexts, there is unlikely to be a single bifurcation technique that can be employed for all lesions requiring 2 stents.

In conclusion, we believe that the preliminary data presented for the single string technique are promising, and depending on the results of future clinical testing, this technique may have a role in complimenting other existing 2-stent strategies for the treatment of complex bifurcation lesions.

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