Advanced Stenting Strategies for Complex Coronary Artery Bifurcation Lesions

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Percutaneous coronary stenting of bifurcation lesions constitute a challenge for interventional cardiology. It is continuously a main focus of discussion among invasive cardiologists, and has been for over 20 years. There are a few root causes of side branch failure: strut jailing of the side branch, incomplete coverage of a gap with a drug-eluting stent (DES), barotrauma from angioplasty of the side branch, and neointimal proliferation, affecting late loss. Bifurcation lesions are complex, can be very time-consuming and costly, and carry a high risk of restenosis. Despite refinement of the advanced technology and techniques we now have in our interventional cache, the surgeons are still procuring a considerable piece of the pie!

This article is not intended in any way to be an academic or scientific study on bifurcation intervention. It is rather an informal tool on the various strategies that interventionalists are now using to approach various bifurcating lesions. While you are reading these various strategies, keep in mind that these are very basic instructions, and every operator has his or her own technique and level of expertise. Some of these strategies "overlap" into others. The names we have given each of these strategies can vary from one operator to the next, as the standardization of each strategy is yet to be recognized. There will always be different opinions, but most interventionalists will agree on these basic concepts.

The strategies we will explain are:

- T stent
- V stent
- Y stent
- Double Barrel or Double D
- Trousers or "Culotte" stent
- Crush stent
- The "Back-stop" technique
- The "Tail-Wire" (or Szabo) technique

It is important to note the angulation of the bifurcation, as it will dictate how to approach the lesion. All strategies present their own level of expertise and some are more challenging due to lesion-specific complexities.

Part of the caveat of bifurcation angioplasty or stenting is the snow-plow effect, or "axial plaque redistribution."[1] This is caused by the balloon or stent shifting the plaque to the area of least resistance. Unfortunately, this area tends to be in the ostium of a branch. It can

Figures 1–5.

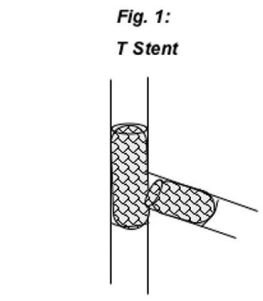


Fig. 1:
T Stent

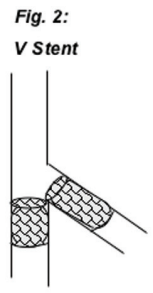


Fig. 2:
V Stent

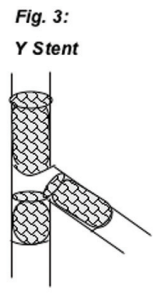


Fig. 3:
Y Stent

Fig. 4:
Double Barrel or Double D Stent
or "V Technique" by Dr. Teirstein

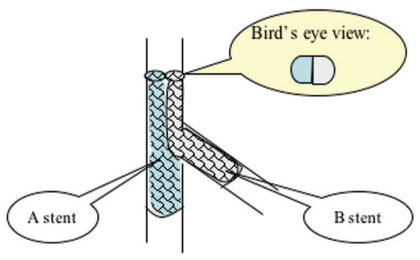
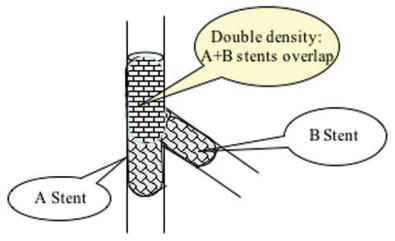


Fig. 5:
Trousers or "Culotte" Stent



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Learning Objectives:
Upon completion of this educational activity, participants should be able to:
1) Describe some of the root causes of side branch failure when stenting bifurcation lesions
2) Recognize different bifurcating lesion morphologies
3) Recognize which strategy that should be utilized as most optimal for a successful outcome.

Credits:

Physicians	1 AMA Category 1 credit
Nurses	1 Contact Hours
Technologists	1 AMA Category 1 credit

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cause a relatively simple angioplasty to become complex, with major consequences. The following strategies can alleviate some of the undesirable problems that can occur during bifurcation stenting.

T Stent

The T stent[2] strategy (Figure 1) is a strategy well suited for when the side branch originates from the main branch at an angle between 60˚ and 90˚ at the carina. In a lesion with the angle less than 60˚, there might be too large an unstented gap at the side branch ostium that would be undesirable for the overall success of the procedure. The T stent strategy consists of two stents, one in the side branch in a T-shaped configuration. The side branch is usually pre-dilated first. Some operators prefer to do provisional stenting of the side branch if the angioplasty had a sub-optimal result. If a stent is required in the side branch, there are two options. The first option is to stent the main branch, rewire the side branch through the strut, inflate through the stent, then stent through the strut. The second option is to stent the side branch first, carefully cover the ostium, and have minimal strut protruding into the main branch. The backstop technique[6] (described later) can help position the stent precisely. Most operators agree that optimal predilatation be obtained before stent delivery and a kissing balloon should follow stent delivery.

Role of the Jailed Wire Technique in T stenting. Some operators are using this technique in T stenting for three reasons.[1] First, the guidewire, left in place in the side branch, can favorably modify the angle of both branches and enable the operator to pass the third wire through the strut into the side branch. Second, the jailed wire can help keep the side branch open when stenting the main branch. Third, the risk of jailed wire rupture during pullback is low unless a hydrophilic wire is being utilized.

V Stent

The V Stent[1,11] (Figure 2) consists of two stents positioned and inflated, simultaneously or not, at each ostium. The lesions should first be prepared by re-dilatation. In this approach, a wire is not needed to pass through a stent strut. Some operators are extending the two stents side by side proximally up the main branch in a double-barrel fashion (a technique that will be explained later.)

Y Stent

The Y Stent[11] (Figure 3) consists of adding a stent in the main branch proximal to the V stents already deployed. This technique often leaves an unprotected gap near the carina devoid of the benefit of a DES.

Figure 6. Crush Technique.

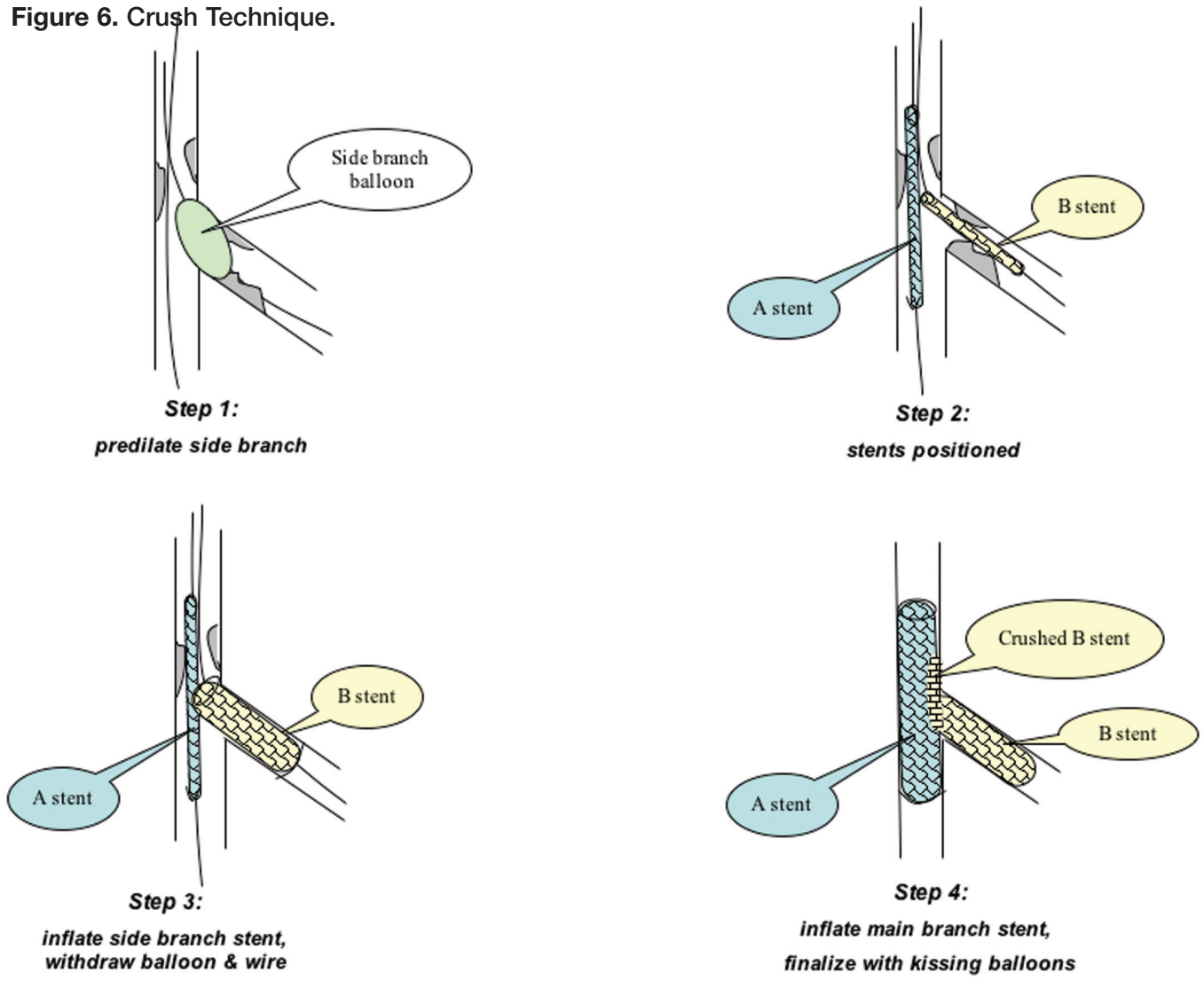
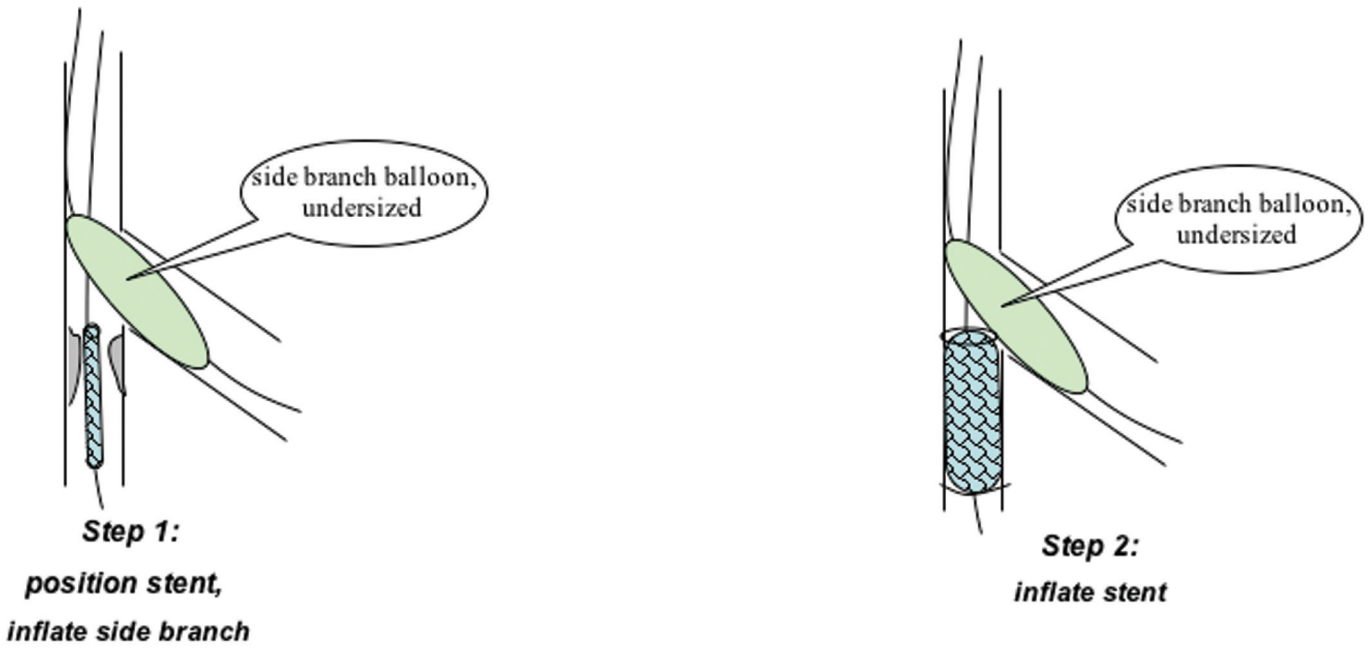


Figure 7. Backstop Technique for ostial main branch.



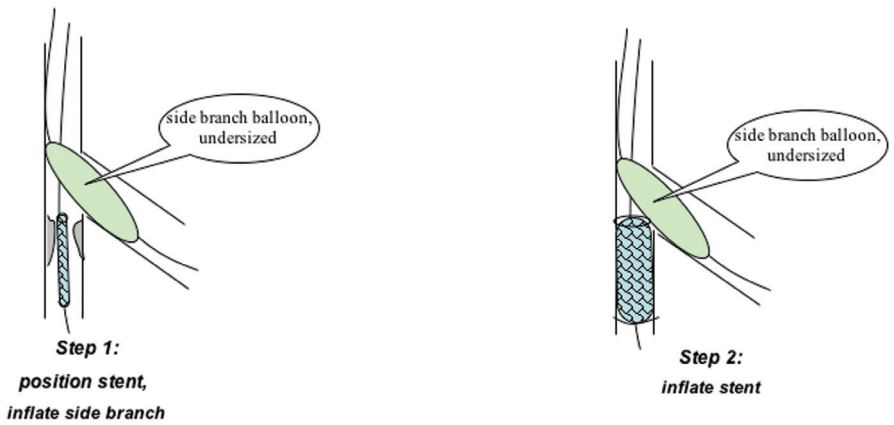
A "Modified Y" technique was described to us by Dr. Richard Fortuna (Scripps, La Jolla, Ca.) Dr. Fortuna is a very high-volume operator, and comments that his technique is easy, quick, and he has great acute and long-term results. His technique is as follows:

Wire both the main and side branch, then stent the main branch and rewire the side branch (thus removing the original wire). Next, dilate the side branch ostium, bring a stent into the side branch ostium and at the same time, put a post-dilatation balloon in the main branch. Deploy a side branch stent and post dilate at same time. There is complete coverage of side branch ostium with minimal overlap of metal and the deployment can be the final kiss.

Double Barrel or Double D Stent

This strategy (Figure 4) is also a form of the "V" Stent, and has also been called "Simultaneous Kissing Stents."[4] It is basically the same as the V stent,[3] except that the stent in the side branch and the stent in the main branch extend proximally up the main branch together, in a double-barrel configuration. These stents are often inflated simultaneously at nominal atmospheres, but a new technique was explained at the 2005 Scripps Interventional Course (Scripps Clinic, La Jolla, California) suggesting that simultaneous kissing of the stents might not allow optimal flush opposition to the wall. Some operators are now alternating low and high inflation atmospheres between the side branch and main branch to get a more "flush" opposition

Figure 8a. Backstop Technique for ostial side branch.



to the intimal wall with the stents. An example of this would be to inflate both stents simultaneously with the side branch at five atmospheres (atm), the main branch at 11 atm, then alternating one more time with the side branch at 11 atm, and main branch at 5 atm. A final kissing inflation should be done simultaneously with both at low atmospheres.

Trousers or "Culotte" Technique

This is a very complex strategy[3,5,6,8] that consists of deploying a stent in the main branch, wiring through a strut to the side branch and after pre-dilation to the side branch, removing balloon and wire from the main branch and stenting through to the side branch (Figure 5). The main branch is again rewired and pre-dilated with a balloon, and both side branches and main branch stents are finalized with simultaneous kissing balloons. Given that this strategy is time-consuming and has reportedly poor results due to suboptimal flush opposition with excess metal,[1] it is slowly losing popularity.

Crush Technique

The Crush Technique[3] (Figure 6) consists of positioning both stents in the bifurcation with the side branch stent overlapping into the main

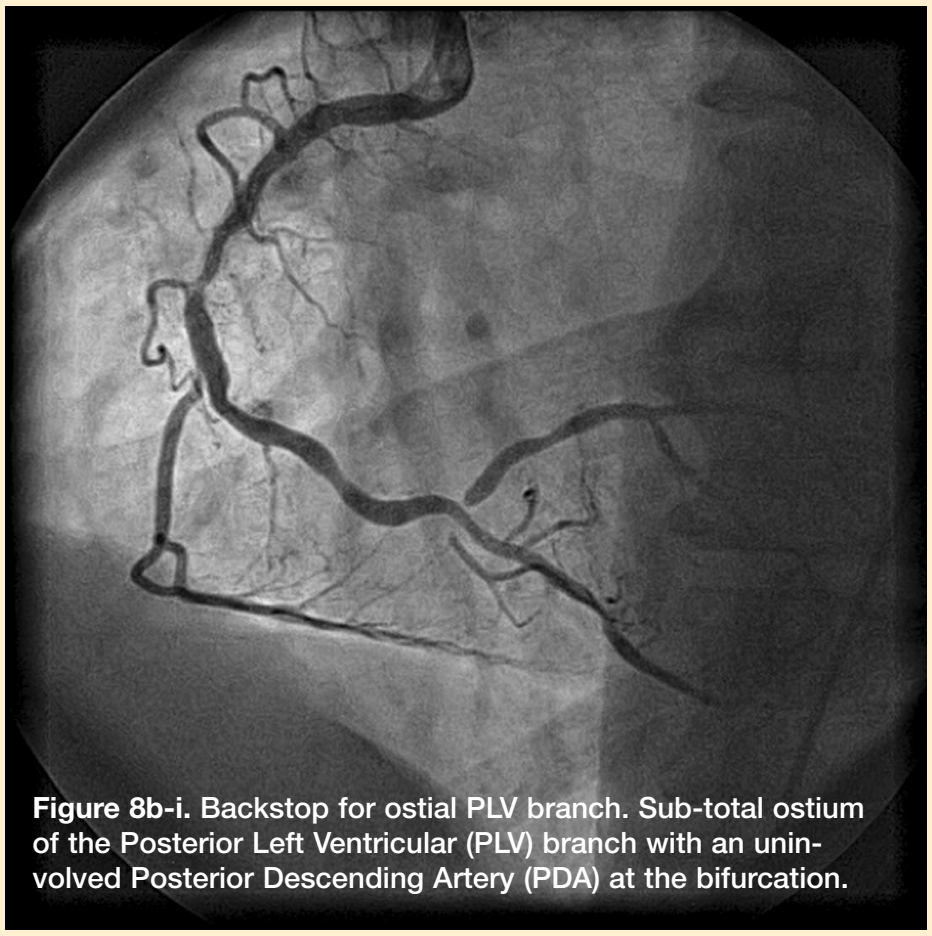


Figure 8b-i. Backstop for ostial PLV branch. Sub-total ostium of the Posterior Left Ventricular (PLV) branch with an uninvolved Posterior Descending Artery (PDA) at the bifurcation.

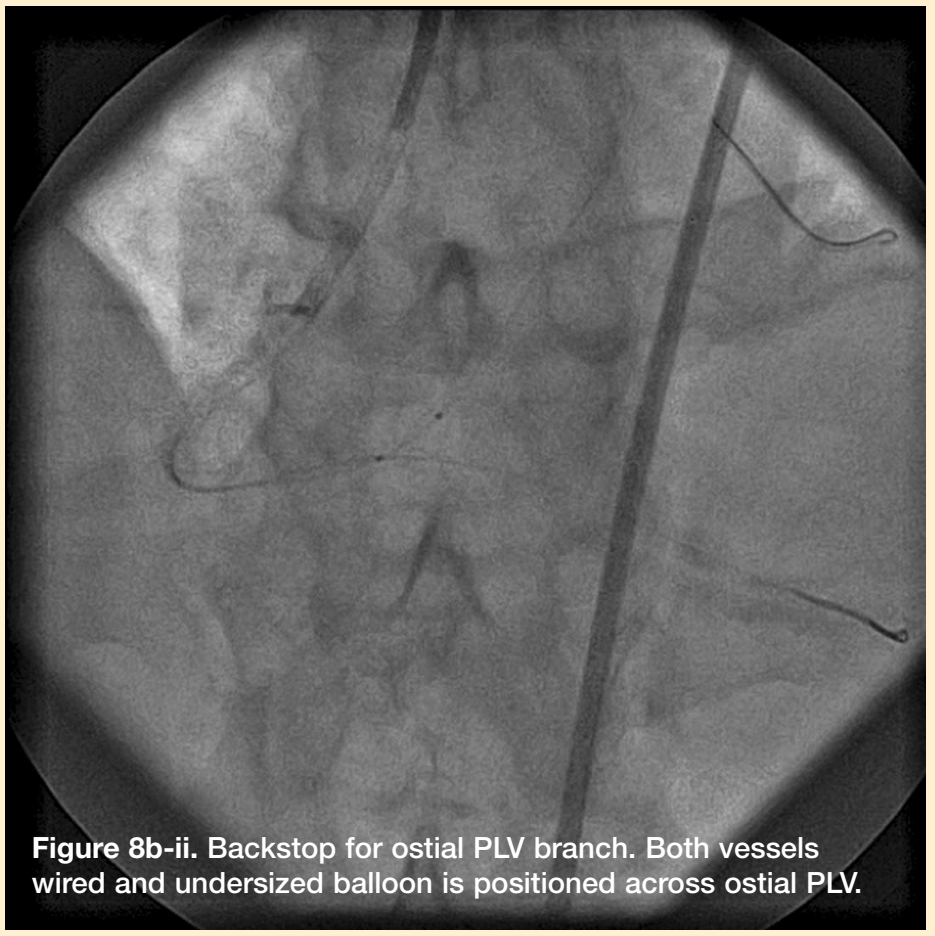


Figure 8b-ii. Backstop for ostial PLV branch. Both vessels wired and undersized balloon is positioned across ostial PLV.

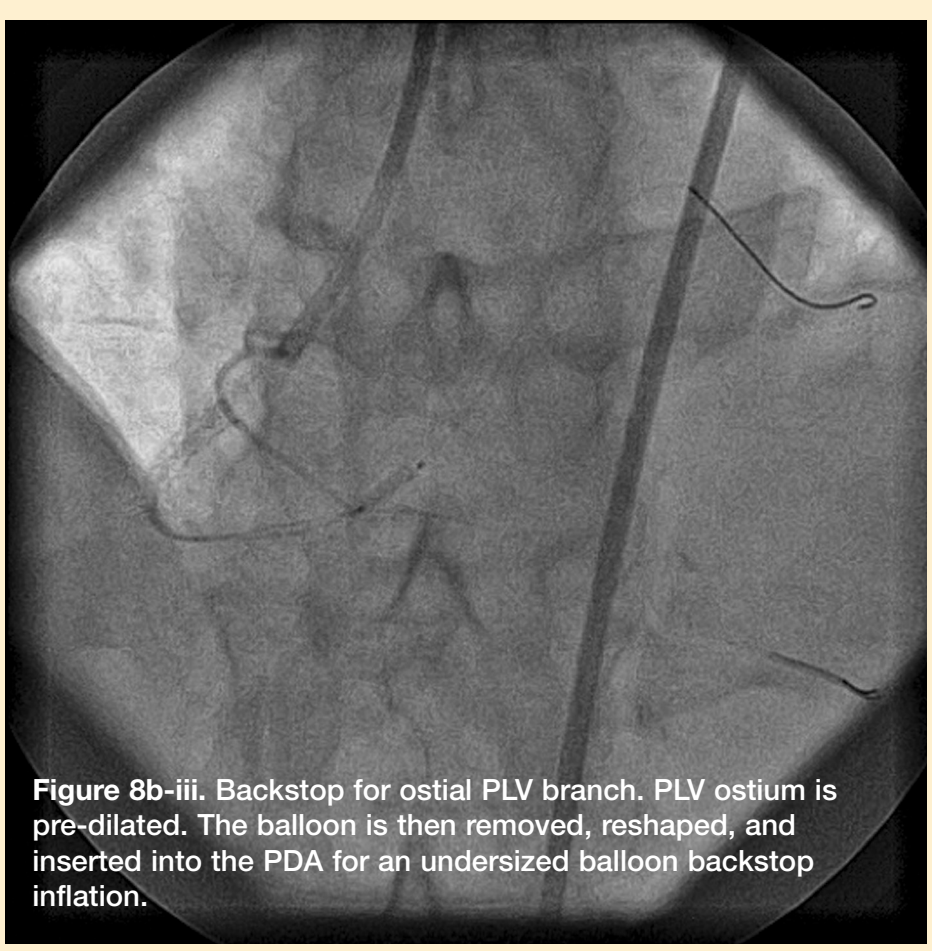


Figure 8b-iii. Backstop for ostial PLV branch. PLV ostium is pre-dilated. The balloon is then removed, reshaped, and inserted into the PDA for an undersized balloon backstop inflation.

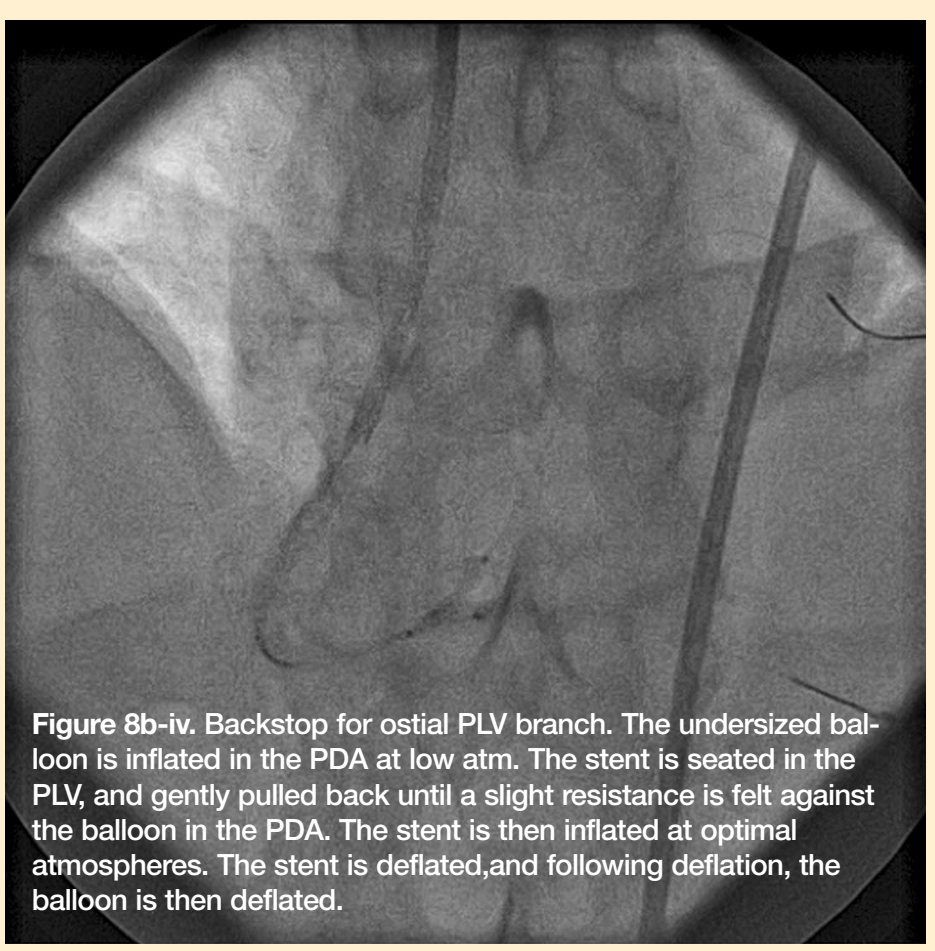


Figure 8b-iv. Backstop for ostial PLV branch. The undersized balloon is inflated in the PDA at low atm. The stent is seated in the PLV, and gently pulled back until a slight resistance is felt against the balloon in the PDA. The stent is then inflated at optimal atmospheres. The stent is deflated,and following deflation, the balloon is then deflated.

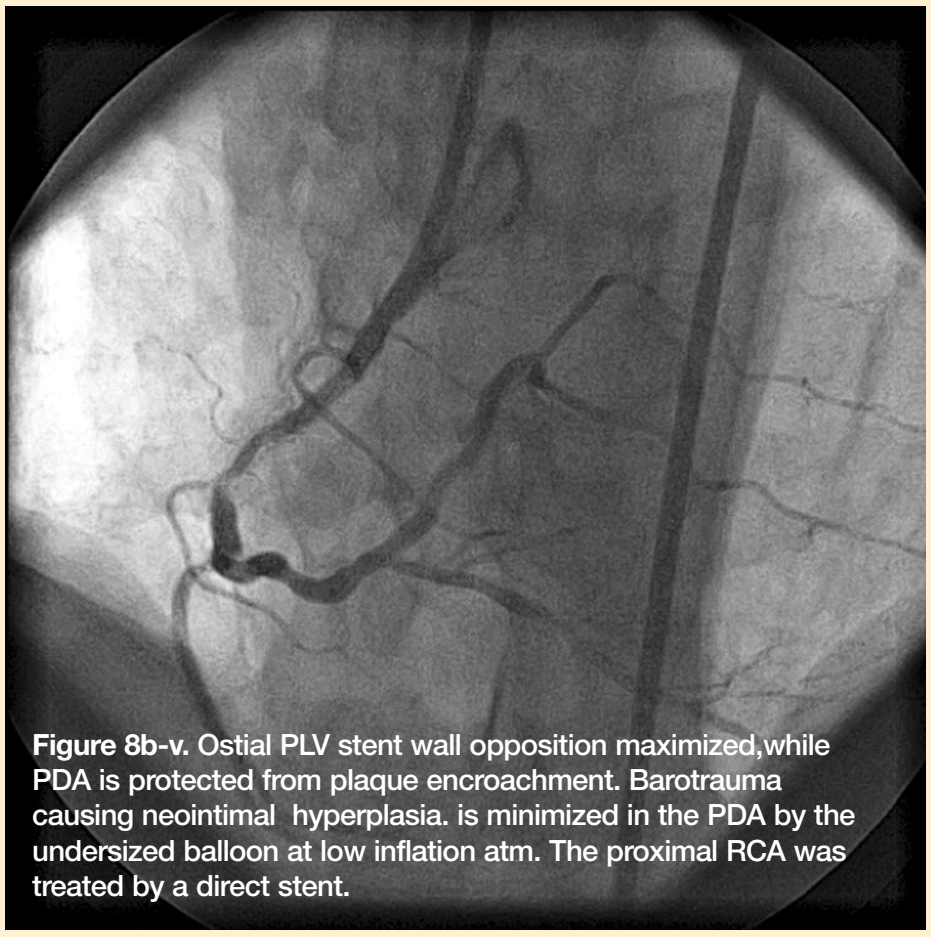


Figure 8b-v. Ostial PLV stent wall opposition maximized,while PDA is protected from plaque encroachment. Barotrauma causing neointimal hyperplasia. is minimized in the PDA by the undersized balloon at low inflation atm. The proximal RCA was treated by a direct stent.

branch. After deployment of the stent in the side branch, balloon and wire are withdrawn from the side branch. The stent in the main branch is inflated and "crushes" the part of the side branch stent that is overlapping into the main branch. Optimal results are then achieved when the side branch is re-wired and a final kissing balloon inflation is performed at the bifurcation.

Backstop Technique

This technique[7] (Figures 7–8b-v) helps to position the ostial stent of the main branch stent without having to use two stents at the bifurcation. It also helps to eliminate the undesirable effect of "snowplowing" plaque into the ostium of a "clean" vessel when the balloon is inflated in a lesion on the bifurcation. This method consists of the placement of two guidewires in both vessels (main and side branch). A stent is then positioned carefully at the stenotic site at the bifurcation. The plain balloon is then positioned half in the side branch and half in the main vessel. It should be purposely undersized as not to disrupt the intimal wall. Some operators prefer to simultaneously inflate the balloon and stent (balloon at low atmospheres, stent nominal atmospheres). Other operators are inflating the balloon first, slightly pulling on the uninflated stent until some resistance is felt, then inflating the stent. This technique avoids the plaque shift and saves the healthy branch from having to be stented. It is also cost-effective and eliminates a very complex bifurcation kissing stent procedure.

Tail-wire (Szabo) Technique

This very unique technique[9,10] (Figure 9) was described to me by Sharon Bosler, RT. She witnessed Dr. Morton Kern perform this procedure at Irvine Regional Medical Center in Irvine, California. In a paper from the 2005 TCT meeting in Washington D.C., presented by S. Szabo et al., he recently described this technique.

After wiring the aorto-ostial lesion, a second angioplasty guide wire is positioned in the aorta to anchor to the stent at the ostial lesion by passing the proximal end of the anchor wire through the last cell, or "strut" of the stent. Dr. Kern advises the use of a short wire that is capable of docking, or connecting to another wire, as this has a tapered tip at the end that helps you to" thread" through the strut. The stent then travels over both the primary wire into the artery and over the anchor wire, which stops the forward motion of the stent at the aorto-ostial junction. The stent is then deployed at low atmospheres. The tail wire is rewired and the stent is inflated at high atmospheres.

This technique can also be used in ostial-bifurcating lesions (Figure 10):

A. The stent is advanced over both the primary wire and the anchor wire which resides in the other branch.
B. The stent is advanced into the ostial lesion.
C. The stent advancement is stopped by the anchor wire and then deployed at low atmospheres. The anchor wire is removed and the stent is then inflated at high atmospheres. This gives the operator an accurate and precise ostial stent placement.

(My thanks to Dr. Morton Kern for allowing me to describe this very novel technique, and my good friend Laura Minarsch, who helped me with this resource.)

Continuing Education Quiz

Choose the single best answer to the following questions.

1. What are some of the root causes for side branch failure in bifurcating lesions?
a) Strut jailing of the side branch
b) Incomplete coverage of a gap with a drug-eluting stent
c) Barotrauma from angioplasty of the side branch, causing neointimal proliferation affecting late loss
d) All of the above

2. Axial plaque redistribution is also known as the "snowplow" effect.
a) True
b) False

3. An unstented gap at the side branch ostium affecting the overall success of the T Stent technique is most likely due to an angle of less than 60 degrees at the carina.
a) True
b) False

4. A hydrophilic wire is the best choice when utilizing the "Jailed Wire technique."
a) True
b) False

5. When "Y Stenting," the wire is always carefully passed through the strut of the main branch stent.
a) True
b) False

6. A double barrel kissing stent should always be inflated simultaneously at low atmospheres.
a) True
b) False

7. When the crush technique is utilized, it is necessary to finish with a kissing balloon inflation.
a) True
b) False

8. The side branch balloon in the backstop technique should be undersized in order to avoid disrupting the intima and causing the process of neointimal proliferation.
a) True
b) False

9. The backstop technique is designed to:
a) Avoid the plaque shift (snowplow) into the main or side branch
b) Save the healthy branch from having to be stented
c) Eliminate a complex kissing stent
d) Be a more cost-effective procedure
e) All of the above

10. Another option for treatment of bifurcation lesions, other than stenting, would be:
a) Medical treatment
b) Surgery
c) No treatment
d) All of the above

"We don't endorse or advocate the use of any of these strategies. We suggest that the reader conduct his/her own research. This article is only a reference guide to some of the strategies utilized at various seminars and courses."

Conclusion

The future will be the true test for these techniques. Although coronary artery bifurcation can be treated with an acceptable rate of late loss success, surgical treatment still constitutes a widespread therapeutic option, especially with multi-vessel disease and diabetic patients. The more data that results from randomized studies on methods and equipment, the more we realize how much we really need a good dedicated DES bifurcation stent. Currently, there are dedicated DES bifurcation stents[11] waiting for FDA approval, and others still being developed, such as the bio-degradable or bioabsorbable metallic stents.[12] Until then, it is comforting to know that we have the ability to utilize the strategies and techniques for our workhorse stents to keep us away from the surgeon.

Again, we don't endorse or advocate the use of any of these strategies. We suggest that the reader conduct his/her own research. This article is only a reference guide to some of the strategies utilized at various seminars and courses. We recommend that anyone interested in getting more information seek out this article's references, or visit:

- www.tctmd.com
- www.europcronline.com
- www.pubmed.com
- www.webmd.com
- www.invasivecardiology.com

On these websites, the reader will be able to find more information on the equipment used and different techniques on these strategies and their relative restenosis rates.

Acknowledgements

Dr. Paul Teirstein's expertise with bifurcating lesions prompted me to write this article and share some of these very innovative techniques, and, hopefully help others in our field understand the different strategies that various interventionalists are using for complex bifurcation lesions.

I would like to thank my wife Christine (Shu-lung) for her cartoon illustrations, drawn to help describe these techniques (a picture is worth a thousand words!).

My thanks to Dr. Howard Elkin for the pictures of his "Backstop" procedure. He recently informed me that this 61-year-old male was previously unable to go on the treadmill for more than three minutes because of chest pain. After the backstop procedure, his treadmill test is negative and he is now a very happy, active person.

Finally, I would like to thank the excellent cath lab staff and cardiologists at Presbyterian Intercommunity Hospital, Whittier, California, for their expertise and encouragement for me to write this article. ■

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3 = Neutral
2 = Disagree
1 = Strongly Disagree

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Figure 9. Aorto-ostial Lesion Tail Wire or Szabo Technique

Step 1:

anchor wire inserted thru the last strut of stent.

Step 2:

stent advanced over both the primary wire & anchor wire which resides outside the ostium in the aorta

Step 3:

stent advanced into the ostial lesion. The stent advancement is stopped by the anchor wire.

Step 4:

inflate stent at low atm.

Finalize by removing tail anchor wire and a high atm inflation.

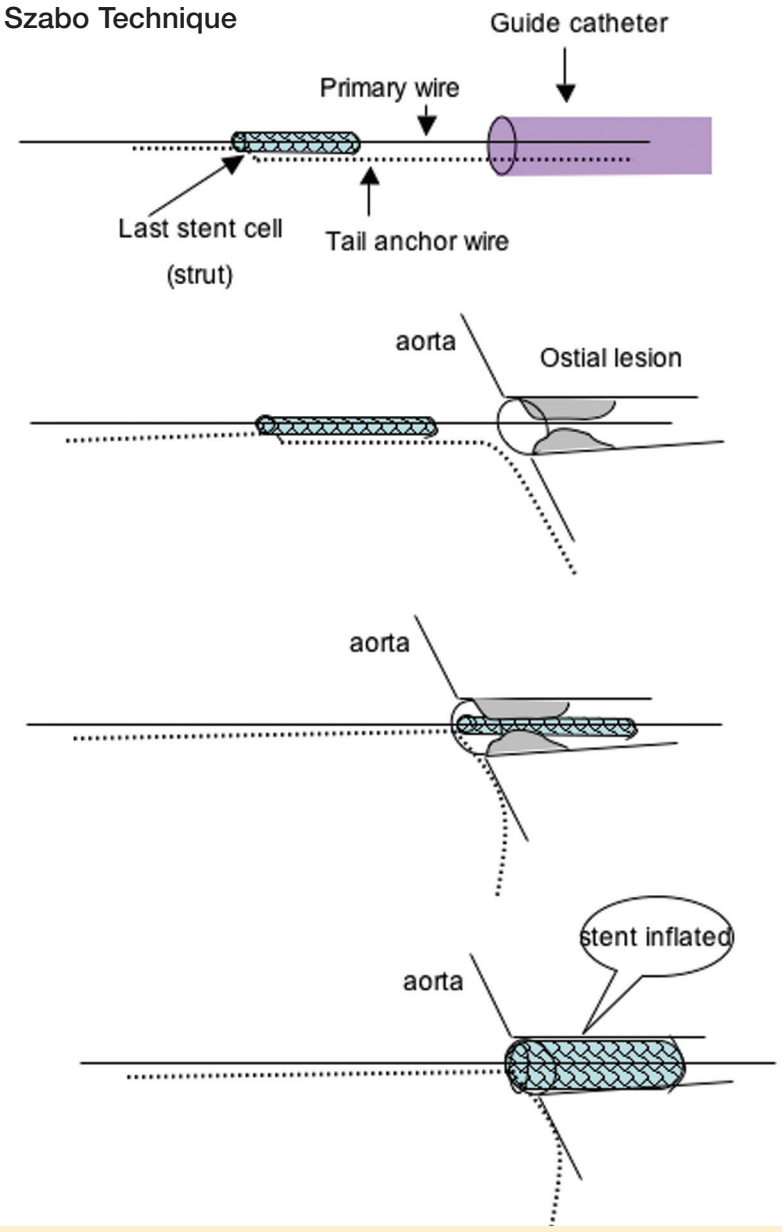

Figure 10. Ostial Bifurcation Lesion Tail Wire or Szabo Technique

Step 1:

anchor wire inserted thru the last strut of the stent.

Step 2:

stent advanced over both the primary wire & the anchor wire which resides in the other branch.

Step 3:

stent is advanced in to the ostial lesion. The stent advancement is stopped by the anchor wire.

Step 4:

inflate stent at low atm.

Finalize by removing tail anchor wire and a high atm inflation