The Side Branch Ostium: Understanding the Achilles Heel of Treating Bifurcation Coronary Disease

Ismail L. Bekdash, MD, John McB. Hodgson, MD

Department of Cardiology, Geisinger Health System, Danville, PA

Angioplasty of lesions involving a bifurcation remains one of the most challenging lesion subsets in the field of coronary intervention. A general approach to dealing with bifurcation lesions is to avoid intervention of the side branch (SB) if possible. Angiographic or flow criteria are used to determine SB intervention; however, angiographic evaluation alone can be inaccurate. Performing intravascular ultrasound prior to intervention is a useful strategy. This aids the interventional cardiologist in determining whether main branch stenting alone is sufficient or if stenting of the SB is also warranted.

[Rev Cardiovasc Med. *2010;11(suppl 1):S38-S42 doi: 10.3909/ricm11S1S0003*]

Key words: Bifurcation coronary disease • Fractional flow reserve • Intravascular ultrasound • Side branch ostium • Stenosis

Atherosclerosis develops frequently at branch points because of turbulence resulting in high endothelial stress. As a result, bifurcation lesions are present in 20% or more of lesions undergoing angioplasty.[1] Bifurcations have been classified according to the angulation between the main branch (MB) and the side branch (SB) and according to the location of the plaque burden. When the angulation is $< 70°$ and access to the SB is easy, they are classified as Y-shaped lesions. When the angulation is $> 70°$ and access to the SB is more difficult, they may be called T-shaped lesions. There have been 4 major attempts to categorize bifurcations, including the Duke, Sanborn, Safian, and Lefèvre classifications.[2] The Medina classification is the newest classification system for coronary bifurcation lesions.[3]

Regardless of classification, angioplasty of lesions involving a bifurcation remains one of the most challenging lesion subsets in the field of coronary intervention. SB compromise after stent implantation most commonly results from the snowplow phenomenon—the shifting of plaque during stent deployment or high pressure after dilation.[4-6] One of the largest studies of first-generation stents, involving 182 lesions with 224 SBs, described a SB occlusion rate of 19%.[5] Independent predictors of SB occlusion post stent deployment include reference SB diameter at baseline, degree of ostial SB stenosis before stenting, and origin of the SB within the lesion of the parent vessel.[6]

There are 2 strategies for intervening on a bifurcation lesion: provisional SB stent placement and planned SB stent placement. The provision strategy is preferred for most bifurcation lesions over a systematic 2-stent strategy because of lower restenosis and thrombosis rates. When the SB ostium is not diseased the likelihood of closure after the MB is stented is low, and if needed the SB can usually be reopened with balloon inflation. During the application of the provisional strategy, the operator must decide whether the jailed SB requires dilation or stenting after MB stent implantation.

Angiographic or flow criteria are typically used in the decision to perform further SB intervention. However, angiographic evaluation alone is sometimes inaccurate and does not reflect the functional severity of short, ostial lesions. Angiographic overestimation due to angulation, branch overlap, or imaging artifact has led to intervention on lesions that are not physiologically significant.[7] Therefore, better evaluation modalities for such complex interventions are warranted.

Fractional Flow Reserve Use for SB Ostial Evaluation

Fractional flow reserve (FFR) is an easily obtainable, lesion-specific parameter for the physiologic evaluation of epicardial coronary artery stenosis that takes into account the interaction between the anatomic stenosis and the area of perfusion supplied by a specific coronary artery.[8-10] Previous studies have validated the usefulness of FFR in angiographically ambiguous lesions.[7,11-13]

Table 1
Discordance Between FFR and Angiographic SB Assessment

FFR	≥70% Stenosis (n = 25)	50%–70% Stenosis (n = 30)
≥0.75	20	30
<0.75	5	0

FFR, fractional flow reserve; SB, side branch.
Reprinted from *The American Journal of Cardiology,* Vol. 93, A Ziaee et al, "Lack of relation between imaging and physiology in ostial coronary artery narrowings," pp. 1404–1407, Copyright 2004, with permission from Excerpta Medica, Inc.[7]

FFR-guided SB evaluation can be easily performed by passing a pressure sensor guidewire through the struts of the stent in the main vessel (MV). FFR is measured at least 5 mm distal to the jailed SB ostial stenosis. The pressure wire is then pulled back and FFR is measured at the MB to evaluate the influence of the proximal lesion.

Hyperemia is typically induced by intracoronary adenosine in bolus doses of 50 to 200 μg or intravenous adenosine at 140 μg/kg/min.[14] It is important to recognize that angiographic evaluation overestimates the functional severity of ostial lesions in every step of the provisional strategy for bifurcation lesions.

Ziaee and collegues[7] compared angiographic severity with physiologic assessment in 55 ostial stenoses. There were 25 lesions with > 70% diameter stenosis and 30 with angiographic stenosis between 50% and 70%. Among the 25 lesions with > 70% stenosis on angiography, 20 of those lesions (80%) had an FFR > 0.75 and only 5 (20%) had an FFR < 0.75. All 30 patients with angiographic stenoses between 50% and 70% had an FFR > 0.75 (Table 1).

Percutaneous interventions on ostial lesions in jailed SBs may be difficult, with a higher rate of complications, including dissection, thrombosis, spasm, and late restenosis.[15,16] Because FFR is a lesion-specific parameter it may be useful in the decision to treat a jailed SB lesion.

> *Because FFR is a lesion-specific parameter it may be useful in the decision to treat a jailed SB lesion.*

Koo and associates[17] studied 97 jailed SB lesions in 92 patients (vessel size > 2.0 mm, percent stenosis > 50% by visual estimation) after MB stent implantation. The FFR was measured 5 mm distal and proximal to the ostial lesion of the jailed SB. Mean FFR was 0.94 ± 0.04 and 0.85 ± 0.11 at the MB and jailed SB, respectively. There was a negative correlation between the angiographic percent diameter stenosis and FFR ($r = -0.41$; $P < .001$). However, no lesion with < 75% stenosis had an FFR < 0.75. Among the 73 lesions with ≥ 75% stenosis,

Table 2
Relation of FFR and Angiographic Assessment of Jailed SB Lesions

	≥75% Stenosis	50%–75% Stenosis
All Vessels (n = 94)		
FFR < 0.75	20 (27%)	0
FFR ≥ 0.75	53	20
Vessels ≥ 2.5 mm (n = 28)		
FFR < 0.75	8 (38%)	0
FFR ≥ 0.75	13	7

FFR, fractional flow reserve; SB, side branch.
Reprinted from *Journal of the American College of Cardiology,* Vol. 46, BK Koo et al, "Physiologic assessment of jailed side branch lesions using fractional flow reserve," pp. 633–637, Copyright 2005, with permission from the American College of Cardiology Foundation.[17]

only 20 lesions were functionally significant.[17]

In a study involving 110 patients treated with a provisional strategy, SB FFR was measured in 91 patients; SB intervention was performed only if the FFR was < 0.75. FFR measurement was repeated after the SB intervention and at 6-month follow-up angiography. In 26 of 28 SB lesions with an FFR < 0.75, balloon angioplasty (kissing balloon) was performed. An FFR ≥ 0.75 was achieved in 92% of the lesions although the mean residual angiographic stenosis was 69 ± 10%. During follow-up, there were no changes in FFR in the SB lesions (with or without angioplasty at the time of original procedure). The functional restenosis (FFR < 0.75) rate was only 8% (5/65). Clinical outcomes of these provisionally treated patients were compared with 110 patients with similar bifurcation lesions treated without FFR guidance. There was no difference in 9-month cardiac event rates between the 2 groups.[14]

FFR is an accurate way to determine those SB lesions requiring intervention. If, after MB stent deployment, there is a > 70% stenosis in the SB ostium, then FFR plays an important role in further management. If FFR is > 0.75, no further treatment is necessary, whereas if FFR is < 0.75 then treatment with kissing balloon dilation (± stenting) to establish an FFR > 0.75 is recommended. This strategy is illustrated in Figure 1.

Intravascular Ultrasound Use in Assessing SB Disease

Intravascular ultrasound (IVUS) is routinely used to clarify angiographic ambiguity in many clinical scenarios. There has been limited application of IVUS in bifurcation lesion intervention. One reason for this may be that pre-stent IVUS of both branches is uncommon and advancement of the IVUS probe through a stent into the SB can be problematic.[18]

Preintervention IVUS provides information not available by angiography alone and can be used to predict SB occlusion after percutaneous coronary intervention. SBs having diffuse plaque around their ostium are at the greatest risk. Furukawa and coworkers[19] reported 81 bifurcation lesions in 72 patients. SBs were classified into 2 groups: group 1 had ostial SB stenosis due to atherosclerotic plaque only in the MV (n = 61), and group 2 had plaque truly involved in the SB ostium (n = 20). There was no significant difference between the 2 groups in the extent of ostial stenosis as assessed by angiography. After MB intervention, 7 SBs occluded in group 2, compared with only 5 SBs in group 1 (35% vs 8%; P = .003).[19] This strategy is illustrated in Figure 2.

Stent positioning for ostial lesions is imprecise because it is often difficult, if not impossible, to profile the ostium of a coronary artery by angiography due to vessel overlap or foreshortening, and there is usually "bobbing" or to and fro motion of the stent/balloon system caused by cardiac contraction. This is especially common with ostial left anterior descending artery (LAD) stenosis. IVUS can be used to confirm precise stent positioning at the ostium of a coronary artery.[20] A helpful maneuver is to position the IVUS transducer at the carina by observing the IVUS images and then record the position of the transducer fluoroscopically to establish angiographic landmarks. The stent can then be placed using these IVUS-defined landmarks. Finally, IVUS has documented the beneficial effect on stent geometry produced by final kissing balloon dilation, now considered a requirement after bifurcation intervention.[21]

IVUS can be used to confirm precise stent positioning at the ostium of a coronary artery.

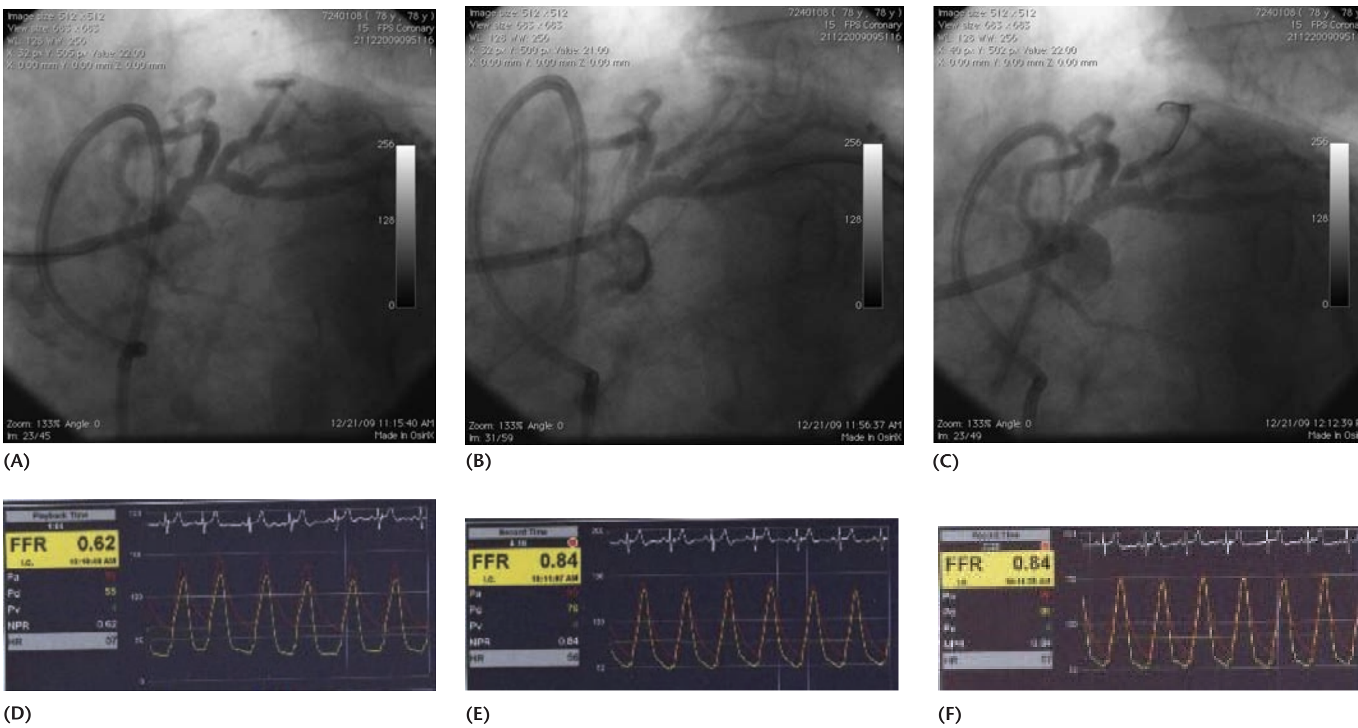

Figure 1. **(A)** *This left anterior descending artery (LAD) caudal angiogram shows the lesion in the left circumflex artery (LCX) with no apparent involvement of the LAD or ramus branch ostia.* **(B)** *After stent implantation from the LCX into the left main, the LAD ostium appears hazy and the ramus ostium appears stenosed >70%.* **(C)** *Based on functional flow reserve (FFR) measures, the LAD was balloon dilated. The ramus was not treated. This is the final angiogram.* **(D)** *FFR determination with the wire in the LAD reveals a significant stenosis (FFR 0.62).* **(E)** *After balloon dilation, the LAD FFR rose to 0.84.* **(F)** *FFR in the ramus branch was 0.84. No treatment was performed.*

Conclusions

A general approach to dealing with bifurcation lesions is to avoid intervention of the SB if possible. A useful strategy is to perform IVUS prior to intervention. If IVUS shows no involvement of the SB then stenting of the MB alone should be attempted. If IVUS shows diffuse disease of the SB then planned stenting of both the MB and SB is recommended. For ambiguous cases, or if the SB ostia appears narrowed > 70% after MB stent placement, measuring FFR in the SB is recommended. If the FFR is > 0.75 no further treatment is needed, whereas if the FFR is ≤ 0.75 kissing balloon of the SB to establish a FFR > 0.75 is recommended. If an adequate result cannot be achieved after kissing balloon, then SB stenting is required. ■

Dr. Bekdash and Dr. Hodgson have no real or apparent conflicts of interest to report.

References

1. Louvard Y, Lefèvre T, Morice MC. Percutaneous coronary intervention for bifurcation coronary disease. *Heart.* 2004;90:713-722.

Main Points

- The provision for intervening on a bifurcation lesion strategy is preferred for most bifurcation lesions over a systematic 2-stent strategy because of lower restenosis and thrombosis rates; when the side branch (SB) ostium is not diseased the likelihood of closure after the main branch is stented is low.
- Independent predictors of SB occlusion after stent deployment include reference SB diameter at baseline, degree of ostial SB stenosis before stenting, and origin of the SB within the lesion of the parent vessel.
- Angiography is typically used to determine whether further SB intervention is required; however, angiography alone can be inaccurate. Fractional flow reserve has been proven useful in evaluating angiographically ambiguous lesions.
- Intravascular ultrasound can be utilized to confirm accurate stent positioning at the ostium of a coronary artery prior to intervention.

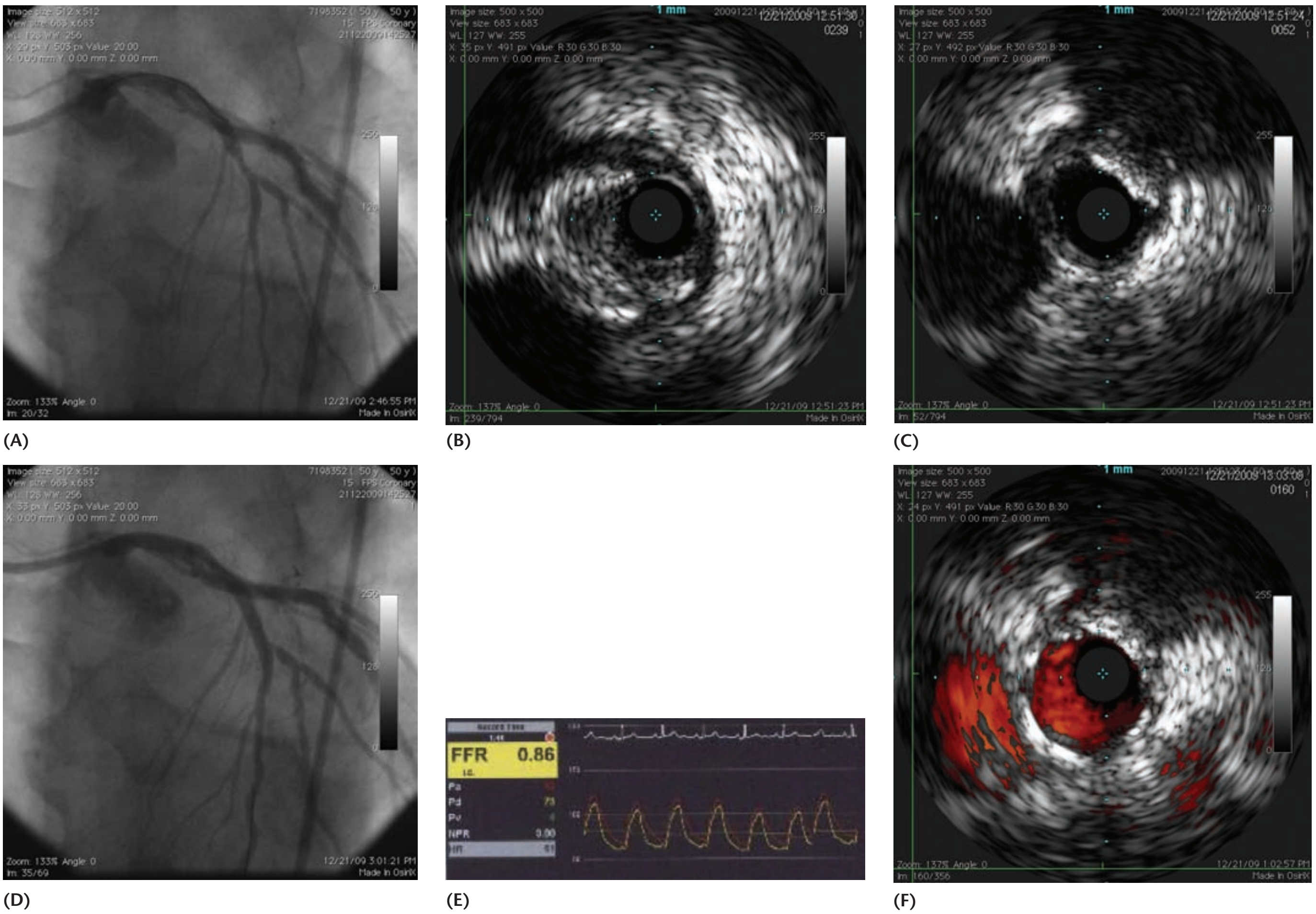

Figure 2. (A) *Angiography of the left anterior descending artery (LAD) shows a lesion involving the large diagonal. The functional flow reserve (FFR) in this lesion was* $<$*0.75, and intervention is planned.* **(B)** *Preintervention intravascular ultrasound (IVUS) of the LAD lesion showing a luminal area of* <3 *mm*^{2}. **(C)** *Preintervention IVUS at the diagonal ostium (at 9:00) showing no diagonal involvement.* **(D)** *Post main branch stent placement showing some narrowing of the diagonal ostium.* **(E)** *FFR obtained in the diagonal reveals insignificant limitation (0.86). No further intervention is performed.* **(F)** *Post-stent IVUS at the bifurcation showing good color flow into the diagonal branch.*

2. Iakovou I, Ge L, Colombo A. Contemporary stent treatment of coronary bifurcations. *J Am Coll Cardiol*. 2005;46:1446-1455.
3. Medina A, Suárez de Lezo J, Pan M. A new classification of coronary bifurcation lesions. *Rev Esp Cardiol*. 2006;59:183-184.
4. Fischman DL, Savage MP, Leon MB, et al. Fate of lesion-related side branches after coronary artery stenting. *J Am Coll Cardiol*. 1993;22:1641-1666.
5. Aliabadi D, Tilli FV, Bowers TR, et al. Incidence and angiographic predictors of side branch occlusion following high pressure intracoronary stenting. *Am J Cardiol*. 1997;80:994-997.
6. Poerner TC, Kralev S, Voelker W, et al. Natural history of small and medium-sized branches after coronary stent implantation. *Am Heart J*. 2002;143:627-635.
7. Ziaee A, Parham WA, Herrmann SC, et al. Lack of relation between imaging and physiology in ostial coronary artery narrowings. *Am J Cardiol*. 2004;93:1404-1406.
8. Pijls NHJ, Van Son JAM, Kirkeeide RL, et al. Experimental basis of determining maximum coronary myocardial and collateral blood flow by pressure measurements for assessing functional stenosis severity before and after PTCA. *Circulation*. 1993;87:1354-1367.
9. De Bruyne B, Bartunek J, Sys SU, Heyndrickx GR. Relation between myocardial fractional flow reserves calculated from coronary pressure measurement and exercise-induced myocardial ischemia. *Circulation*. 1995;92:39-46.
10. Pijls NHJ, De Bruyne B, Peels K, et al. Measurement of fractional flow reserve to assess the functional severity of coronary artery stenoses. *N Engl J Med*. 1996;334:1703-1708.
11. Lopez-Palop R, Pinar E, Lozano I, et al. Utility of the fractional flow reserve in the evaluation of angiographically moderate in-stent restenosis. *Eur Heart J*. 2004;25:2040-2047.
12. Jasti V, Ivan E, Yalamanchili V, et al. Correlations between fractional flow reserve and intravascular ultrasound in patients with an ambiguous left main coronary artery stenosis. *Circulation*. 2004;110:2831-2836.
13. Leesar MA, Masden R, Jasti V. Physiological and intravascular ultrasound assessment of an ambiguous left main coronary artery stenosis. *Catheter Cardiovasc Interv*. 2004;62:349-357.
14. Koo BK, Park KW, Kang HJ, et al. Physiological evaluation of the provisional side-branch intervention strategy for bifurcation lesions using fractional flow reserve. *Eur Heart J*. 2008;29:726-732.
15. Mathias DW, Mooney JF, Lange HW, et al. Frequency of success and complications of coronary angioplasty of a stenosis at the ostium of a branch vessel. *Am J Cardiol*. 1991;67:491-495.
16. Sawada Y, Kimura T, Shinoda E, et al. Poor outcome of balloon angioplasty (BA) for ostial left anterior descending and circumflex: impact of new angioplasty devices. *Circulation*. 1994;90:I-436.
17. Koo BK, Kang HJ, Youn TJ, et al. Physiologic assessment of jailed side branch lesions using fractional flow reserve. *J Am Coll Cardiol*. 2005;46:633-637.
18. van der Waal EC, Mintz GS, Garcia-Garcia HM, et al. Intravascular ultrasound and 3D angle measurements of coronary bifurcations. *Catheter Cardiovasc Interv*. 2009;73:910-916.
19. Furukawa E, Hibi K, Kosuge M, et al. Intravascular ultrasound predictors of side branch occlusion in bifurcation lesions after percutaneous coronary intervention. *Circ J*. 2005;69:325-330.
20. Wong P. Two years experience of a simple technique of precise ostial coronary stenting. *Catheter Cardiovasc Interv*. 2008;72:331-334.
21. de Lezo JS, Medina A, Martín P, et al. Ultrasound findings during percutaneous treatment of bifurcated coronary lesions. *Rev Esp Cardiol*. 2008;61:930-935.