Percutaneous Coronary Intervention for Coronary Bifurcation Lesions

William Finch, MD, Michael S. Lee, MD
Division of Cardiology, UCLA Medical Center, Los Angeles, CA

Percutaneous coronary intervention (PCI) of lesions at coronary bifurcations poses a technical challenge. Short-term complications, including periprocedural myocardial infarction, and long-term complications such as in-stent restenosis and stent thrombosis, are higher in patients with bifurcation lesions. Techniques for PCI of bifurcation lesions include stenting of the main branch alone, and the use of two or more stents to cover the main and side branches. Two- or three-stent techniques include T-stenting, crush, culotte, simultaneous kissing stents, V-stenting, and Y-stenting. The goal of these techniques is to minimize areas of vessel that are not covered by stent. Dedicated bifurcation stents exist, including stents with apertures that allow standard stents to be placed within the aperture. Simultaneous kissing balloon angioplasty in the two branches should be performed to optimize angiographic results. Many studies exist comparing the different techniques; however, no consensus exists on the preferred method.

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KEY WORDS

Percutaneous coronary intervention • Coronary bifurcation lesion • Simple stenting • Complex stenting

Atherosclerotic lesions at the bifurcation of coronary arteries may develop because of high-shear stress from turbulent blood flow. Up to 15% of percutaneous coronary interventions (PCIs) involve bifurcation lesions.[1] The main complication of bifurcation PCI is "snow plowing," when plaque shifts into the side branch (SB), potentially compromising it. Bifurcation lesions can increase the complexity of PCI, because plaque can shift into the SB, potentially compromising its flow. As a result, rates of restenosis, stent thrombosis, and periprocedural myocardial infarction (MI) may be higher.[1,2] Several options are available to treat bifurcation lesions, although a consensus on the ideal approach has not been reached.

The Medina system is a common classification used to grade bifurcation lesions.[3] The three segments of bifurcation include the proximal segment of the main vessel (MV), the main branch distal segment (MB), and the SB. Each is represented by a score of 0 or 1, in that order, separated by commas or periods. A 0 indicates no significant stenosis and a 1 indicates >50% stenosis. For example, a bifurcation with stenosis in the proximal segment and SB is notated as 1.0.1. Bifurcation lesions have further been stratified into *true* and *nontrue* bifurcation lesions.[4] A true bifurcation lesion is one in which both the proximal or distal MV and the SB are involved (Medina 0.1.1, 1.0.1, or 1.1.1), whereas all others are nontrue.

Stenting techniques for bifurcation lesions may also be classified using the MADS (Main, Across, Distal, Side) system.[3] Each letter of the acronym denotes a different strategy for the initial stent placed. ***M*** indicates that the first stent is placed in the proximal MB (not extending across the SB); ***A*** indicates the first stent is in the MV across the SB; ***D*** utilizes a double stent implantation (either one in each distal segment not extending into the MB, or with both stents extending into the MB); and ***S*** indicates that the first stent is implanted within the SB, usually with protrusion into the proximal segment. Each of these initial strategies can then be modified with additional stent implantation.

Outcomes of Coronary Bifurcation Lesions

PCI of true bifurcation lesions is associated with a higher rate of major adverse cardiac events (MACE) when compared with nontrue lesions,[5] driven predominantly by periprocedural MI.[6] Among true bifurcations, SB occlusion has been observed more frequently in Medina 1.1.1 and 1.0.1 lesions, whereas Medina 1.1.1 and 0.1.1 lesions are associated with higher risk of MI or cardiac death.[5] The RESOLVE (Risk Prediction of Side Branch Occlusion in Coronary Bifurcation Intervention) score has been developed to predict the risk of SB occlusion during PCI of bifurcation lesions.[7] RESOLVE scores range from 0 to 43, and points are assigned for plaque distribution on the same side as the SB, lower Thrombolysis in Myocardial Infarction (TIMI) flow prior to stenting, greater stenosis proximal to bifurcation, higher bifurcation angle, greater ratio of MV to SB, and greater stenosis of the SB. The RESOLVE score has a C-statistic of 0.77, indicating good predictive value with the risk of SB occlusion divided into quartiles.

Even after PCI, bifurcation lesions are at high risk for recurrence of disease and restenosis.[8] If stent thrombosis occurs in bifurcation lesions, both in-hospital and long-term mortality are significantly higher compared with nonbifurcation lesions.[9] In primary PCI for ST-elevation MI, the SB originates from the culprit lesion in 29% of cases, with SB occlusion occurring in only 10% of cases.[10] PCI of bifurcation lesions with chronic total occlusion is associated with significantly higher procedural time, contrast load, coronary perforation leading to cardiac tamponade, and lower angiographic success.[11]

Simple Stenting Versus Complex Stenting

Bifurcation lesions can be treated with a one-stent approach or with multiple stents. The one-stent approach is preferred, if possible, but it may lead to plaque shifting into the SB during MB stenting. Provisional stenting, or the practice of stenting an SB only if necessary, may be performed if the angiographic result is suboptimal (residual SB stenosis >50%, fractional flow reserve <0.75, or <TIMI grade 3 flow).[12] Final simultaneous kissing balloon inflation should be performed after stenting to maintain SB patency, as it reduces plaque shifting into the SB and restenosis.[13,14]

Various techniques for multistent bifurcation stenting have been developed, including the crush, culotte, V-stenting, Y-stenting, simultaneous kissing stenting, T-stenting, and modified T-stenting techniques.[15] Multiple studies have compared one-stent bifurcation PCI (simple stenting) with multiple stent techniques (complex stenting). Retrospective studies reported that complex stenting did not significantly change target lesion revascularization (TLR) and MACE.[16] However, the rate of periprocedural MACE was increased in patients who

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underwent complex stenting (13%) compared with simple stenting (0%). This is likely due to the increased procedural complexity. This is supported by findings of the Nordic Bifurcation Study, which found that complex stenting required higher contrast dose and fluoroscopy times, and resulted in higher postprocedural troponin levels.[2] Several randomized trials and observational studies subsequently compared complex and simple stenting with SB angioplasty and confirmed the lack of benefit with complex stenting compared with simple stenting.[2,17-22] The British Bifurcation Coronary Study reported an increased rate of periprocedural MI, and a higher rate of MI after discharge from the hospital, whereas the Bifurcations Bad Krozingen trial reported no difference in MACE at 1 year.[23] A meta-analysis of the randomized trials reported increased rates of periprocedural MI and lack of improvement in long-term outcomes with multistent strategies.[24-29] A registry of 3162 patients undergoing bifurcation stenting reported that, although first-generation drug-eluting stents (DES) favored the one-stent technique, outcomes were similar between one-stent and two-stent techniques using second-generation DES.[30] Nevertheless, complex stenting is required to obtain optimal angiographic results when the ostium of the SB is severely diseased.

Complex Stenting Strategies for PCI of Bifurcation Lesions

T-stenting Technique

A stent is first placed in the MV across the SB into the MB, followed by a stent placed in the SB through the struts of the first stent (Figure 1).[15] However, the ostium of the SB is not covered by either stent, which can result in ostial restenosis. Modified T-stenting reverses the order of stent placement, with improved ostial coverage by the SB stent. The T and protrusion technique also allows

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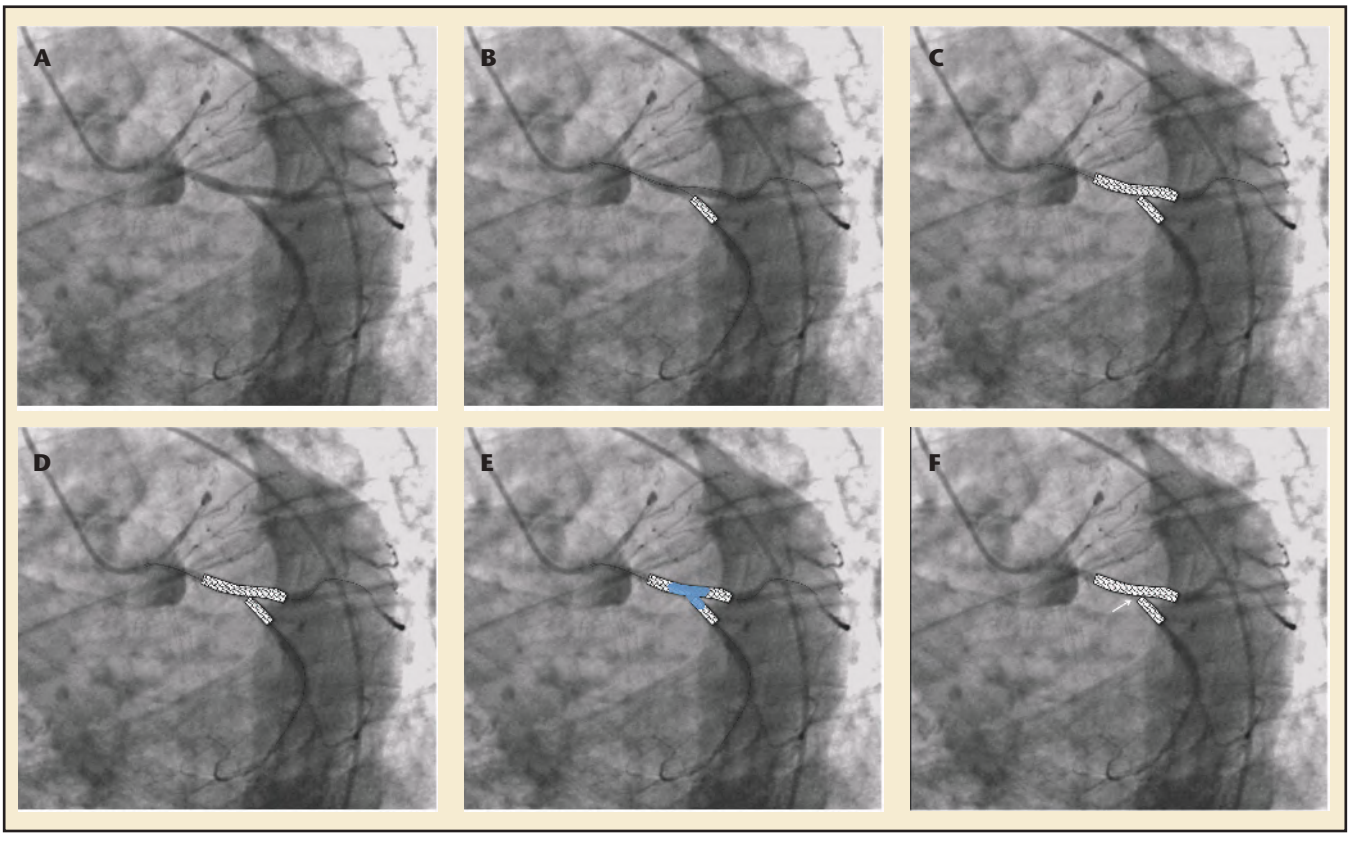
Figure 1. Coronary angiograms. **(A)** T-stenting. **(B)** Side-branch stenting. **(C)** The side branch wire is removed followed by stenting of the main vessel into the main branch. **(D)** A guide wire is readvanced into the side branch. **(E)** Final kissing balloon angioplasty is performed (angioplasty balloons represented by *blue area*). **(F)** The ostium of the side branch (*arrow*) may not be adequately covered.



ostial stent coverage by first placing the MB stent (Figure 2).[31] The SB stent is deployed through the struts of the MB stent followed by final kissing balloon inflation.

Crush Technique

One stent is placed in the SB with the proximal segment protruding into the proximal MV while another stent or balloon is placed in the MB with the proximal segment protruding in the MV and overlapping the SB stent (Figure 3).[32] The SB stent is expanded first. After the SB balloon and wire are removed, the MB stent is expanded, causing the portion of the SB stent in the MV to be crushed. This differs from T-stenting in that the SB stent protrudes into the MB by several millimeters. The crush technique resolves the issue of incomplete SB ostial coverage with T-stenting. The double kissing (DK) crush technique is a variation of the crush technique.[33,34] The sequence of events includes stenting of the SB, balloon crush of the SB stent, kissing balloon angioplasty, and MB stenting and a second kissing balloon inflation.

Culotte Technique

This technique also provides complete ostial coverage of the SB. In the first step, one stent is expanded in the SB with protrusion into the MV (Figure 4).[15] A balloon is then advanced into the MB through the first stent's struts and then dilated. A second stent is expanded within this opening which covers the MV and MB. Final kissing balloon angioplasty is performed.

V-stenting Technique

One stent is placed in each branch without extending into the MV.[15,35] Two variations of this technique provide coverage of the MV. Y-stenting starts off with V-stenting in the two branches, and then is followed by a third stent placed in the MV.[36] The simultaneous kissing stent utilizes the same technique as the V stent with the exception that the stents are expanded simultaneously in the MV and overlap.[37]

Single-string Technique

In this technique, the SB stent is first positioned with a single cell protruding into the MB.[38] Next, a guide wire is advanced through this single cell. Following balloon dilation of this cell, the MB stent is then expanded within this SB stent cell. The final step is kissing balloon inflation. This technique has the advantage of minimal overlap, and inflation of the single cell (which becomes a "single string") pulls the SB stent toward the MB, ensuring optimal ostial coverage.

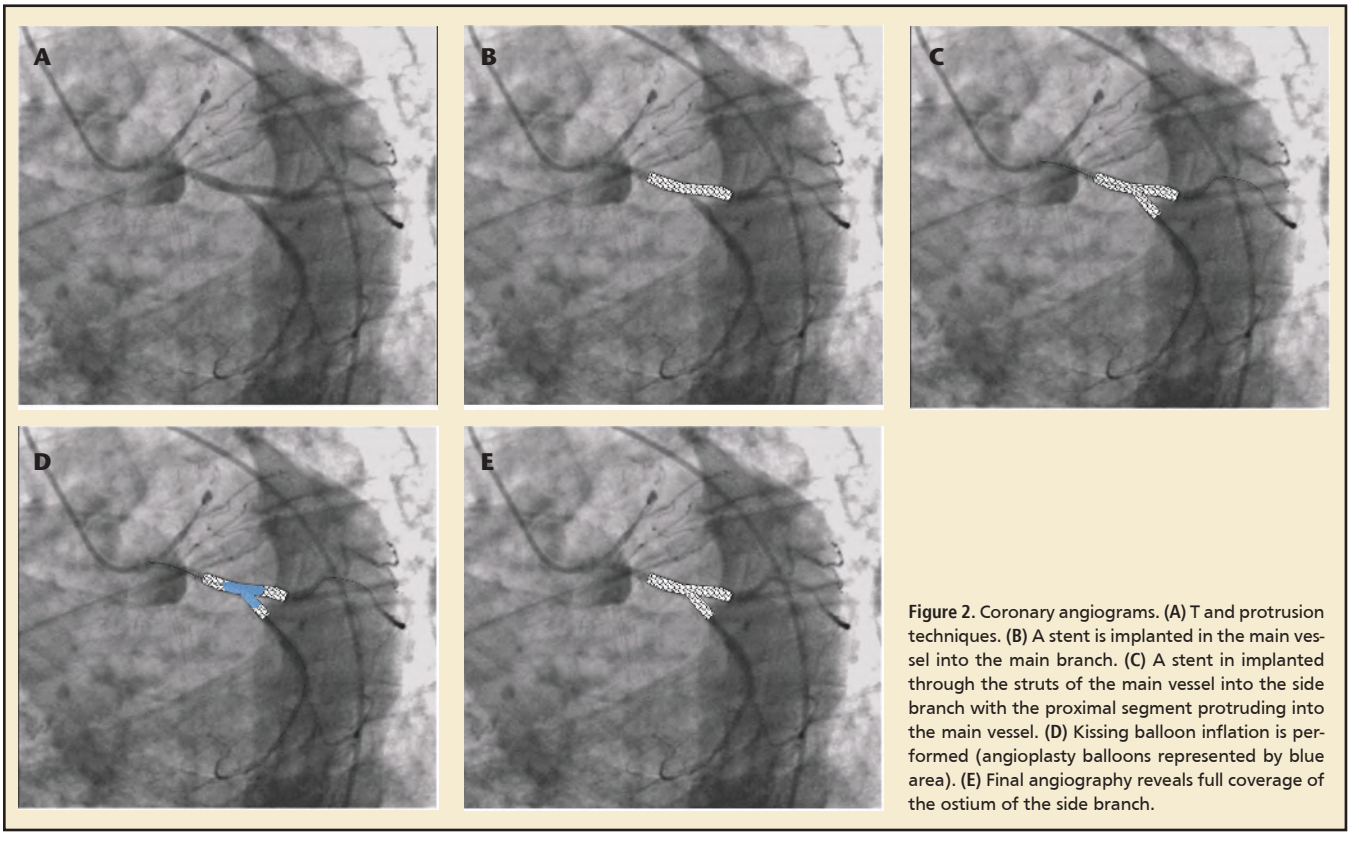


Figure 2. Coronary angiograms. **(A)** T and protrusion techniques. **(B)** A stent is implanted in the main vessel into the main branch. **(C)** A stent in implanted through the struts of the main vessel into the side branch with the proximal segment protruding into the main vessel. **(D)** Kissing balloon inflation is performed (angioplasty balloons represented by blue area). **(E)** Final angiography reveals full coverage of the ostium of the side branch.

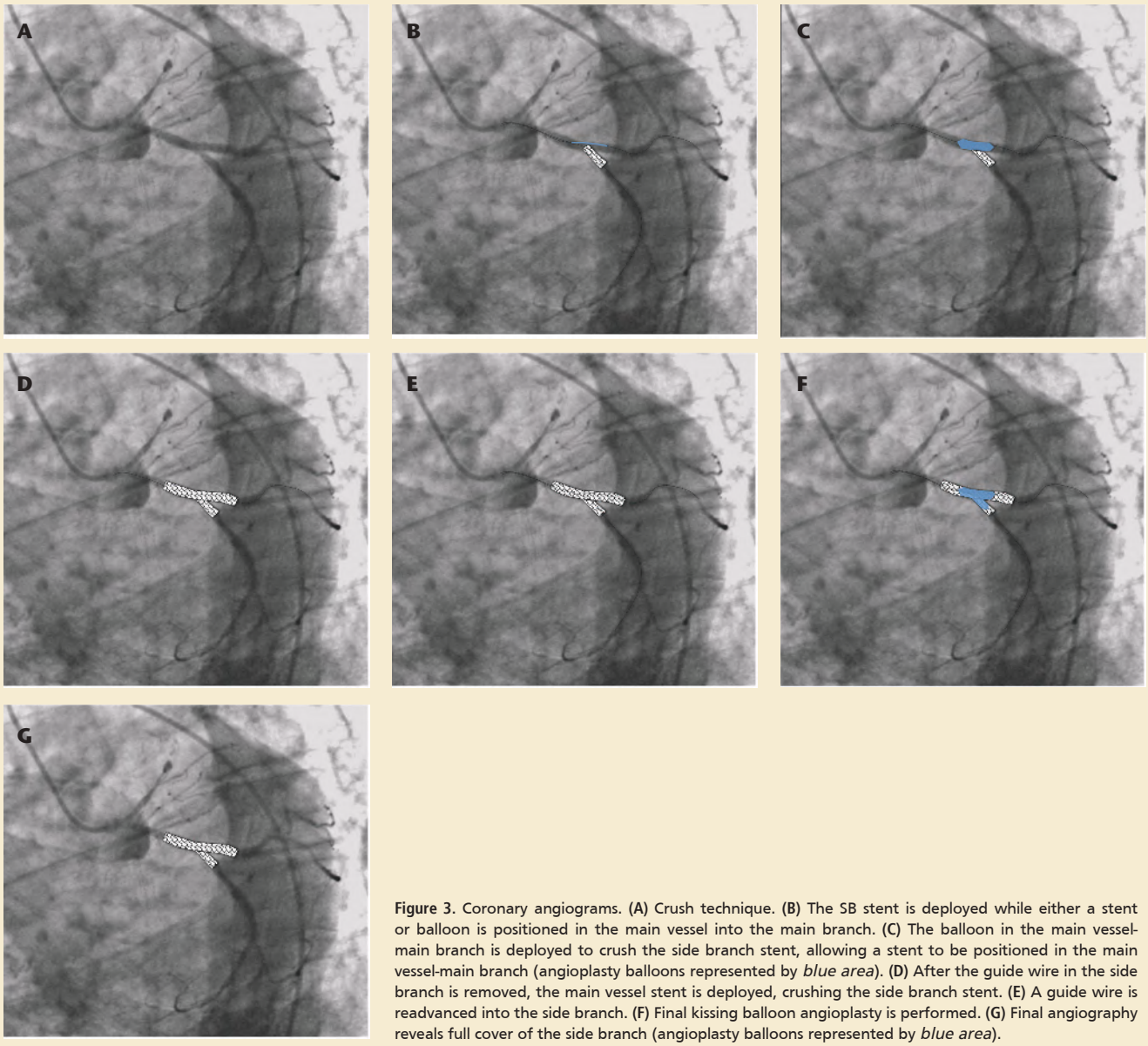


Figure 3. Coronary angiograms. **(A)** Crush technique. **(B)** The SB stent is deployed while either a stent or balloon is positioned in the main vessel into the main branch. **(C)** The balloon in the main vessel-main branch is deployed to crush the side branch stent, allowing a stent to be positioned in the main vessel-main branch (angioplasty balloons represented by *blue area*). **(D)** After the guide wire in the side branch is removed, the main vessel stent is deployed, crushing the side branch stent. **(E)** A guide wire is readvanced into the side branch. **(F)** Final kissing balloon angioplasty is performed. **(G)** Final angiography reveals full cover of the side branch (angioplasty balloons represented by *blue area*).

Clinical Data With Bifurcation Stenting

Studies have been published that compare a specific complex stenting strategy with another complex stenting strategy. In nonrandomized studies, simultaneous kissing stents have a lower rate of TLR; however, randomized studies have not reproduced this.[35] Although the culotte technique significantly reduced the in-stent restenosis rate compared with the crush technique, the rate of MACE was not significantly different.[39] The Double Kissing Crush Versus Provisional Stenting Technique for Treatment of Coronary Bifurcation Lesions (DKCRUSH)-I trial demonstrated that the DK technique improved long-term (24 mo) MACE and TLR compared with the standard crush technique.[33] The DKCRUSH-III trial reported a lower rate of MACE driven by a lower rate of TLR with DK stenting compared with culotte stenting in unprotected left main bifurcation lesions.[40,41]

Dedicated Bifurcation Stent

A dedicated bifurcation stent is a bifurcating stent that extends into both branches.[42] Alternatively, it may be a single-vessel stent with an aperture built into the side of the stent to allow a standard stent to be advanced into the SB.

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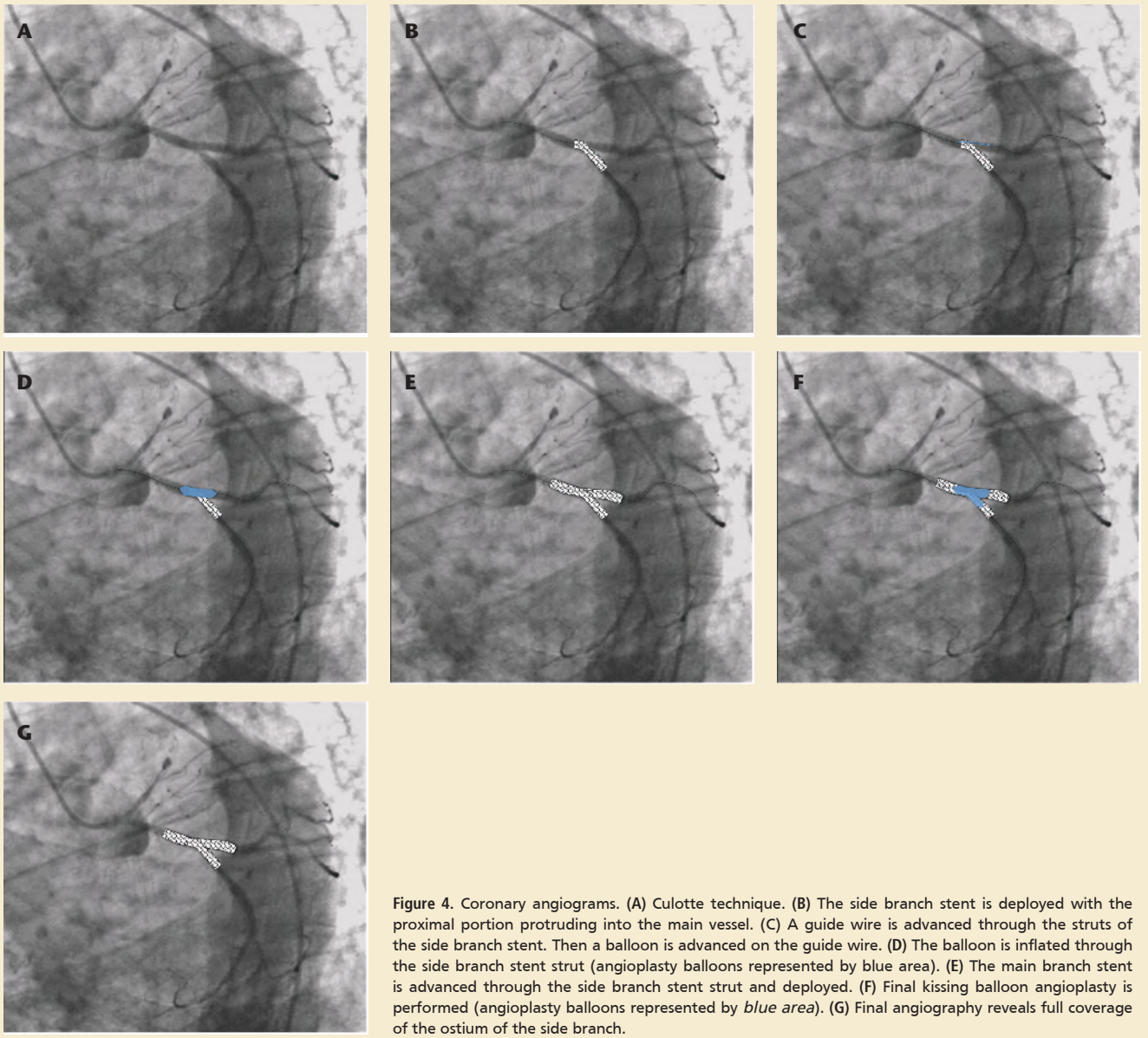

Figure 4. Coronary angiograms. **(A)** Culotte technique. **(B)** The side branch stent is deployed with the proximal portion protruding into the main vessel. (C) A guide wire is advanced through the struts of the side branch stent. Then a balloon is advanced on the guide wire. **(D)** The balloon is inflated through the side branch stent strut (angioplasty balloons represented by blue area). **(E)** The main branch stent is advanced through the side branch stent strut and deployed. **(F)** Final kissing balloon angioplasty is performed (angioplasty balloons represented by *blue area*). **(G)** Final angiography reveals full coverage of the ostium of the side branch.

Stenting (POLBOS) I trial compared the BiOSS® Expert (Balton, Warsaw, Poland) paclitaxel-eluting dedicated bifurcation stent (DBS) to standard DES.[44] Although MACE rates did not differ, the TLR rate was higher in the DBS group. The TRYTON (Prospective, Single Blind, Randomized Controlled Study to Evaluate the Safety & Effectiveness of the Tryton Side Branch Stent Used With DES in Treatment of de Novo Bifurcation Lesions in the Main Branch & Side Branch in Native Coronaries) trial reported a numerically higher periprocedural MI rate with the Tryton (bare metal stent; Tryton Medical, Durham, NC) compared with provisional stenting.[45]

Ancillary Techniques for Bifurcation PCI

Coronary Atherectomy

Small case series of directional and rotational atherectomy demonstrated higher rates of non–Q-wave MI.[46-48] Other studies have found that the risk of SB compromise is reduced following atherectomy compared with percutaneous transluminal coronary angioplasty alone.[49] Intravascular ultrasound can be used to guide atherectomy of left main coronary artery bifurcation lesions in order to achieve the minimal residual plaque burden.[50]

Drug-eluting Stents

Unsurprisingly, DES stents have been shown to reduce rates of SB

restenosis and TLR when compared with bare metal stents.[51] Bifurcation stenting with sirolimus-eluting stents is associated with lower rates of TLR compared with paclitaxel-eluting stents.[52] Subgroup analyses of recent clinical trials of biodegradable polymer stents (bioresorbable stents) have found that biodegradable polymer stents are associated with similar or superior long-term efficacy compared with standard sirolimus- or everolimus-eluting stents.[53,54]

Bifurcation stenting with sirolimus-eluting stents is associated with lower rates of TLR compared with paclitaxel-eluting stents.

Fractional Flow Reserve

The DKCRUSH-VI trial randomized patients with true bifurcation lesions to either angiography-guided or fractional flow reserve (FFR)-guided provisional stenting.[55] Indications for SB stenting in the angiography group included TIMI flow <3, dissection >type A, or ostial SB stenosis >70%, whereas an SB FFR of <0.8 was used as a threshold to stent the SB in the FFR group. The 1-year rates of MACE and TVR were similar in both groups, suggesting that FFR does not provide any benefit over standard angiography.

Conclusions

Various treatment options are available for PCI of bifurcation lesions. The majority of data on this topic to date indicate that simple or provisional stenting is associated with superior outcomes compared to complex stenting. Nevertheless, complex stenting techniques are necessary in many cases. In these cases, the ideal complex stenting strategy has yet to be determined, although some fare better than others in randomized trials. Dedicated bifurcation stents have not demonstrated improved outcomes compared with current bifurcation techniques. Further trials and registry data comparing techniques are likely to continue to provide further guidance on the ideal strategy. ■

References

1. Whitlow P. Bifurcation lesion DES. Presented at: Complex Coronary Valvular & Vascular Cases. June 17-20, 2009; New York, NY: 2009. https://web.archive.org/web/20121218235133/http://www.cccsymposium.org:80/archives_2009.html.
2. Steigen TK, Maeng M, Wiseth R, et al; Nordic PCI Study Group. Randomized study on simple versus complex stenting of coronary artery lesions: the Nordic bifurcation study. *Circulation*. 2006;114:1955-1961.
3. Louvard Y, Medina A. Definitions and classifications of bifurcation lesions and treatment. *EuroIntervention*. 2015;11(suppl V):V23-V26.
4. Latib A, Colombo A. Bifurcation disease: what do we know, what should we do? *JACC Cardiovasc Interv*. 2008;1:218-226.
5. Park TK, Park YH, Song YB, et al. Long-term clinical outcomes of true and non-true bifurcation lesions according to Medina classification- results from the COBIS (COronary BIfurcation Stent) II registry. *Circ J*. 2015;79:1954-1962.
6. van Houwelingen KG, van der Heijden LC, Lam MK, et al. Long-term outcome and chest pain in patients with true versus non-true bifurcation lesions treated with second-generation drug-eluting stents in the TWENTE trial. *Heart Vessels*. 2016;31:1731-1739.
7. Dou K, Zhang D, Xu B, et al. An angiographic tool for risk prediction of side branch occlusion in coronary bifurcation intervention: the RESOLVE score system (Risk prEdiction of Side branch OccLusion in coronary bifurcation interVEntion). *JACC Cardiovasc Interv*. 2015;8:39-46.
8. Roh JH, Lee JH, Kim YH, et al. Procedural predictors of angiographic restenosis after bifurcation coronary stenting (from the choice of optimal strategy for bifurcation lesions with normal side branch and optimal

MAIN POINTS

- Atherosclerotic lesions at the bifurcation of coronary arteries may develop because of high-shear stress from turbulent blood flow. Up to 15% of percutaneous coronary interventions (PCIs) involve bifurcation lesions. Bifurcation lesions can increase the complexity of PCI, and PCI of true bifurcation lesions is associated with a higher rate of major adverse cardiac events.
- Bifurcation lesions can be treated with a one-stent approach or with multiple stents. The one-stent approach is preferred, if possible. Provisional stenting, or the practice of stenting a side branch (SB) only if necessary, may be performed if the angiographic result is suboptimal. Final simultaneous kissing balloon inflation should be performed after stenting to maintain SB patency.
- Various techniques for multistent bifurcation stenting have been developed, including the crush, culotte, V-stenting, Y-stenting, simultaneous kissing stenting, T-stenting, and modified T-stenting techniques. Complex stenting is required to obtain optimal angiographic results when the ostium of the SB is severely diseased.
- A dedicated bifurcation stent is a bifurcating stent that extends into both branches. Alternatively, it may be a single-vessel stent with an aperture built into the side of the stent to allow a standard stent to be advanced into the SB. However, dedicated bifurcation stents have not demonstrated improved outcomes compared with current bifurcation techniques.

stenting strategy for true bifurcation lesions studies). *Am J Cardiol.* 2015;116:1050-1056.
9. Armstrong EJ, Yeo KK, Javed U, et al. Angiographic stent thrombosis at coronary bifurcations: short- and long-term prognosis. *JACC Cardiovasc Interv.* 2012;5:57-63.
10. Kralev S, Poerner TC, Basorth D, et al. Side branch occlusion after coronary stent implantation in patients presenting with ST-elevation myocardial infarction: clinical impact and angiographic predictors. *Am Heart J.* 2006;151:153-157.
11. Galassi AR, Boukhris M, Tomasello SD, et al. Incidence, treatment, and in-hospital outcome of bifurcation lesions in patients undergoing percutaneous coronary interventions for chronic total occlusions. *Coron Artery Dis*. 2015;26:142-149.
12. Brueck M, Scheinert D, Flaschskampf FA, et al. Sequential vs. kissing balloon angioplasty for stenting of bifurcation coronary lesions. *Catheter Cardiovasc Interv.* 2002;55:461-466.
13. Rizik DG, Klassen KJ, Hermiller JB. Bifurcation coronary artery disease: current techniques and future directions (part 1). *J Invasive Cardiol*. 2008;20:82-90.
14. Niemala M, Kervinen K, Erglis A, et al; Nordic-Baltic PCI Study Group. Randomized comparison of final kissing balloon dilatation versus no final kissing balloon dilatation in patients with coronary bifurcation lesions treated with main vessel stenting: the Nordic-Baltic Bifurcation Study III. *Circulation*. 2011;123:79-86.
15. Iakovou I, Ge L, Colombo A. Contemporary stent treatment of coronary bifurcations. *J Am Coll Cardiol*. 2005;46:1446-1455.
16. Yamashita T, Nishida T, Adamian MG, et al. Bifurcation lesions: two stents versus one stent – immediate and follow-up results. *J Am Coll Cardiol*. 2000;35:1145-1151.
17. Colombo A, Moses JW, Morice MC, et al. Randomized study to evaluate sirolimus-eluting stents implanted at coronary bifurcation lesions. *Circulation*. 2004;109:1244-1249.
18. Pan M, de Lezo JS, Medina A, et al. Rapamycin-eluting stents for the treatment of bifurcated coronary lesions: A randomized comparison of a simple versus complex strategy. *Am Heart J*. 2004;148:857-864.
19. Colombo A, Bramucci E, Saccà S, et al. Randomized study of the crush technique versus provisional side-branch stenting in true coronary bifurcations: the CACTUS (Coronary Bifurcations: Application of the Crushing Technique Using Sirolimus-Eluting Stents) Study. *Circulation*. 2009;119:71-78.
20. Gao Z, Xu B, Yang Y, et al. Comparison between one-stent versus two-stent technique for treatment of left main bifurcation lesions: a large single-center data. *Cath Cardiovasc Interv*. 2015;85:1132-1138.
21. Kim YH, Lee JH, Roh JH, et al. Randomized comparisons between different stenting approaches for bifurcation coronary lesions with or without side branch stenosis. *JACC Cardiovasc Interv.* 2015;8:550-560.
22. Palmerini T, Marzocchi A, Tamburino C, et al. Impact of bifurcation technique on 2-year clinical outcomes in 773 patients with distal unprotected left main coronary artery stenosis treated with drug-eluting stents. *Circ Cardiovasc Intervent.* 2008;1:185-192.
23. Hildick-Smith D, de Belder AJ, Cooter N, et al. Randomized trial of simple versus complex drug-eluting stenting for bifurcation lesions: the British Bifurcation Coronary Study: old, new, and evolving strategies. *Circulation*. 2010;121:1235-1243.
24. Ferenc M, Gick M, Kienzle RP, et al. Randomized trial on routine vs. provisional T-stenting in the treatment of de novo coronary bifurcation lesions. *Eur Heart J.* 2008;29:2859-2867.
25. Niccoli G, Ferrante G, Porto I, et al. Coronary bifurcation lesions: to stent one branch or both? A meta-analysis of patients treated with drug eluting stents. *Int J Cardiol*. 2010;139:80-91.
26. Hakeem A, Khan FM, Bhatti S, et al. Provisional vs. complex stenting for coronary bifurcation lesions: meta-analysis of randomized trials. *J Invasive Cardiol.* 2009;21:589-595.
27. Zhang F, Dong L, Ge J. Simple versus complex stenting strategy for coronary bifurcation lesions in the drug-eluting stent era: a meta-analysis of randomised trials. *Heart*. 2009;95:1676-1681.
28. Katritsis DG, Siontis GC, Ioannidis JP. Double versus single stenting for coronary bifurcation lesions: a meta-analysis. *Circ Cardiovasc Intervent*. 2009;2:409-415.
29. Korn HV, Yu J, Ohlow MA, et al. Interventional therapy of bifurcation lesions: a TIMI flow-guided concept to treat side branches in bifurcation lesions – a prospective randomized clinical study (Thueringer Bifurcation Study, THUEBIS Study as Pilot Trial). *Circ Cardiovasc Interv*. 2009;2:535-542.
30. Lee JM, Hahn JY, Kang J. Differential prognostic effect between first- and second-generation drug-eluting stents in coronary bifurcation lesions: patient-level analysis of the Korean bifurcation pooled cohorts. *JACC Cardiovasc. Interv*. 2015;8:1318-1331.
31. Burzotta F, Gwon HC, Hahn JY, et al. Modified T-stenting with intentional protrusion of the side-branch stent within the main vessel stent to ensure ostial coverage and facilitate final kissing balloon: the T-Stenting and Small Protrusion technique (TAP-stenting). Report of bench testing and first clinical Italian-Korean two-centre experience. *Catheter Cardiovasc Interv*. 2007;70:75-82.
32. Colombo A, Stankovic G, Orlic D, et al. Modified T-stenting technique with crushing for bifurcation lesions: immediate results and 30-day outcome. *Catheter Cardiovasc Interv*. 2003;60:145-151.
33. Chen SL, Zhang JJ, Chen Y, et al. Study comparing the double kissing (DK) crush with classical crush for the treatment of coronary bifurcation lesions: the DK-CRUSH-1 bifurcation study with drug-eluting stents. *Eur J Clin Invest*. 2008;38:361-371.
34. Chen SL, Kwan TW. Twenty-four-month update on double-kissing crush stenting of bifurcation lesions. *J Interv Cardiol.* 2009;22:121-127.
35. Schampaert E, Fort S, Adelman AG, Schwartz L. The V-stent: a novel technique for coronary bifurcation stenting. *Cathet Cardiovasc Diagn*. 1996;39:320-326.
36. Fort S, Lazzam C, Schwartz L. Coronary 'Y' stenting: a technique for angioplasty of bifurcation stenoses. *Can J Cardiol*. 1996;12:678-682.
37. Sharma SK, Choudhury A, Lee J, et al. Simultaneous kissing stents (SKS) technique for treating bifurcation lesions in medium-to-large size coronary arteries. *Am J Cardiol*. 2004;94:913-917.
38. Toth GG, Pyxaras S, Mortier P, et al. Single string technique for coronary bifurcation stenting: detailed technical evaluation and feasibility analysis. *JACC Cardiovasc Interv.* 2015;8:949-959.
39. Rizik DG, Klassen KJ, Hermiller JB. Bifurcation coronary artery disease: current techniques and future directions (part 2). *J Invasive Cardiol*. 2008;20:135-141.
40. Erglis A, Kumsars I, Niemelä M, et al; Nordic PCI Study Group. Randomized comparison of coronary bifurcation stenting with the crush versus the culotte technique using sirolimus eluting stents: the Nordic Stent Technique Study. *Circ Cardiovasc Interv*. 2009;2:27-34.
41. Chen SL, Xu B, Han YL, et al. Comparison of double kissing crush versus culottes stenting for unprotected distal left main bifurcation lesions: results from a multicenter, randomized, prospective DKCRUSH-III study. *J Am Coll Cardiol*. 2013;61:482-488.
42. Chen SL, Xu B, Han YL, et al. Clinical outcome after DK crush versus culotte stenting of distal left main bifurcation lesions: the 3-year follow-up results of the DKCRUSH-III Study. *JACC Cardiovasc Interv*. 2015;8:1335-1342.
43. Cervinka P, Bystron M, Spacek R, et al. Treatment of bifurcation lesions using dedicated bifurcation stents versus classic bare-metal stents: randomized, controlled trial with 12-month angiographic follow up. *J Invasive Cardiol*. 2008;20:516-520.
44. Gil RJ, Bil J, Dzavik V, et al. Regular drug-eluting stent vs dedicated coronary bifurcation BiOSS expert stent: multicenter open-label randomized controlled POLBOS I Trial. *Can J Cardiol*. 2015;31:671-678.
45. Généreux P, Kumsars I, Lesiak M, et al. A randomized trial of a dedicated bifurcation stent versus provisional stenting in the treatment of coronary bifurcation lesions. *J Am Coll Cardiol*. 2015;65:533-543.
46. Mansour M, Fishman RF, Kuntz RE, et al. Feasibility of directional atherectomy for the treatment of bifurcation lesions. *Coronary Artery Dis*. 1992;3:761-765.
47. Rihal CS, Garratt KN, Holmes DR Jr. Rotational atherectomy for bifurcation lesions of the coronary circulation: technique and initial experience. *Int J Cardiol*. 1998;65:1-9.
48. Ito H, Piel S, Das P, et al. Long-term outcomes of plaque debulking with rotational atherectomy in side-branch ostial lesions to treat bifurcation coronary disease. *J Invasive Cardiol*. 2009;21:598-601.
49. Dauerman HL, Higgins PJ, Sparano AM, et al. Mechanical debulking versus balloon angioplasty for the treatment of true bifurcation lesions. *J Am Coll Cardiol*. 1998;32:1845-1852.
50. Hu FB, Tamai H, Kosuga K, et al. Intravascular ultrasound-guided directional coronary atherectomy for unprotected left main coronary stenoses with distal bifurcation involvement. *Am J Cardiol*. 2003;92:936-940.
51. Thuesen L, Kelbaek H, Kløvgaard L, et al; SCANDSTENT Investigators. Comparison of sirolimus-eluting and bare metal stents in coronary bifurcation lesions: subgroup analysis of the Stenting Coronary Arteries in Non-Stress/Benestent Disease Trial (SCANDSTENT). *Am Heart J*. 2006;152:1140-1145.
52. Song YB, Hahn JY, Choi SH, et al. Sirolimus- versus paclitaxel-eluting stents for the treatment of coronary bifurcations results: from the COBIS (Coronary Bifurcation Stenting) registry. *J Am Coll Cardiol.* 2010;55:1743-1750.
53. Grundeken MJ, Wkrzykowska JJ, Ishibashi Y, et al. First generation versus second generation drug-eluting stents for the treatment of bifurcations: 5-year follow-up of the LEADERS All-Comers randomized trial. *Catheter Cardiovasc Interv.* 2016;87:E248-E260.
54. Orvin K, Carrie D, Richardt G, et al. Comparison of sirolimus eluting stent with bioresorbable polymer to everolimus eluting stent with permanent polymer in bifurcation lesions. *Catheter Cardiovasc Interv*. 2016;87:1092-1100.
55. Chen SL, Ye F, Zhang JJ, et al. Randomized comparison of FFR-guided and angiography-guided provisional stenting of true coronary bifurcation lesions: the DKCRUSH-VI trial (Double Kissing Crush Versus Provisional Stenting Technique for Treatment of Coronary Bifurcation Lesions VI). *JACC Cardiovasc Interv*. 2015;8:536-546.