26 Contemporary Treatment of Coronary Bifurcation Lesions

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About Us

The Sussex Cardiac Centre is the tertiary cardiac center for Sussex serving a population of over 1.2 million people. It offers treatment in all areas of cardiovascular disease. The unit has a big research department, with particular interests in coronary and structural heart intervention. The BBC ONE trial comparing single- vs. two-stent strategies to treat bifurcation disease was run from the Sussex Cardiac Centre, as is the current EBC MAIN trial. This chapter is based on treatment strategies used within this center and reflects current local practice.

What Is a Bifurcation?

A bifurcation lesion is a lesion occurring at or adjacent to a significant division of a major epicardial coronary artery [1]. Bifurcations represent 10–15% of all lesions treated by percutaneous coronary intervention (PCI).

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Planning a Bifurcation Lesion Procedure

The Evidence

- To date the evidence from randomized control trials of single- vs. two-stent strategies suggests that using a single-stent strategy where possible offers the best outcome to patients.
- Two-stent techniques are associated with higher rates of major adverse cardiovascular events (MACE), largely driven by higher rates of periprocedural myocardial infarction (PMI).
- Most recently, the 5-year survival from a patient-level pooled analysis of the Nordic Bifurcation Study and the British Bifurcation Coronary Study was published confirming a provisional single-stent approach was associated with lower long-term mortality than a systematic two-stent technique [2].

The Anatomy and the Medina Classification

- Refer to a bifurcation lesion using standardized anatomical jargon.
- The proximal main vessel (PMV), distal main vessel (DMV), and the side branch (SB).
- The Medina classification (Fig. 26.1) is a simple and now universal classification of

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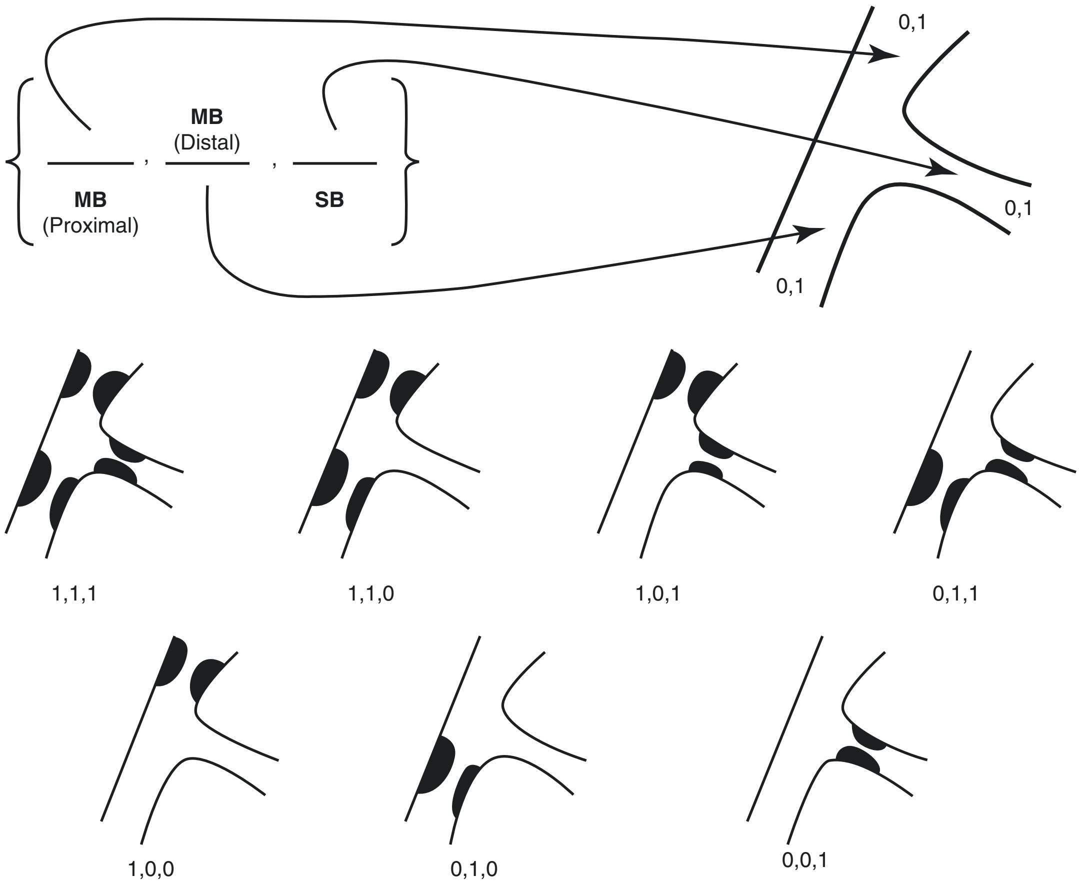

Fig. 26.1 The Medina classification of coronary bifurcation lesions. Reproduced with permission from Medina A, de Lezo JS, Pan M. Rev Esp Cardiol. 2006;59(2),183–4

bifurcation lesions that offers a standardized way to describe and hence interpret treatment of bifurcations [3].

- Limitations of the Medina classification do exist since it does not consider:
  - Bifurcation angles
  - Extent of calcification
  - Lesion lengths
  - Functional significance of the lesions
  - Plaque distribution and plaque burden as seen directly by intracoronary imaging such as intravascular ultrasound (IVUS)
  - Fate of the side branch (SB) upon dilatation of the main vessel (MV)

Murray's Law

- This is a useful law to help determine vessel size and therefore stent choice when undertaking bifurcation stenting.
- Finet's adaptation of Murray's law suggests that the proximal vessel diameter is the sum of the distal main vessel and the side branch vessel diameters multiplied by 0.678.
- This approximation holds good for most coronary vessel diameters [4].
- $D_{mother} = 0.678 \times (D_{daughter1} + D_{daughter2})$, where D_{mother} = proximal main vessel, $D_{daughter1}$ = distal main vessel, and $D_{daughter2}$ = side branch vessel

Catheter Choice and Access Site

- Bifurcations, including left main stem (LMS) lesions, can be adequately treated using six French guiding catheters, which allows two wires and two balloons to track without issue.
- New radial sheaths, such as glidesheath slender (Terumo Inc., Japan), offer the ability to upsize to 7F if required (6F to 7F).
- The access site should, however, be at the operator's discretion.

The Provisional or Single-Stent Technique

- This should be considered the standard approach for treating bifurcations, and is endorsed by the European Bifurcation Club (EBC) [5].
- Points to consider:
  - Wiring of the SB should be considered unless losing it is considered irrelevant, or the side branch is large caliber and undiseased at its ostium. Most of the MACE related to bifurcation procedures results from periprocedural myocardial infarction (PMI).
  - A narrow angle between the MV and SB, ostial SB disease and small SB vessels are markers of possible SB occlusion after MV stenting.
  - Adequate MV lesion preparation should be performed using adjunctive techniques if required, and may have to be conducted up-front if impossible to wire the SB.
  - Use coronary wires that the operator is most familiar with, but recrossing may be helped with hydrophilic wires.
  - Drug-eluting stents (DES) are recommended for bifurcation stenting, and should be chosen on their ability to accommodate expansion to the proximal MV diameter, but should also be sized with consideration paid to the distal MV diameter.
  - 30 s inflations are recommended to achieve adequate stent expansion.
- There are four main steps and another 4 if the side branch requires attention (see Fig. 26.2)
  - Step 1: Wire both branches
  - Step 2: Pre-dilatation and MV stenting using a stent diameter according to the distal MV reference.
  - Step 3: Proximal optimization technique (POT).
  - Step 4: If Thrombolysis in Myocardial Infarction (TIMI) III flow is present into the SB, the procedure can be stopped.
- If the SB needs attention (e.g., significant flow limitation, <TIMI III flow), the following steps are required:
  - Step 5: Rewire the SB through the MV distal strut, ideally via "pullback rewiring" from MV to SB.
  - Step 6: Remove jailed SB wire (watch for guide catheter deep-throating).

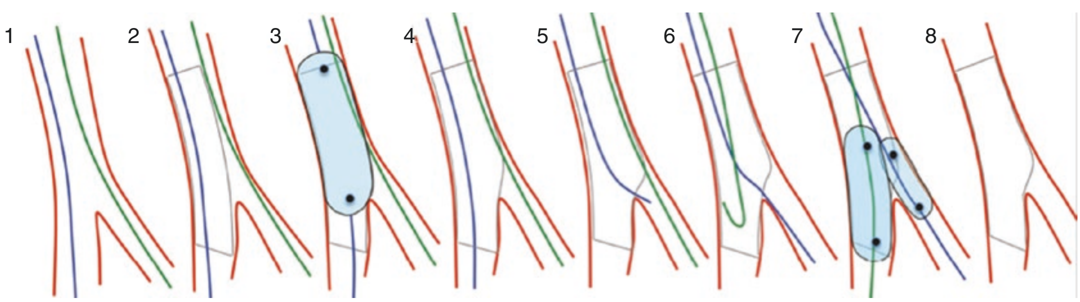

Fig. 26.2 Provisional bifurcation stenting. Steps 1–4 represent the main steps involved in stenting of the main vessel. Steps 5–8 indicate the maneuvers involved if the side branch also requires attention

  - Step 7: Kissing balloon inflation, ideally with short noncompliant balloons in order to avoid SB dissection and stent distortion.
  - Step 8: Further proximal post-dilatation or re-POT to account for MV stent distortion from the kissing balloon inflation.
- Issues to note when considering SB intervention:
  - How large and how hemodynamically significant does the SB appear to be?
  - At what angle does the SB come out from the MV (see Fig. 26.3)?
  - Is there significant ostial or proximal SB disease?
  - Will the SB be difficult to wire?
  - Comorbid state and risk profile of the patient and will this impact upon the importance of the SB?
  - The level of MV disease and degree of plaque burden.
- Routine SB pre-dilatation should be avoided but considered in the presence of severe ostial SB disease. While this may facilitate rewiring, there is a risk of dissecting the SB and therefore failure to rewire.

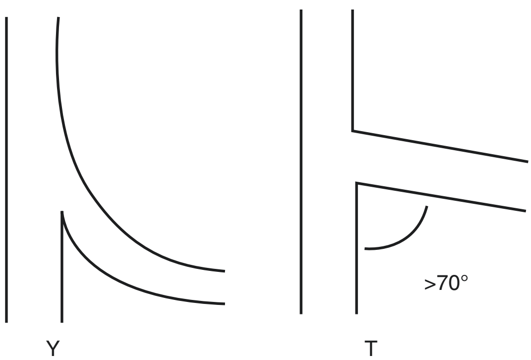

Fig. 26.3 Side branch angulation and morphology. Y-shaped angulation: coronary wire access relatively straightforward but risk of plaque shift much greater. T-shaped angulation: coronary wire access more difficult but risk of plaque shift less

The Proximal Optimization Technique (POT)

- The POT was devised by Darremont, and relates to a method of expanding the stent up to and including the carina, using a balloon sized to the proximal vessel diameter (Fig. 26.4).
- This produces a curved expansion of the stent into the bifurcation point and facilitates recrossing, distal recrossing, kissing inflations, and ostial stent coverage of the side branch (Fig. 26.5).
- Noncompliant or semi-compliant balloons should be used.

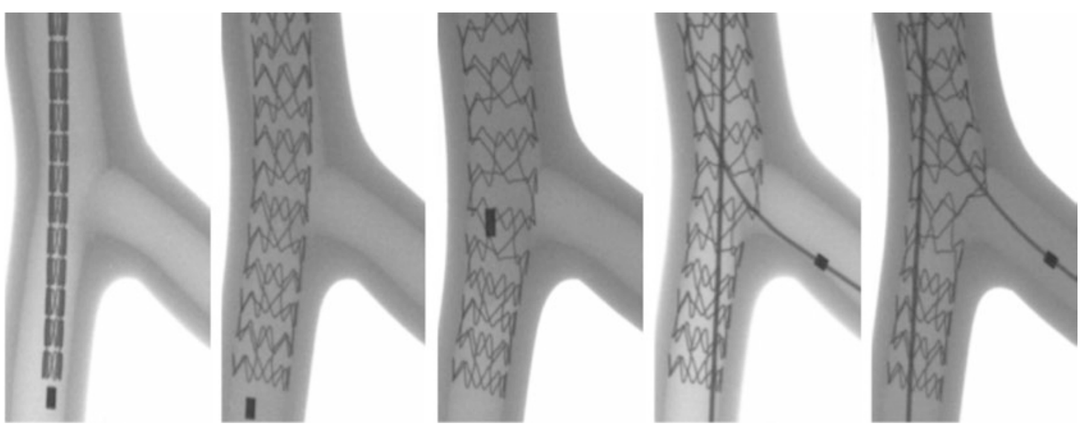

Fig. 26.4 The Proximal Optimization Technique (POT). From left to right—the stent size is selected according to the diameter of the distal main vessel. Once deployed the stent in the main vessel is fully apposed distally (beyond the bifurcation) but not proximally. The POT is performed with a balloon sized to the proximal main vessel diameter, with the distal balloon marker placed just proximal to the carina. Once performed, the POT facilitates wire access through the distal strut (see Fig. 26.5), which, after kissing balloon inflation, allows for good side branch scaffolding. Reproduced with permission from Sawaya et al. J Am Coll Cardiol Intv 2016;9:1861–78

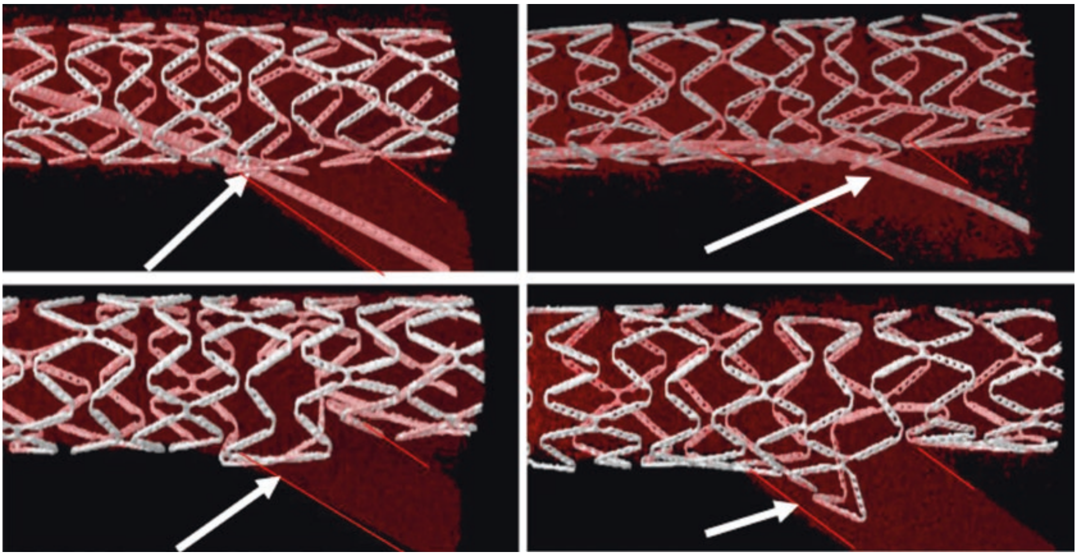

Fig. 26.5 The importance of distal cell recrossing close to the carina after main vessel stenting. Appropriately performed proximal optimization of the main vessel stent facilitates recrossing of the coronary wire through the strut closest to the carina. This in turn allows for improved scaffolding of the side branch ostium compared to proximal recrossing of the wire, which tends to push the struts inward toward the main vessel lumen. The white arrow indicates the location of wire recrossing and its effect on side branch scaffolding. Reproduced with permission from Sawaya et al. J Am Coll Cardiol Intv 2016;9:1861–78

Kissing Balloon Inflations in Simple Stenting

- Nordic III has established that there is no systematic clinical advantage to a routine kissing strategy when a single-stent treatment is used, despite theoretical advantages, but also no systematic disadvantage [6].

Side Branch Stenting Technique in a Provisional Strategy

- In essence SB stenting in a provisional strategy is a "bail-out" and should be considered when there is:
  - Significant compromise to SB flow
  - Presence of a major SB dissection
  - When the SB is significantly diseased and large enough to lead to significant residual ischemia
- T-stenting of the SB can be used in the majority of cases when SB dilatation is performed properly through a distal strut (Fig. 26.6).
- If the angle is close to 90°, modified T-stenting (also known as T and protrude—i.e., TAP) should be considered, as other techniques are associated with a high risk of stent mal-apposition. This requires precise deployment of the SB stent at the ostium (Fig. 26.7).
- Therefore knowledge of where a stent sits relative to its proximal marker is key to this (and varies by manufacturer) as well as finding an optimal view to avoid too much protrusion inside the MV stent or worse still a gap between the two stents.
- If the SB ostium is not properly covered by the MV stent, an overlapping technique is necessary, and we usually use the culotte.
- Crush stenting is a non-provisional technique, which commits the operator to a two-stent technique at the outset, the results of which were inferior to culotte in the NORDIC II trial (Fig. 26.8).

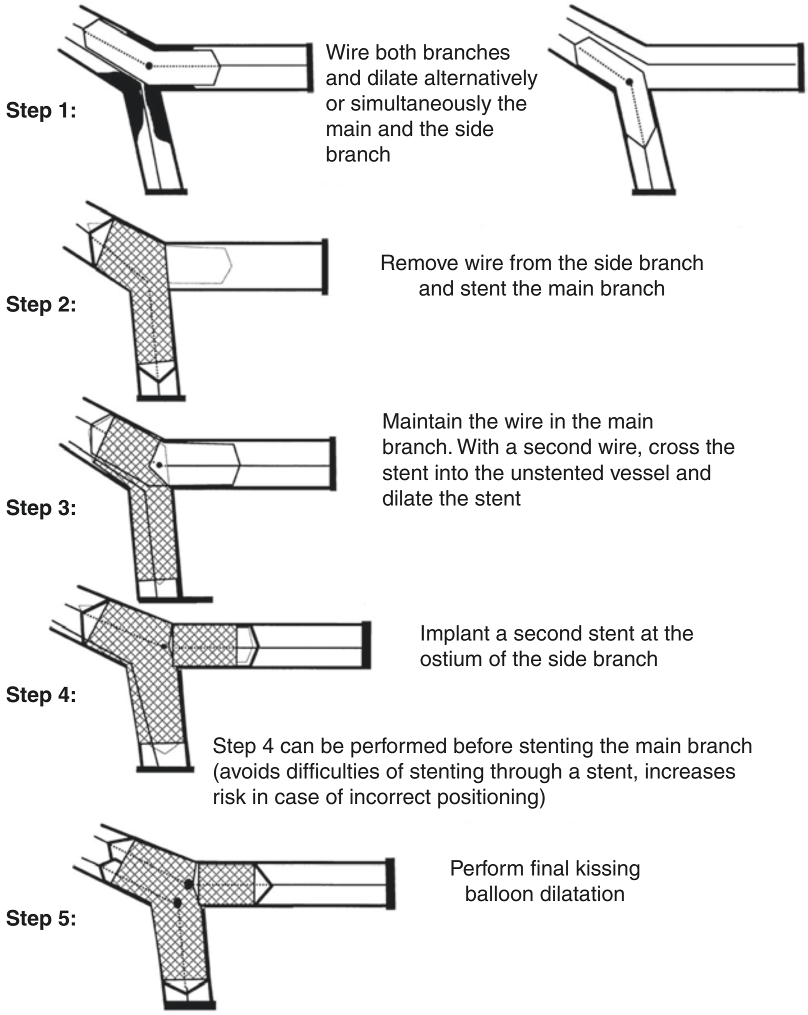

Fig. 26.6 T-stenting technique of the side branch. Reproduced with permission from Iakovou et al. J Am Coll Cardiol 2005;46:1446–55

When to Use Two-Stent Techniques

- The aim should be to start most procedures with a single-stent strategy.
- However the recent EBC II trial, which compared a single- vs. two-stent technique with the culotte in a large SB (>2.5 mm diameter and >5 mm length ostial stenosis) found no specific benefit to the two-stent technique [7].

What Technique?

- The aim as a trainee should be to become competent with single-stent bifurcations and then to aim to become well trained in one complex strategy. Intuitively it is much better to be able to perform one complex strategy well rather than two or more poorly.
- Bifurcations treated with two stents, despite refinements in technique such as POT and kissing balloon inflations, remain higher risk for early stent thrombosis. Therefore, as a department we would recommend the culotte technique and T protrusion stenting (discussed above).
- Crush stenting by name alone does not sound a sensible thing to do to a stent. Crushing makes recrossing more difficult and success rates are lower. The DK-crush technique is superior but requires more instrumentation (Fig. 26.9).

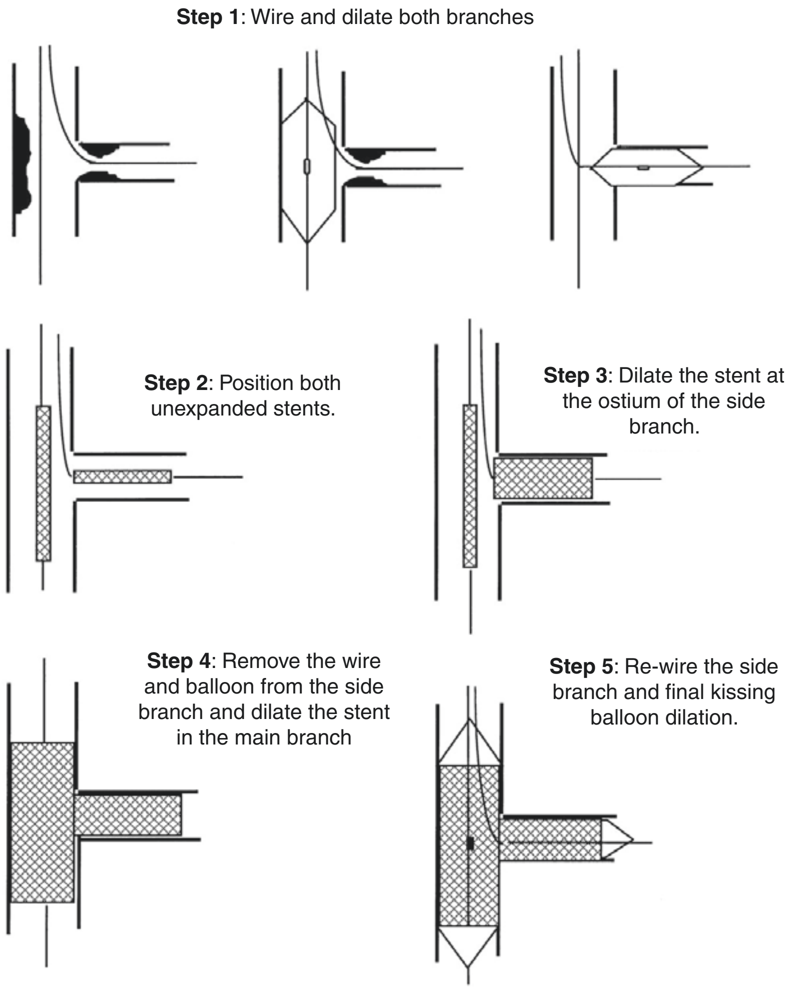

Fig. 26.7 Modified T-stenting of the side branch. Reproduced with permission from Iakovou et al. J Am Coll Cardiol 2005;46:1446–55

How to Perform a Culotte

- The culotte technique efficacy has been documented in many trials (Nordic I, II, IV and BBC-1) [1]. The only limitation to this technique can be significant size discrepancy between the PMV and the SB (Fig. 26.10).
- Two steps are considered mandatory. Firstly, stent platform selection needs to be based on expansion characteristics in order to avoid major mal-apposition in the MV.
- Secondly, the POT is mandatory to correct for any suspected mal-apposition occurring in the MV during the procedure.

- Step 1: Wire the MV and SB
- Step 2: Pre-dilate and stent SB with SB stent extending back into MV
- Step 3: POT SB stent (aim to use NC balloon sized to proximal main vessel)
- Step 4: Rewire MV via SB stent and then remove jailed MV wire
- Step 5: Dilate MV through stent struts and stent MV (stent size chosen on basis of DMV reference diameter)
- Step 6: POT MV stent (aim to use NC balloon at least 0.5–1 mm greater than stent reference diameter)
- Step 7: Recross into SB through distal cell where possible and then remove trapped SB wire.
- Step 8: Pre-dilatation of SB stent to reopen ostium
- Step 9: Kissing balloon inflation, ideally with short noncompliant balloons, sized to the SB and DMV respectively. Individual

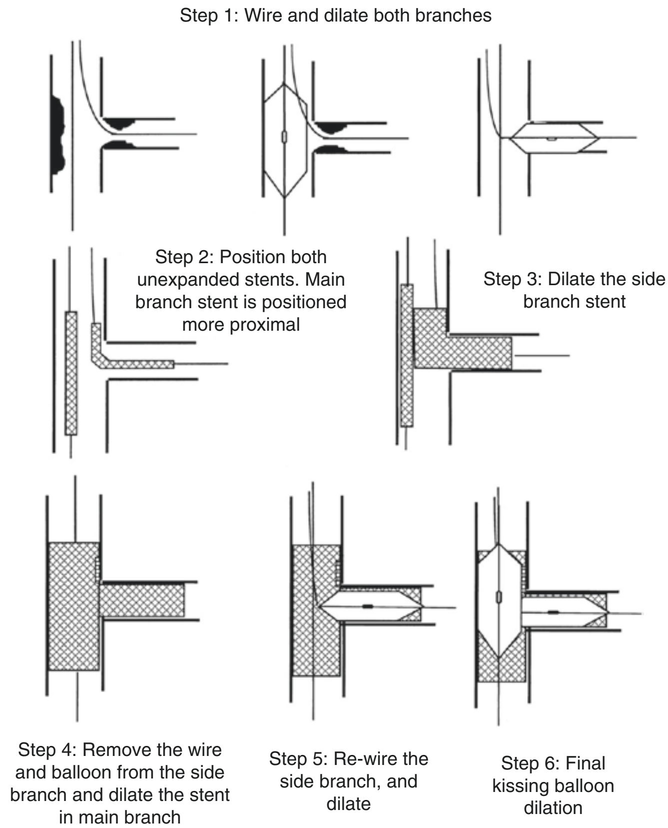

Fig. 26.8 Crush stenting technique of the side branch. Reproduced with permission from Iakovou et al. J Am Coll Cardiol 2005;46:1446–55

high-pressure dilatation prior to the kissing inflation is recommended.

- Step 10: Further proximal post-dilatation or re-POT to account for MV stent distortion from kiss

Imaging and Bifurcations

- Angiographic assessment of bifurcations has several limitations and therefore may be aided by intracoronary imaging.
- Optical coherence tomography (OCT) is a high resolution imaging technique, which allows for superior imaging of the luminal surface, calcium, stent positions, wires, and the SB ostium from both MV and SB pull-backs, relative to IVUS.
- However OCT may increase the use of contrast and can be suboptimal in very large vessels and aorto-ostial assessment [8].
- IVUS, by way of contrast, has better depth penetration allowing better characterization of plaque burden and does not require optimal vessel flushing during acquisition.
- Both modalities enable lesion assessment, evaluation of pre-dilatation, reference sizing and evaluation of adequate vessel and stent expansion after stenting [9–13].
- Probably the most beneficial aspect of imaging in complex two-stent interventions is evaluation of wire positions after stent rewiring to ensure optimal SB recrossing [14–16].

Left Main Stem Bifurcations (See Also Chap. 27)

- There is increasing evidence to suggest that PCI with DES is a non-inferior revascularization option relative to the "gold standard" of coronary artery bypass grafting (CABG) in patients with significant LMS disease.

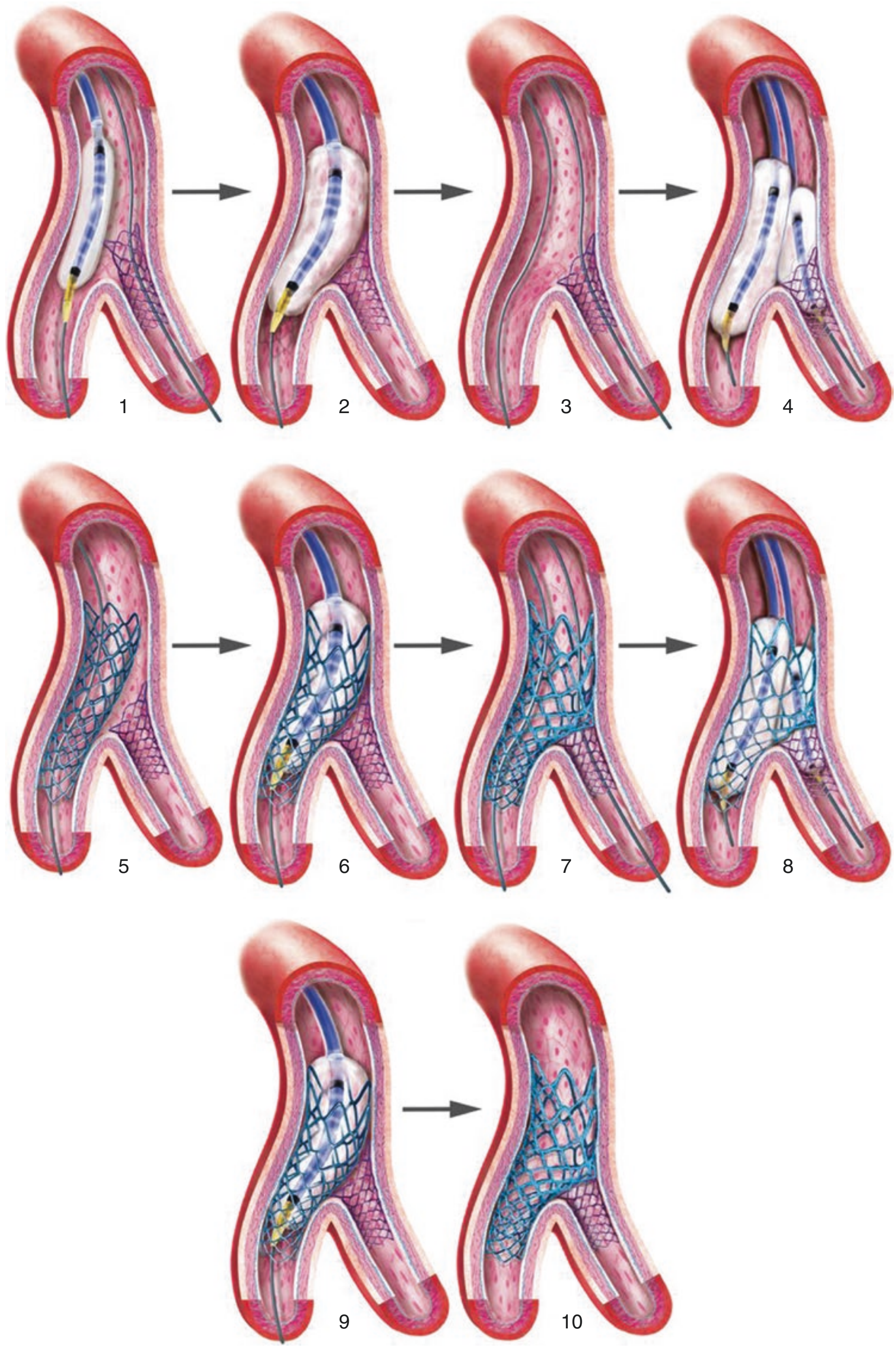

Fig. 26.9 The double kissing (DK) crush technique. (*1*) Side branch (SB) stenting with short main vessel (MV) protrusion. (*2*) Ostial SB stent balloon crush. (*3*) Recross SB with coronary wire. (*4*) First kissing balloon inflation. (*5*) Remove SB wire and stent MV across the ostium of the SB. (*6*) Perform a proximal optimization of the MV stent (see also Fig. 26.4). (*7*) Rewire the SB via the MV stent and the crushed SB stent. (*8*) Second kissing balloon inflation. (*9*) Second proximal optimization of the MV stent. (*10*) Final result. Reproduced with permission from Sawaya et al. J Am Coll Cardiol Intv 2016;9:1861–78

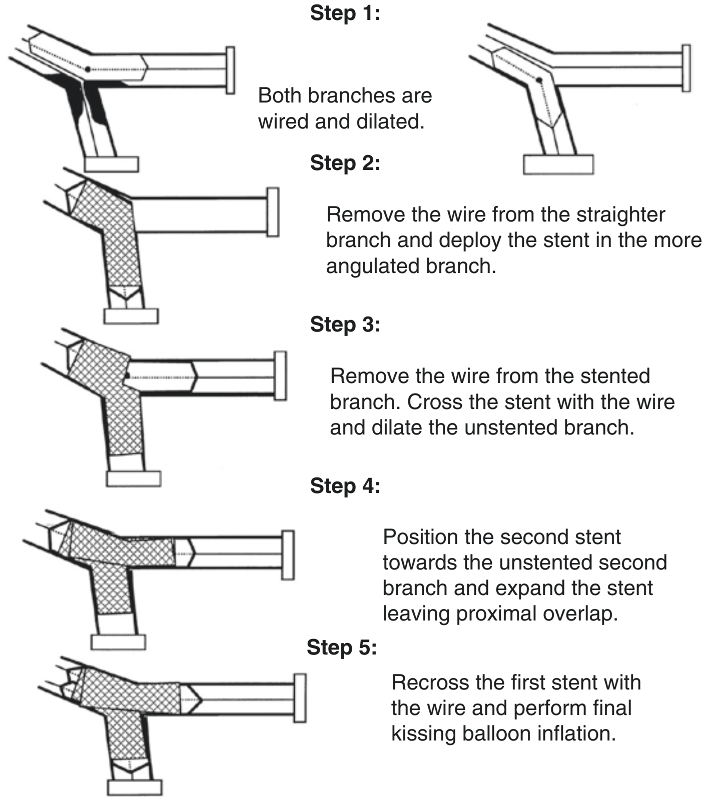

Fig. 26.10 The culottes stenting technique. Reproduced with permission from Iakovou et al. J Am Coll Cardiol 2005;46:1446–55

- The left main stem (LMS) is the largest bifurcation of the coronary tree and has a number of unique features:
  - The myocardium subtended by the LMS generally accounts >50% of the total myocardial mass
  - The PMV reference diameter generally measures between 4.5 and 5.5 mm
  - The SB is always a major epicardial coronary artery
  - The left circumflex artery (LCx) is often considered the SB
  - Occlusion of the LCx is not acceptable as it supplies a large myocardial territory

LMS Treatment and Techniques

- As for all bifurcation lesions, a provisional or single-stent approach is recommended in most cases, as data from observational non-randomized studies suggest that this technique where feasible has a higher rate of target lesion revascularization relative to two-stent techniques.
- Most issues arising from LMS bifurcations can be overcome by sensible stent selection and positioning, and by use of the POT technique.
- If a two-stent technique is required and the vessels are of similar size, then a culotte may be feasible.
- If there is an angle of or close to 90° (T-shape angulation), the T or TAP would be recommended in the majority of double-stenting cases.
- The randomized European Bifurcation Club Left Main (EBC MAIN) study is currently recruiting and is looking specifically at whether a single- or two-stent strategy is best for true bifurcation LMS disease, with respect to death, target lesion revascularization (TLR), and myocardial infarction at 1 year, and angina status, stent thrombosis, death, myocardial infarction, and TLR at three- and five-year clinical follow-up.

Bioresorbable Vascular Scaffolds and Bifurcations

- Bioresorbable stents (BRS) may offer potential advantages compared with metallic DES for bifurcation PCI, particularly as there is potential for "un-jailing" of the SB ostium as the device resorbs.
- However there are limitations to this technology currently, in particular strut thickness and limited expansion capacity, as well as the signals for increased early and late scaffold thrombosis, particularly in small vessels.
- If BRS is to be used for bifurcations, then clearly the provisional strategy remains the default technique.

Important Points to Consider When Using BRS in Bifurcations

- Appropriate vessel sizing (confirmed by intracoronary imaging, ideally OCT or equivalent) is required to facilitate correct size of scaffold as the expansion capacity of the Absorb BRS allows post-dilatation up to 0.5 mm above the nominal diameter.
- Lesion preparation is key and often 1:1 balloon sizing is required with noncompliant (NC) balloons to confirm adequate vessel expansion.
- There is no data yet to determine if BRS sizing should be made on the basis of DMV or PMV diameter.
- POT is mandatory with an NC balloon within 0.5 mm of the scaffold diameter.
- Routine use of kissing balloons is not recommended due to the risk of scaffold fracture, but if required, a low-pressure KISS or "SNUGGLE" technique can be used.
- All procedural results should be checked and confirmed for distal dissection, under-expansion, and mal-apposition with intracoronary imaging.
- Currently the ABC-1 trial, performed in our department, is looking at the provisional strategy with ABSORB (ABSORB scaffold, Abbott Vascular, USA) in bifurcations, with randomization to proximal or distal vessel sizing.

Two-Stent Techniques Using Absorb BRS

- It is the feeling of the department that, while technically feasible, any form of two-stent strategy with BRS should only be considered as part of a clinical trial, especially due to a late signal of potential scaffold thrombosis in these patients.

Dedicated Bifurcation Stents

- Dedicated bifurcation devices remain a niche area, mainly because of the fact that they are not "user friendly."
- Two main dedicated systems are commercially available—the Tryton (Tryton Medical, USA) and Axxess systems (Biosensors, Switzerland), respectively.
- Data for the Tryton stent is encouraging in some respects but the device remains limited by the fact that it is not drug-eluting.

Medina Classification 0,0,1 Treatment

- Rarely do these lesions require intervention as most often any symptoms can be adequately treated with optimal medical therapy.
- If required, a pressure wire study to determine fractional flow reserve can be useful to confirm physiological impairment to flow from the anatomical obstruction.
- One always needs to be careful to make sure that any treatment does not have a negative effect on the MV.
- Other possible techniques have involved the use of drug-eluting balloons but there remains a lack of head-to-head trial data in this group of patients.

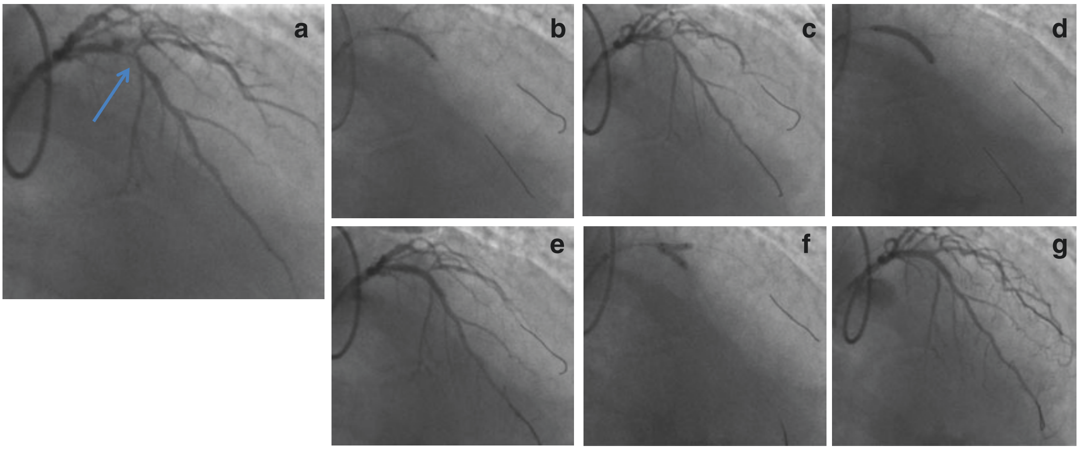

Fig. 26.11 Provisional bifurcation stenting. Plates (**a**–**g**): (**a**) diagnostic angiogram revealing a critical stenosis of the proximal left anterior descending (LAD) artery involving the first diagonal side branch bifurcation (arrow); (**b**) both the LAD and D1 have been wired followed by predilatation of the LAD; (**c**) angiogram following predilatation with Thrombolysis In Myocardial Infarction (TIMI) 3 flow in the side branch; (**d**) stent deployment in the proximal LAD across the ostium of the D1 side branch; (**e**) angiogram post stent deployment demonstrating "pinching" of the D1 ostium; (**f**) kissing balloon inflations of both the proximal LAD and ostial D1; (**g**) final angiographic result with TIMI 3 flow down the LAD and D1

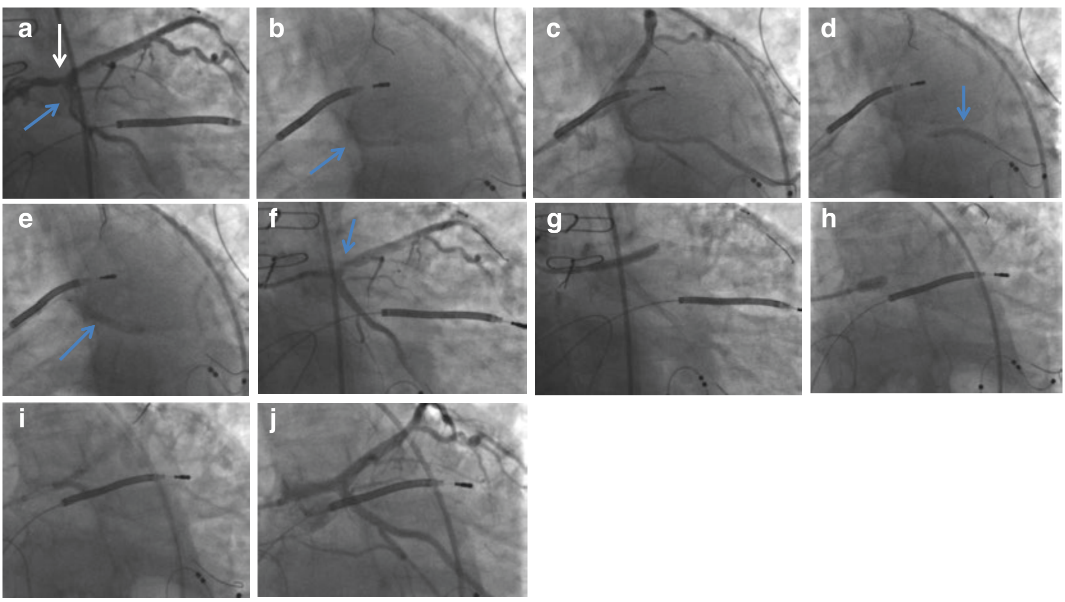

Fig. 26.12 T-stenting. Plates (**a**–**j**): (**a**) Diagnostic angiogram showing significant distal left main stem (LMS—white arrow) extending into proximal left circumflex (LCx—blue arrow) disease; (**b**) wiring of both the left anterior descending (LAD) artery and pre-dilatation of the LCx (arrow); (**c**) angiogram after pre-dilatation; (**d**) first stent deployed into mid-LCx (arrow); (**e**) second stent deployed to cover ostial LCx (arrow); (**f**) positioning of LMS-LAD stent (arrow); (**g**) stent deployed to LMS-LAD; (**h**) proximal optimisation (POT) positioning distal balloon marker at the carina; (**i**) sequential high pressure inflations followed by final kissing balloon inflation; (**j**) final angiographic result

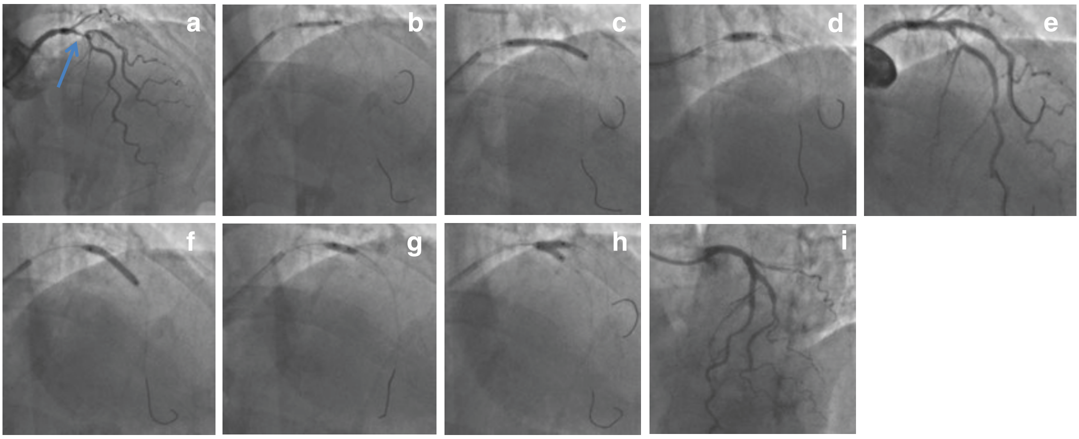

Fig. 26.13 Culotte stenting. Plates (**a**–**i**): (**a**) diagnostic angiogram demonstrating a critical stenosis at the LAD/D1 bifurcation; (**b**) pre-dilatation of the diagonal which is shown to be a relatively large vessel in comparison with the LAD; (**c**) stent deployment into diagonal; (**d**) proximal optimisation of the D1 stent to prepare for re-crossing into LAD. The distal marker of the balloon loaded onto the diagonal wire is positioned at the carina; (**e**) angiogram after proximal optimisation. Re-crossing of the coronary wire from D1 stent into LAD; (**f**) second stent deployed into LAD, the proximal segment of both stents now overlapping at the bifurcation; (**g**) proximal optimisation of the LAD stent; (**h**) kissing balloon inflations after performing sequential high pressure inflations to both stented vessels; (**i**) final angiographic result

Conclusions

- When treating bifurcations, where possible, aim to use a single-stent technique.
- Systematic use of the Medina classification is recommended, despite its limitations.
- The provisional single-stent technique should be the default strategy for most bifurcations.
- The POT technique should be considered a standard step in bifurcation treatment.
- When using a provisional technique, kissing inflations are not considered mandatory.
- When using a provisional technique and a side branch stent is required, T, TAP and culotte are all potentially good techniques.
- OCT and IVUS may help guide bifurcation treatment, in particular optimizing SB rewiring position (Figs. 26.11, 26.12, and 26.13).

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