Summary of Practice Considerations for Percutaneous Coronary Intervention of Left Main Bifurcation Disease

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L eft main bifurcation percutaneous coronary intervention is a challenging subset that requires expertise in techniques that are in constant modification. Imaging is important in lesion preparation and optimising outcomes. The interventionalist needs to be highly skilled in the different techniques as missteps may lead to stent thrombosis and critical in-stent restenosis. Lesion classification between simple and complex identifies those who would best benefit from a two-stent technique. Current technical approaches and practice considerations are summarised in this manuscript.

Technical approaches to left main (LM) revascularisation by percutaneous techniques continues to be in evolution. This manuscript will attempt to summarise the current best practices for LM percutaneous coronary intervention (PCI).

Following a clinical decision for PCI of left main bifurcation (LMB) stenosis, based on angiographic, imaging and functional severity, and supported by current guidelines and publications, the following practice considerations are recommended.[1–6]

Angiographic assessment

Multiple angiographic views should be utilised including the left anterior oblique (LAO) caudal, shallow LAO caudal, right anterior oblique caudal, anteroposterior caudal and LAO cranial views. Procedural strategy and the best working view should be identified. The Medina Classification describes bifurcation lesions and is the most common terminology used in studies involving strategies for LMB PCI. The SYNTAX score, which describes disease complexity, did not discriminate outcomes in contemporary trials of PCI compared to coronary bypass for LM disease.[7–10]

Imaging

Guidance with intravascular ultrasound and optical coherence tomography (OCT) should be considered in all stages of LMB PCI for improved outcomes.[11–13] Intracoronary imaging during procedural planning identifies the reference vessel diameter, length, extent, composition of plaque and lesion preparation strategy.[1,14] Intraprocedural OCT for the LM may be challenging but can assist in the wire crossing of stent struts into the side branch (SB) by choosing the appropriate cell (proximal or distal).[15,16] Post-procedural imaging is essential to evaluate for malapposition and to optimise the minimal stent area of the LMB and SBs.

Lesion classification

The key to LMB PCI is preservation of the SB, generally the left circumflex, without alteration in the main vessel (MV) stent architecture. Complexity of the LMB anatomy is associated with PCI outcomes. Lesions can be classified as simple or complex according to a number of variables. The DEFINITION II trial validated these variables as described in the DEFINITION criteria.[17–19] An SB lesion diameter stenosis ≥70% and/or a lesion length >10 mm constituted major criteria. Minor criteria included moderate to severe calcification, thrombus-containing lesion, lesion length >25 mm, multiple lesions, reference vessel diameter <2.5 mm or bifurcation angle <45 degrees. The presence of one major and/or two minor criteria qualifies as a complex lesion.

The technical approach to LMB PCI depends on whether a provisional or two-stent strategy is planned, which is predominantly based on classifying LMB as simple or complex.

Key procedural elements

LM PCI can be performed with a 6 Fr guiding catheter either by radial or femoral access.

Aggressive lesion preparation of the MV is required with pre-dilatation of the SB, if the two-stent strategy is planned. This may require coronary atherectomy.[20,21] With preserved left ventricular function, mechanical circulatory support (MCS) is not typically required. MCS should be considered with depressed left ventricular ejection fraction, the presence of occluded right coronary artery, low cardiac output, the need for atherectomy or decompensated heart failure without an opportunity for medical stabilisation.[22]

- The SB must be wired.[23] This is important since the left circumflex (LCx) artery is the most common SB and supplies a large amount of myocardium.
- The stent is always sized to the distal vessel, generally the left anterior descending (LAD) artery.[24] For lesions with a variation of 0.75 mm or greater in proximal and distal MV diameter, selection of a stent platform with sufficient ability for stent expansion to avoid malapposition is necessary. A 1:1 sizing is recommended using angiography, but it is more precise with intravascular imaging.
- The proximal optimisation technique (POT) is essential with balloon inflation of a short non-compliant (NC) balloon sized to the LM (ideally with intravascular imaging) with a stent length of at least an 8 mm balloon to be safely placed in LM without overlapping the carina. POT is also recommended after kissing balloon inflation (KBI).[25–28]
- KBI is absolutely necessary after a two-stent technique.[29–32]
- Intracoronary imaging is needed to optimise post-dilation of the stent using NC balloons. A mean stent area at the carinal confluence of >8 mm^2 is mandated with improved outcomes associated with a mean stent area >10 mm^2.[13,33–35]

Stenting techniques

The interventionalist should be familiar with at least four stenting techniques based on lesion complexity.[17]

Simple lesion
- Provisional stenting (PS): bailout strategies with conversion of PS to a two-stent technique;
- T-stenting and with minimal protrusion (also known as the TAP technique); and
- Culotte stenting.

Complex lesion
- Double kiss crush stenting or culotte stenting.

An upfront dedicated two-stent strategy in complex LMB lesions is recommended over a provisional strategy based on a series of trials, including the recent DEFINITION II study, and is supported by cardiovascular society guidelines.[18,36–39]

Provisional stenting

The majority of LMB stenosis are simple lesions, and a single stent approach using a provisional technique is used in >70% of cases.

- A single stent is used, generally a crossover from the LAD to the LM and preferably covering the entire LM. This is followed by POT with no SB dilatation, or KBI. The stent is sized to the distal vessel.
- If intervention is required to the SB, either a fresh wire is used or guidewire exchange occurs. The MV wire is pulled back with careful attention to the guiding catheter that is pulled back to prevent deep intubation, which may result in stent distortion or LM injury. The guidewire is inserted into the SB through the most distal cell (closest to the carina). The jailed SB wire is then pulled back and placed in the MV. Alternatively, a fresh wire can be used with a gentle double curve at the tip, crossing the LM into the LAD with the tip pointing upwards. The tip is then gently pulled back with a downward rotation to enter the SB. In select instances, a dual lumen microcatheter can be used to avoid wiring under a proximal strut and to facilitate SB rewiring. POT, KBI and re-POT is then performed. It is important to pay attention to the position of the POT balloon; the distal marker should be proximal to the neocarina to ensure that the neo-metal carina is not pushed back towards the LCx ostia, causing the re-jailing of the SB ostia.
- An alternative strategy is POT-SB inflation and re-POT (PSP). This optimises the result of PS, maintaining circular geometry, reducing SB ostium strut obstruction and access to the LCX, the risk of SB occlusion and global strut malapposition.[40]

If the result of the SB is inadequate after MV stenting with residual dissection, high-grade stenosis, thrombolysis in myocardial infarction (TIMI) flow <III or an fractional flow reserve (FFR) of <0.75 (though not validated in LM PCI, ischaemic thresholds of FFR <0.80 and instantaneous wave-free ratio/resting full-cycle ratio of 0.89 are being used), a second stent can be placed using either a T/TAP or culotte technique after guidewire exchange.[41–44]

Special care should be taken during LM stenting to avoid longitudinal stent deformation. Pulling back of the jailed wire or a partially deflated balloon may deep seat the guiding catheter and damage the stent. Optimal control of the guide catheter with disengagement from the LM is crucial to avoid this complication.

Kissing balloon inflations in provisional stenting

Routine KBIs in PS is not recommended.[29–32,45–47] When indicated, the LCx is rewired through a distal cell overlying the SB. A short NC balloon is used in the unstented SB to prevent the occurrence of dissection and to avoid oval distortion in the LM. Balloon diameters for the LM and SB are chosen according to Murray's law.[48,49] The SB is first inflated to 12 atmospheres, then partly deflated back to 4 atmospheres, with subsequent simultaneous inflation of both balloons at 12 atmospheres with simultaneous deflations. Final KBI is mandatory in two-stent techniques, including a PS strategy that converts to a two-stent technique.

Crossover to a two-stent strategy
T-stenting and the TAP technique

T-stenting or the TAP technique is used to optimise the SB, when the SB is compromised during PS and the results are suboptimal (occluded vessel, < TIMI-3 flow, SB dissection) after POT is performed.[42] The SB is recrossed with another wire through a distal cell (closest to the carina) and the jailed SB branch wire is withdrawn. After placement of the SB stent, a 'neocarina' is created by the SB stent struts protruding inside the LM at the level of the carina. The SB take-off angle and the site of strut crossing are major determinants of neocarina length. When the SB has a perpendicular take-off ('T'-shape), minimal SB stent protrusion inside the LM is needed to cover the SB ostium successfully. With acute SB angles (Y shapes), the SB ostia is longer and oval-shaped. Hence there is wider protrusion of the SB stent inside the LM, resulting in a longer neocarina. It is critical to limit protrusion while implanting the SB stent to <2 mm. KBI is the final step of the TAP technique. Deflations should be simultaneous or in rapid sequence with the MV balloon first to avoid crushing of the protruding stents, otherwise the protruded stent in the LM will keep the same position as before KBI.[48]

Culotte stenting

Following PS, POT and distal wire recrossing, SB stent struts are dilated. The second stent is then deployed from the SB into the MV, with the proximal struts just proximal to the edge of the MV stent using a stent diameter based on the SB reference diameter. A second POT is performed followed by a second wire exchange and final KBI.[44]

The main disadvantage of this technique is stent under expansion with three layers of stent at the carina. In a closed-cell design there is a 'napkin-ring' restriction of stent expansion. These factors are independent predictors of stent thrombosis and restenosis.[37,45]

Double kissing crush stenting

There are 11 procedural steps:[37,50,51]

1. Short (<2 mm) protrusion of SB stent into the LM, with another balloon positioned from the LM to the LAD.
2. Balloon crush: recent data suggest that a short NC balloon sized to the distal LM with the distal tip at the carina may result in a more complete 'crush'. Intravascular imaging can assist in appropriate balloon sizing, and this balloon can be used later for POT.
3. Rewire the proximal cell (not the distal cell, which is the recommended practice when using PS). This should ideally be performed in the LAO caudal projection to allow operators to see that the wire is away from the carina (OCT can be used to direct the wire through a proximal cell).
4. Alternate balloon inflation of the SB and MV balloon to at least 16 atmospheres, followed by the first KBI.
5. After the first KBI, withdraw the wire and balloon from the SB.
6. Stent the MV, which is sized to the distal reference, i.e., the LAD.
7. Perform the first POT with a short NC balloon sized to the distal LM with the distal tip at the carina (this can be the same NC balloon as in step 2).
8. Rewire the SB from the proximal cell.
9. Alternate balloon inflation of the SB and the MV balloon to at least 16 atmospheres.
10. Perform a second KBI.
11. End the procedure with second and final POT.

Final imaging is a must![11,34]

Left main trifurcations

Trifurcations are encountered in 10% of cases and pose technical challenges. In these instances, a single stent strategy is recommended, particularly if the SBs have limited disease. When significant SB disease is present, any two-stent technique might be used according to the specific anatomy; a minor SB (LCx or ramus) is generally identified and treated using a provisional technique. Favourable early and long-term results have been reported, even in true trifurcation lesions that are at high risk of restenosis.[52,53]

Duration of dual antiplatelet therapy

For the two-stent technique, the duration of dual antiplatelet therapy is extended for >1-year, as this results in decreased target lesion failure and thrombotic events compared with therapy continued for less than a year.[54] Hence, unless the patient has a high bleeding risk, long-term dual antiplatelet therapy should be considered. For the single stent provisional approach, standard guideline-directed therapy should be considered. ❏

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