Left Main Coronary Artery Lesions and Optical Coherence Tomography

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Optimal treatment of left main coronary artery (LMCA) lesions requires a highly tailored approach that incorporates patient comorbidities, clinical presentation, the extent of coronary artery disease (CAD), lesion characteristics and local expertise.[1,2] Coronary artery bypass grafting (CABG) is the treatment for LMCA lesions that has the highest evidence level in guideline recommendations.[2,3] However, the evidence for percutaneous coronary intervention (PCI) has increased in recent years and is now class IIa for ostial and trunk LMCA lesions and IIb for distal LMCA bifurcation treatment in stable patients suited for PCI.[2,3] However, these lesion-specific recommendations cannot be viewed in isolation. Multi-specialty heart team evaluation is indicated for patients with LMCA lesions whenever possible.[2]

Fractional flow reserve (FFR) is the current gold standard for evaluation of the functional severity of coronary lesions.[2,4,5] This also applies to LMCA lesions where assessment of both the left anterior descending artery (LAD) and the circumflex artery (Cx) may be indicated to determine whether revascularisation is indicated and, if so, to which extent.[6,7] A specific caveat for the use of FFR in the LMCA includes the necessity of taking the effect of downstream stenoses into account.[8] Intracoronary imaging methods, including intravascular ultrasound (IVUS)[9,10] and optical coherence tomography (OCT), may also be used for assessing lesion severity though cut-off values are under discussion.

OCT is a light-based imaging modality that can provide high resolution in vivo images of the coronary artery (axial resolution 10 to 20 μm). Because the resolution of OCT is 10x greater than that of IVUS with 20x faster image capture, it can provide precision information very quickly and aid physicians in the treatment of cardiovascular disease, including LMCA disease. OCT can be used to assess atherosclerotic plaque and visualise thrombus, which is a catastrophic event in LM disease, and also to evaluate the lumen area with accurate automated measurements. During PCI, it can aid in stent placement and be used to assess stent apposition and tissue coverage and in the identification and quantification of stent coverage. OCT has been used successfully in the context of diagnosing LMCA disease and in PCI. However, use of OCT to image the LMCA can be challenging because of the issue of vessel size and anatomical access. Optimal OCT imaging occurs in vessels <4 mm in diameter, while the average LMCA diameter is 3.5–4.5 mm. Additionally, access may be difficult depending on LCMA curvature and take off.

Clinical Use of OCT

- OCT is a light-based imaging modality that can provide high resolution *in vivo* images of the coronary artery (axial resolution 10–20 μm).
- OCT can be used to:
  - Assess atherosclertotic plaque and visualise thrombus
  - Evaluate lumen area with automated measurements
  - Aid in stent placement
  - Assess stent apposition and tissue coverage

PCI of ostial and trunk LMCA lesions has been associated with favourable results. However, distal LMCA bifurcation treatment poses significant challenges and is prone to target failure.[11] Better results have been achieved with some treatment strategies and stent techniques.[12] The unfavourable results reported in some trials of PCI of LMCA lesions may be due to use of earlier generation stents and to various technical issues during stenting. Guide catheter induced dissections, vessel and stent underexpansion, uncovered lesion areas, multiple malapposed stent layers, dense jailing of the ostia, longitudinal compression of stents and accidently crushed stents may all contribute to worse outcomes.[13–17] Additionally, superior results of PCI of LMCA lesions may be achieved with the use of newer generation drug-eluting stents compared with bare metal stents and first-generation drug-eluting stents.

Lesion Characteristics

The LMCA shows considerable variation in length, and in rare cases no trunk is present. The angulation of the Cx also varies but is often in the range of 70–100 degrees. The LMCA frequently shows distinct patterns of atherosclerosis extending from the distal LMCA toward the proximal LAD and also from the LMCA to the proximal Cx. The carina is in most cases free of atheroma. An intermediate branch is present in approximately 20 % of cases.

Treatment Principles

Direct stenting has been used in selected patients with acceptable results though predilatation of the lesion may precede stent implantation. In severely calcified lesions, debulking by rotablation may be indicated prior to predilatation. The use of cutting or scoring balloons can also contribute to better stent expansion in some cases. Predilatation of areas that will not be covered by stent should be avoided.[18] Predilatation of the Cx prior to stenting the main vessel with subsequent rewiring of the predilated side branch (SB) may increase the risk of the guidewire entering dissections, though its clinical impact is unknown.

The goals of stent implantation should be coverage of stenotic areas and adequate expansion of the vessel. Choosing the correct type of stent according to the nominal available sizes and maximum expansion capacity may also be of importance for the treatment of large coronary arteries. When placing a stent that extends from a large diameter LMCA to the LAD, it may be especially advisable to size the stent according to the LAD but to ensure that the selected platform has a maximum expansion capacity above the reference diameter of the LMCA.

Aorta-ostial Lesions

Stent deployment for LMCA ostial coverage is particularly demanding as the risk of the stent protruding into the aorta necessitates careful positioning. Stent protrusion may interfere with engagement of the guiding catheter. It may also increase the risk of crushing the stent when manipulating the guiding catheter as well as interfere with subsequent coronary angiography. Evaluation of stent position with at least two correctly angulated angiographic projections is crucial prior to stent expansion. Immediate adequate stent expansion and apposition may be of importance to avoid collision with the guiding catheter and lower the risk of longitudinal stent compression.

Distal LMCA Bifurcation Lesions

PCI of distal LMCA bifurcation lesions should be carefully planned, continuously evaluated during the procedure and carefully executed to ensure optimal results. The preferred strategy for most distal LMCA lesions is provisional side branch stenting. If significant disease is present in the proximal Cx, a two-stent strategy may be used. Two-stent strategies should be considered, especially in cases involving long Cx lesions where scaffolding of the Cx ostium after kissing balloon dilatation is not sufficient to maintain patency of the Cx.[19]

Provisional LMCA Bifurcation Treatment Strategy

The provisional side branch treatment strategy includes: 1) sizing the stent according to the distal reference diameter; 2) deploying the stent across the ostium of the Cx; 3) post-dilatation of the stent if necessary to ensure expansion of the distal main vessel (LAD) according to the reference diameter and 4) post-dilatation of the proximal main vessel (LMCA) from the proximal stent edge to just proximal to the carina. In the case of Thrombolysis in Myocardial Infarction (TIMI) grade III flow in the Cx and less than 75 % ostial diameter stenosis, the procedure can be finalised. In the case of Cx ostial compromise or <TIMI grade III flow, kissing balloon dilatation should be performed. If the TIMI flow is still < than grade III, the Cx should be stented.[20]

Post-dilatation of the LMCA portion of the main vessel stent may lower the risk of collision with the guiding catheter and lower the risk of abluminal rewiring of the LMCA stent. It may also facilitate rewiring of the Cx.[19]

A single stent approach from the LMCA towards the Cx has been presented[21] and may be an option in select cases, including patients with left dominant coronary circulation or a protective LIMA graft to the LAD. However, this strategy remains to be evaluated in larger clinical trials before it can be recommended.[22]

Kissing Balloon Dilatation in Provisional Treatment

Kissing balloon dilatation may be optimised after main vessel stenting by rewiring the Cx through a distal stent cell if possible. This ensures optimal scaffolding of the stent in the ostium.[23,24] However, stent choice may be limited if kissing balloon dilatation is attempted using only the criteria listed above. Ensuring that the second wire is not advanced at the abluminal side of the LMCA stent may be crucial prior to deflating a balloon delivered by the second wire. Both compliant and non-compliant balloons may be used for kissing balloon dilatation though non-compliant balloons may have theoretical advantages.[25] Final kissing balloon dilatation is mandatory when any two-stent technique is used whether provisional or planned.[16,19]

Side Branch Stenting in Provisional Treatment

Stenting the Cx in provisional treatment can be performed with a number of techniques; 1) the provisional T-technique: deployment of the Cx stent as closely as possible to the ostium of the Cx; 2) the "T-and-protrude" (TAP) technique: full ostial coverage is ensured by extending the proximal edge of the Cx stent 1–2 mm into the LMCA followed by kissing balloon dilatation without rewiring;[26] 3) reverse crush-technique: deployment of the Cx stent extending into the LMCA and subsequently crushing the Cx stent by inflating a balloon in the LMCA across the Cx ostium with subsequent rewiring prior to kissing balloon dilatation and 4) provisional culotte: Cx stent is deployed extending from the LMCA into the Cx and the LAD is subsequently rewire.

Each of these two-stent techniques has its pros and cons. The provisional T technique is simple and most suitable for use in Cx side branches with 90 degree angulation. The technique avoids additional scaffolding of the LMCA but carries the risk of leaving uncovered areas of the Cx ostium. The TAP stenting technique ensures full ostial coverage and alleviates the need for rewiring the Cx. But it also leaves a single layer metal carina. The reverse crush ensures full ostial coverage but entails three stent layers in the LMCA and a potentially higher risk of abluminal rewiring of the Cx stent. The provisional culotte also ensures coverage of the Cx ostium and the stent platform should be able to accommodate a difference in diameter between the LMCA and the Cx. But it carries the risk of jailing the LAD. There is currently no evidence showing that either of the side branch implantation techniques is superior in LMCA treatment.

Planned Two-stent Techniques for LMCA Bifurcations

A large number of planned two-stent techniques and related modifications have been proposed for the treatment of bifurcated

LMCA lesions. Evidence ranges from bench testing to randomised trials. Favourable results have been shown for the DK-crush technique.[12] Modifying the crush technique by performing kissing balloon dilatation after Cx stent implantation but before main vessel implantation is not only justified by the clinical results but also by the lower success rate of final kissing balloon dilatation in the classical and mini-crush techniques.[19] The culotte technique may be used when the size difference between the Cx and the LMCA is small and the angulation of the Cx is not too steep. When the LMCA, the LAD and the Cx ostia are predilated with cutting balloons, jailing one of the branches with a stent can be associated with procedural risk. The mini-crush technique involving placement of a stent in the Cx and one in the LMCA towards the LAD ready for deployment, is a very safe and quick technique that obviates the need for rewiring through a stent with the associated risk of a dissected ostium. However, use of final kissing balloons is also mandatory with this technique.

Use of Intravascular Imaging to Guide LMCA Intervention

Both IVUS and OCT are used to guide LMCA intervention. IVUS is indicated for LMCA treatment by expert consensus. OCT is indicated by expert consensus for the assessment of lesions and for guidance of stent sizing and implantation.[2] Intracoronary imaging enables evaluation of the distribution of plaque including the extent of calcified plaque.[27] In many cases OCT even makes it possible to assess the thickness of calcium plaques which may affect the lesion preparation strategy. Dissections resulting from predilatation are also readily detected by OCT and therefore, can be taken into account when assessing the required stent length. Assessment of reference diameters for stent sizing using OCT is in general performed by assessing lumen diameter at the most healthy looking segments.[28] With IVUS, sizing according to the external elastic membrane is recommended. In cases of diffuse disease, it is often possible to determine the vessel size in areas with fibrotic or fibrocalcific plaque. Alternatively, when there is diffuse disease in one vessel and focal disease in other vessels, the reference size may be determined according to Murray, Finéts or HK model equations.[29] Use of OCT to size the main vessel stent follows the principles described for provisional stenting. However, note that aorta-ostial involvement cannot at present be adequately assessed by OCT due to the need for engaging the guide catheter for clearing the vessel by contrast flushing. After deployment of the LMCA stent, OCT may be used to assess stent expansion.

After deployment of the LMCA stent, OCT may be used to assess stent expansion. Under expansion should be corrected to lower the risk of restenosis. Expansion according to the reference size of the individual segments is recommended. Minimal expansion area cut-off values for the LMCA bifurcation segments that best predict in-stent restenosis have been determined as follows: ostial Cx: 5.0 mm^2, ostial LAD: 6.3 mm^2, LMCA bifurcation segment: 7.2 mm^2 and LMCA: 8.2 mm^2.[17] Note that these values have been derived in an Asian population. The following modifications have been proposed for a Caucasian population; Ostial Cx: 5.5 mm^2, ostial LAD: 6.5 mm^2, LMCA bifurcation segment: 7.5 mm^2 and LMCA: 8.5 mm^2. Detected malapposition can be corrected to ensure fast intimal coverage of the stent if warranted.[30] Proximal malapposition can be corrected to prevent abluminal rewiring and guide catheter collision.

OCT Key Takeaways:

- After deployment of the LMCA stent, OCT may be used to assess stent expansion.
- Detected malapposition can be corrected to ensure fast intimal coverage of the stent if warranted.[30]
- In distal LMCA stenting, OCT can be used to measure the length of the proximal segment for sizing of the post-dilatation balloon.
- If kissing balloon dilatation is indicated, OCT can be used to verify that the guidewire recrosses into the side branch through a distal stent cell to ensure optimal scaffolding and a minimal metal carina.[24]
- Three-dimensional evaluation of the Cx ostium with OCT may emerge as the future standard in the treatment of distal LMCA bifurcation lesions.[31]

In distal LMCA stenting, OCT can be used to measure the length of the proximal segment for sizing of the post-dilatation balloon. If kissing balloon dilatation is indicated, OCT can be used to verify that the guidewire recrosses into the side branch through a distal stent cell to ensure optimal scaffolding and a minimal metal carina.[24] If a stent has been deployed to the proximal Cx, it is advised to rewire in a middle strut hole to lower the risk of abluminal rewiring of the Cx stent.[32] Acquisition of both an LAD to LMCA and a Cx to LMCA pullback ensures full evaluation after treatment using a two-stent technique. If the Cx is jailed, it is advised not to recross with an imaging wire due to the risk of stent distortion. Evaluation of the Cx ostium with a pullback from the LAD to LMCA can be performed with two-dimensional imaging with some limitations by using a combination of cross-sectional images and the longitudinal view rotated to visualise the side branch. Three-dimensional evaluation of the Cx ostium with OCT may emerge as the future standard in the treatment of distal LMCA bifurcation lesions.[32]

Conclusions

PCI of aorta-ostial and trunk LMCA lesions is associated with acceptable outcomes compared with CABG. However, treatment of the LMCA poses significant challenges and less favourable outcomes have been reported. OCT can be used during multiple steps of the LMCA intervention to optimise the results. ■

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