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Stenting of Left Main Coronary Artery Stenosis: Data to Clinical Practice

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Abstract

For several decades, coronary artery bypass grafting (CABG) has been considered as the gold standard treatment of unprotected left main coronary artery (LMCA) disease. However, because of large vessel caliber and anatomic accessibility, percutaneous coronary intervention (PCI) for LMCA has been attractive option for interventional cardiologists. With the marked improvement in technique and technology, PCI has been shown to be feasible for patients with unprotected LMCA stenosis. The recent introduction of drug-eluting stents (DESs), together with advances in pre procedural and post procedural adjunctive pharmacotherapies, has improved outcomes of PCIs of these lesions. The available current evidence comparing efficacy and safety of PCIs using DES and CABG revealed comparable results in terms of safety and a lower need for repeat revascularization for CABG. Still the management can be challenging in high risk anatomic subsets involving LMCA bifurcation lesions and, therefore, an integrated approach combining advanced devices, tailored techniques, adjunctive support of physiologic evaluation, and adjunctive pharmacologic agents should be reinforced to improve clinical outcome.

Keywords: Left main coronary artery disease; Coronary artery bypass grafting; Percutaneous coronary interventions; Bifurcation lesions; Drug-eluting stent

Introduction

Significant unprotected left main coronary artery disease (LMCA) is diagnosed in 5-10% patients undergoing coronary angiography [1,2]. Compared with medical treatment, coronary artery bypass grafting (CABG) of LMCA lesion has shown significant benefit [3-6]. CABG has been the gold standard therapy for LMCA disease until recently. The interventional cardiologists have been emboldened to test the feasibility of percutaneous coronary intervention (PCI) of LMCA mainly as a result of improved technical advances and stent technology [7].

Is LMCA Stenosis Important?

The LMCA is of particular importance as it supplies approximately two-thirds of the blood to the heart and 100% of the blood flow to the left ventricle. As a result, severe LMCA disease would reduce flow to large portion of the myocardium, placing the patient at high risk for life –threatening LV dysfunction and arrhythmias [8]. It is anatomically divided into three regions: the ostium, mid-shaft, and the distal portion [9]. It is a large artery and therefore tends to have a high plaque volume. It also is prone to calcification. Plaque shift and incomplete stent expansion are therefore important technical considerations in stenting of LMCA. The distal LMCA, by definition always ends in a bifurcation, or even trifurcation, giving rise to the left anterior descending (LAD) and left circumflex (LCx) arteries, and probably an intermedius artery. Greater elastic tissue content of this artery explains elastic recoil and high restenosis following balloon angioplasty [10]. Seventy percent of significant LMCA lesions involve the distal bifurcation. Intimal atherosclerosis in the LMCA bifurcation is accelerated primarily in area of low shear stress in the lateral wall close to the LAD and LCx bifurcation. Thus, carina is usually free of disease, which can explain why single-stent strategy can be successfully performed in patients with no or moderate disease by angiography. There are many unresolved issues to optimally treat bifurcational lesions as PCI procedures continue to evolve for this complex lesion:

1) Are increased rates of repeat revasculaization at bifurcation vs. shaft/ostial lesions due to anatomical or technical factors or both?
2) Should single-stent or double-stent strategies be used routinely for bifurcations?
3) Which technique should be preferred amongst double-stent strategies?
4) Whether intravascular ultrasound (IVUS) is to be routinely used for the procedure?
5) What would be the optimal duration of antiplatelet therapy for patients getting distal LMCA stenting?

With the above in mind, the author reviews the evidence supporting PCI for LMCA stenosis, as compared with CABG. And discuss various interventional techniques, as well as adjunctive devices and pharmacotherapy [7].

Evidence of PCI with Drug-Eluting Stent in LMCA Stenosis

The evolution of DES has been a major breakthrough in PCI of LMCA leading to significant reduction in restenosis and target lesion revascularization (TLR) when compared with initial experiences with bare-metal stents (BMS) [11-30]. Three single-centre studies showed high procedural success rates, low procedural complication rates, and encouraging long-term outcome [12-14]. The results were confirmed by the FRIEND (French multicentre RegIstry for stenting of uNprotecteD LMCA stenosis) registry that showed excellent results when stenting LMCA despite having 66% of patients with bifurcation [15]. DES in LMCA PCI has been evaluated in several single- and

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multicentre registries which reveals that stenting is efficient and safe [11-13,17,20-30].

Evidence of PCI vs CABG

To date, a large body of data from observational registries to clinical trials supports the feasibility, efficacy and safety of stenting as compared to CABG for treatment of unprotected LMCA disease. Several observational studies revealed that the early clinical events of LMCA stenting were similar or superior to those of CABG because of significant increase in periprocedural myocardial infarction (MI) or stroke in CABG patients, and that mortality between 30 days and 3 years was similar in both the groups [29,31-33]. However, the risk of target vessel revascularization (TVR) was higher with PCI than CABG. Recent results from the MAIN–COMPARE (Revascularization for Unprotected Left main Coronary Artery Stenosis: Comparison of Percutaneous Coronary Angioplasty Versus Surgical Revascularization) demonstrated that the rates of death, and the combined rates of death, MI, and stroke were not significantly higher with use of stenting compared with CABG. A similar pattern was also observed in patients treated with DES and BMS [29]. Recent data from ASAN-MAIN (ASAN Medical Centre-Left MAIN Revascularization) registry with 5-year follow up comparison with DES and concurrent CABG and 10-year follow up comparison of BMS and concurrent CABG, demonstrated that stenting showed similar long-term mortality and rates of death, Q wave MI, or stroke [34].

The evidence from randomized trials comparing CABG and PCI in LMCA disease is limited. Buszman et al. [35] showed a significant benefit of ejection fraction (EF) improvement and favorable clinical outcomes after PCI than after CABG. In the LMCA subgroup analysis from the SYNTAX (Synergy between PCI with TAXUS and Cardiac Surgery) trial [36], PCI reported the 12 month rate of major adverse cardiac or cerebrovascular events (MACCE), death, MI or stroke, similar to those seen after CABG, but higher rate of TVR was found in DES arm. The long-term 5-year follow-up data of the SYNTAX trial found an increased incidence of MACCE in the PCI group compared with the CABG group, driven primarily by higher incidences of MI and repeat revascularization [37]. However, in the LMCA subset, there wasn't any significant difference in MACCE between treatment groups. When stratified by score, the 5-year incidence of MACCE in patients with LMCA disease was similar between groups with low (<23) and intermediate (23-33) SYNTAX scores, continuing the trend noted at 12 months within the LMCA disease cohort [36]. Therefore, the SYNTAX score continues to be a important tool in the LMCA disease evaluation and suggests that patients with low or intermediate scores have similar long-term outcomes with PCI or CABG. In addition, the SYNTAX data demonstrate a significantly lower rate of stroke in the PCI group at 1 year and maintain a trend at 5 years [36,37].

Another study looking at off-pump CABG (OPCAB) versus PCI in LMCA disease also found a lower incidence of MACCE at 8-year follow-up in the OPCAB group, driven by higher rates of TVR and MI in the PCI group [38]. However, no significant difference in mortality or stroke was revealed in this study.

The Evaluation of XIENCE PRIME Everolimus Eluting Stent System (EECSS) or XIENCE V EECSS Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularization (EXCEL) is ongoing trial randomizing patients with LMCA disease and low or intermediate SYNTAX scores to PCI or CABG, thereby excluding patients who should undergo CABG due to anatomic complexity. Additionally, the trial is using a primary outcome of death, MI, and stroke, notably leaving out TVR [39].

What the Major Society Guidelines Say?

The 2011 American College of Cardiology Foundation/American Heart Association/Society for Cardiovascular Angiography and Interventions (ACCF/AHA/SCAI) guidelines for PCI make a Class IIa recommendation for LMCA PCI in patients with ostial or shaft disease, or in those with low SYNTAX scores (i.e., <23), if they are also felt to be at increased risk for surgical revascularization. A Class IIa recommendation is also made for PCI for unstable angina (UA)/non-ST elevation myocardial infarction (NSTEMI) if a patient is not a candidate for CABG or in the setting of ST-elevation myocardial infarction (STEMI) if coronary flow is compromised and PCI can be performed more rapidly and safely than CABG [40]. Additionally, the guidelines make a Class IIb recommendation for PCI in patients with bifurcation disease, low-intermediate SYNTAX scores (i.e., <33), and increased surgical risk. Though still not fully supportive of LMCA PCI, this is a departure from the last guideline update in 2005 [41] and focused update in 2007 [42], which recommended against LMCA PCI if a patient was eligible for CABG, except in the case of UA/NSTEMI with ongoing hemodynamic instability. The 2010 European Society of Cardiology (ESC) and European Association for Cardio-Thoracic Surgery (EACTS) guideline statement for myocardial revascularization makes a Class IIa recommendation for PCI in the setting of ostial or shaft LMCA disease, either in isolation or with single-vessel coronary artery disease (CAD) [43]. A Class IIb recommendation is made in the setting of left main bifurcation disease with single-vessel CAD, or in left main with 2- or 3-vessel CAD with a SYNTAX score of <33. CABG receives a Class I recommendation in all of these scenarios (Table 1). The 2014 ESC/EACTS guideline statement (Table 1) for myocardial revascularization makes Class 1 recommendation for PCI in setting of LMCA disease with SYNTAX score ≤ 22, II a recommendation with SYNTAX score 23-32 and Class III recommendation for SYNTAX score >32 [44]. Both American and European guidelines recommend Heart Team evaluation in the decision between CABG and PCI for LMCA treatment.

Risk Stratification for Procedural and Long-Term Outcomes

The SYNTAX score [36] is an effective tool for stratification of patients with complex LMCA disease into several levels of risk, which would decide appropriateness of revascularization strategy. In the LMCA subgroup of SYNTAX trial, the patients with a low SYNTAX score have a higher rate of non-distal lesions with mainly isolated LMCA disease or LMCA disease associated with single vessel disease where PCI is favoured over CABG. In contrast, the patients with high SYNTAX score have a higher rate of distal LMCA lesions and a majority of them are associated with two or three vessels disease where CABG stands better than PCI. Combining the SYNTAX and the EuroSCORE (European system for cardiac operative risk evaluation) into a common risk model (Global Risk Classification) was correlated with a significant improvement in predicting cardiac mortality in patients undergoing PCI for LMCA [45]. Another score, the NERS (New Risk Stratification Score) demonstrated a higher sensitivity and specificity to predict clinical outcome [46]. The author is of the opinion that the PCI needs to be performed by experienced interventional cardiologists using IVUS, mechanical support and optimal adjunctive drugs in patients with high clinical risks or complex lesion morphologies based on these risk stratification models.

		2010 ESC/EACTS		2011 ACCF/AHA/SCAI		2014 ESC/EACTS	
		Class	LOE	Class	LOE	Class	LOE
SCAD	Ostial or Trunk left main CAD	IIa	B	IIa	B		
	Bifurcation left main CAD	IIb	B	IIb	B	II	B
	Low SYNTAX score ≤22	NC		IIa	B	IIa	B
	Low-intermediate SYNTAX score 23-32	IIb	B	IIb	B	III	B
	High SYNTAX score ≥32	III	B	NC			
ACS	For UA/NSTEMI if not a CABG candidate	NC		IIa	B		
	For STEMI when distal coronary flow is TIMI flow grade <3 and PCI can be performed more rapidly and safely than CABG	NC		IIa	C		

SCAD= stable coronary artery disease; ACS= acute coronary syndrome; ESC= European Society of Cardiology; EATS= European Association for Cardio-Thoracic Surgery; ACCF= American College of Cardiology Foundation; AHA= American Heart Association; SCAI=Society for Cardiovascular Angiography and Intervention; LOE= Level of evidence; CAD= coronary artery disease; NC= not recommended by guidelines; SYNTAX= Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery; UA/NSTEMI= Unstable angina/non-ST elevation myocardial infarction; STEMI= ST elevation myocardial infarction; CABG= coronary artery bypass grafting.

Table 1: Major society recommendations for the use of percutaneous coronary intervention for unprotected left main coronary artery disease.

DES Choice in Treating LMCA

Few observational data and a large randomized trial, the ISAR-LEFT MAIN (Intracoronary Stenting and Angiographic Results: Drug-Eluting Stents for Unprotected Coronary Left Main Lesions) found that sirolimus-eluting and paclitaxel-eluting stents were equally effective and safe in patients undergoing unprotected LMCA stenting, showing comparable risks of death, MI, repeat revascularization and stent thrombosis [47-50].

ISAR-LEFT MAIN 2 randomizing zotarolimus-eluting stent (ZES) or everolimus-eluting stent (EES) in treating LMCA disease demonstrated no significant difference in the primary endpoint of MACE and angiographic restenosis between ZES and EES [51]. The results of this study suggest that the use of second-generation DESs is feasible, with similar outcomes to those noted with the use of first-generation DESs in ISAR-LEFT MAIN. Additionally, both stent types appear to provide similar results at 1-year follow-up.

Patient Selection

The first step in safely performing PCI is careful patient selection. The choice of PCI or CABG for treatment unprotected LMCA stenosis depends on several clinical and anatomic features. The clinical characteristics of the patients to be considered are age, diabetes, renal function, functional class, cognitive status, valvular disease, carotid disease and other comorbidities. The important angiographic features to consider are LV function, distal or non-distal LMCA involvement, calcification, diffuse disease, multi-vessel involvement, right coronary artery occlusion and quality of distal vessels. The development of SYNTAX score has provided a numerical assessment tool for grading the complexity of the angiographic anatomy. Candidates with favorable outcome for LMCA stenting include those who have good left ventricular function, little to no calcification, and minimal risk factors [52]. LMCA disease is often associated with lesions in the other coronary arteries the treatment of which needs to be addressed while deciding on the treatment strategy of this subset and the feasibility of a complete revascularization approach. Following are the group of patients with unprotected LMCA disease that are likely to have favourable clinical outcomes with PCI as that of CABG [7].

1) Ostial and/ or mid-shaft LMCA disease

2) Isolated LMCA disease

3) LMCA disease plus single-vessel disease

4) LMCA bifurcational disease treatable by single stent approach

5) Low or intermediate Syntax score (Syntax score <33)

Stenting Strategies and Techniques

Ostial and mid shaft lesions

These lesions can essentially be stented as in any other artery and be stented with single-stent strategy with good immediate and long-term outcomes.

Careful imaging must be performed to ensure adequate visualization of the ostium and adjacent aorta. Usually anteroposterior cranial and (or) slightly left anterior oblique cranial projections give the best view. Once guidewire is positioned in distal vessel, the guide catheter should be disengaged slightly from the ostium by pushing gently on the wire to minimize coronary ischemia. The guide catheter can then be gently moved towards the ostium, by slight traction on the wire, to allow contrast injection and imaging. The guide catheter should be short-tipped with side holes. The Amplatz catheter should be avoided in ostial lesions. Ostial lesions are often pre-dilated. The stent needs to be placed carefully with 1-2 mm protruding into the aorta. After deployment, the balloon should be withdrawn slightly into the aorta and proximal part of the stent post-dilated to flare it which ensures good stent apposition at the ostium. IVUS may be used to ensure a satisfactory result [7].

LMCA bifurcation lesion

Distal LMCA lesions are mostly treated as true bifurcation. The exception to this is when one branch is small (usually the LCx), when one branch is chronically occluded or if protected by a patent graft. In these circumstances the distal lesion may be stented with a single-stent technique, stenting across the ostium of the other vessel. True bifurcation lesions may be treated either by single-stent or by a two-stent strategy. Choice of strategy depends on vessel and lesion characteristics [plaque distribution, the diameter of the branches, the angle between them and anatomy of side branch (SB)]. The provisional stenting is a single-stent strategy, although it allows the placement of a second stent if required [T, T and protrusion (TAP), culotte technique]. More complex lesions may require double-stent strategy (T stenting, TAP, mini-crush, double-kiss crush, culotte, V stenting) [7].

Decision making

In deciding the strategy the anatomy and size of the SB (which is

almost always the LCx) are two important features. If the LCx is either occluded, its diameter is less than 2.5 mm, it can be ignored and a stent can be placed between the LMCA and the LAD [53]. A guidewire kept in a small LCx may help to maintain flow after a single stent is placed across the ostium. For a non-diseased LCX ostium, if the angle of bifurcation is of T shape, it is the operator's choice to place a protective guidewire but it may not be necessary. However, if the bifurcation angle is of Y shape, a protective wire is recommended. For a significant and diseased LCx ostium, there are several techniques depending on the angle of bifurcation. If the bifurcation angle is of T shape, the T-stent, mini-crush or TAP stent technique is recommended whereas if the angle is of Y shape, the culotte, mini-crush or double kiss (DK) crush technique is recommended, while T stenting is not [54].

When two stents are used, a final simultaneous inflation of both stents (kissing balloon inflation) at medium pressure (8-10 atm) with noncompliant balloons is considered critical to optimize outcomes. Whatever technique is selected, a final IVUS evaluation should be performed to ensure adequate stent expansion, complete stent strut apposition to the vessel wall, and absence of peri-stent dissection [7].

Single-stent strategy

The provisional T-stenting: This is a single–stent strategy allowing the positioning of a second stent if required (Figure 1). The LAD and LCx are wired. A stent is deployed from LMCA to the LAD. The guidewires are then exchanged, the LAD wire can be withdrawn and passed through the stent struts to the LCx, and the "jailed" wire in the LCx is withdrawn and advanced to the LAD. The proximal optimisation technique (POT) using short oversized non-compliant balloon should be employed just before carina to ensure adequate stent apposition in proximal main branch (MB) [55]. Final kissing balloon inflation (FKBI) may be performed in significant ostial SB lesions [TIMI flow <3 or fractional flow reserve (FFR) <0.8].

Double-stent strategy

The culotte stenting: This technique is suitable for lesions where ostio-proximal segment of LCx is diseased, the angulation between LAD and LCx is <60 degrees and when two vessel are of similar diameter. The MB usually the LMCA-LAD is stenetd. The LCx is rewired through the stent struts and dilated. A second stent is advanced through the struts of the first into the SB (LCx). The LMCA-LCx stent is then deployed. Each limb of the culotte is dilated at high pressure using non-compliant balloon followed by FKBI at medium pressure (Figure 2). In contemporary culotte stenting, POT is recommended after first and second stent deployment, as well as a final POT after kissing balloon inflation. It is advisable to avoid a long overlap of stents in the proximal MB whenever possible (mini-cullote). This technique ensures near-perfect coverage of the carina and the SB ostium. The main disadvantage of the technique is that rewiring both branches through stent struts can be technically demanding, and time-consuming. Open-cell stents are preferred for this technique.

The classical T stenting: This technique is suited when the angle between the two vessels is close to 90 degrees. A stent is deployed in LCx, making sure to cover the ostium with minimal protrusion into the LAD. The LMCA- LAD lesion is then stented. LCx is rewired and dilated followed by FKBI [7]. This technique provides good reconstruction of distal LMCA bifurcation, but is associated with the risk of leaving a small gap between the branches, hence restenosis at the ostium of LCx. For this reason, this technique has largely been replaced by the modified T stenting technique. The T technique is most frequently utilized to cross over from provisional stenting to stenting the SB.

The modified T stenting: It is a variation performed by simultaneously positioning stents at LCx and LAD with LCx stent minimally protruding into the LAD, when the angulations between the branches approach 90 degrees. The LCx stent is deployed first, and then after guidewire and balloon removal from LCx, the LAD stent is deployed. The procedure is completed with FKBI [7].

The T and protrusion (TAP) stenting: This modification of T stenting technique can be used in majority of the bifurcation lesions especially when the bifurcation angle is less than 90 degrees. It can provide good reconstruction of distal LMCA bifurcation with minimal stent overlap [7]. The MB (LMCA-LAD) is stented jailing the SB (LCx) guidewire. Kissing balloon inflation is performed after rewiring the SB. After positioning the proximal edge of the SB stent 1-2 mm inside the MB the stent, the SB stent is deployed at high pressure with deflated balloon kept in the MB stent. Then, SB balloon is slightly retrieved and aligned to the MB balloon. Afterwards, a FKBI is performed in order to reconstruct the carina.

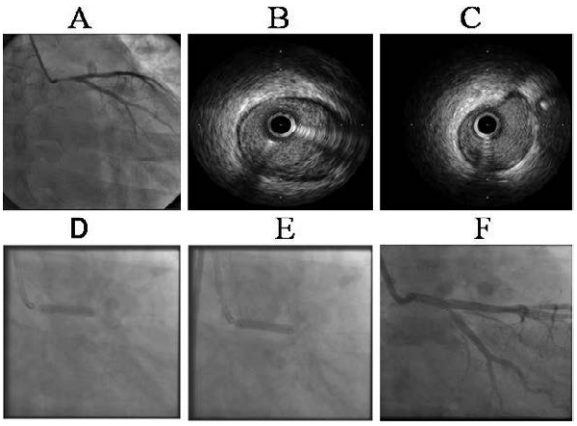

Figure 1: Provisional stenting: **A)** Baseline angiogram showing tight distal LM lesion with near normal LCx ostium; **B)** IVUS depicting significant LAD ostial disease; **C)** IVUS revealing minimal atherosclerotic disease at LCx ostium; **D)** Direct stenting of LMCA-LAD; **E)** Adjunctive in-stent dilation with bigger non-complaint balloon; **F)** Final result.

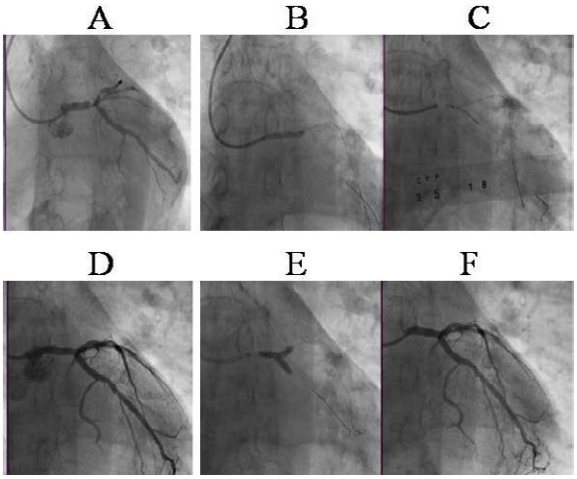

Figure 2: Culotte stenting: **A)** Baseline coronary angiogram; **B)** Pre-dilataion of LMCA-LAD; **C)** First stent deployed in LMCA-LCx; **D)** Second stent deployment in LM-LCx after wire exchange and balloon dilatation; **E)** Kissing balloon inflation; **F)** Final result.

The Mini-crush stenting: The mini-crush technique is suitable for LMCA bifurcation patient with ostial and proximal stenosis of both the MB (LAD) and SB (LCx), in which the diameter of LAD is greater than LCx and the angle between LAD and LCx is less than 60 degrees. The immediate patency of both branches is assured making this technique useful in conditions of instability or complex anatomy. This technique provides excellent coverage of the ostium of the SB. The mini-crush technique can be used in almost all true bifurcation lesions but must be avoided in wide angle bifurcations. The main disadvantage is that in order to perform FKBI, there is need to re-cross multiple struts with wire and a balloon [7].

The SB stent is positioned in the LCx followed by advancement of LAD stent. The LCx stent is pulled back into the LAD about 1-2 mm and is deployed. The deployment of LAD stent crushes the proximal LCx stent against the LMCA wall. LCx is rewired through the stent struts of both LAD and crushed LCx stent to perform FKBI (Figure 3).

The Double Kiss (DK) crush stenting: A stent is placed into LCx and a balloon placed in LMCA-LAD. The stent and balloon are positioned as in standard crush technique. The LCx stent is deployed and then the guidewire and balloon from the LCx are removed. The prepositioned balloon in LMCA-LAD is inflated to crush the protruding segment of LCx stent against vessel wall of the LMCA. The balloon is removed and a stent is deployed in the LMCA-LAD. The wire is then recrossed into the LCx and FKBI is applied to finish the procedure (Figure 4). As a result, the DK crush technique consists of five steps: side-stenting, balloon-crush, first-kissing, second-crush, and FKBI. This technique results in less stent distortion, improved stent apposition, and facilitate FKBI. It may be superior to classic crushing optimizing acute procedural results and possibly improves clinical outcomes by facilitating FKBI [56]. DK-CRUSH II is the only randomized trial to suggest that double stenting may be superior to provisional stenting and associated with a lower rate of restenosis and repeat revascularization [57]. DK-CRUSH III study demonstrated that among patients with bifurcation angle ≥70°, NERS score ≥20, and SYNTAX score ≥23, the 1-year MACE rate in the DK group was significantly less compared to the Culotte group [58].

The V and the simultaneous kissing stent (SKS): The V stenting is performed by placing and deploying two stents together in narrow angled bifurcation. Guidewires are placed in both LAD and LCx and, with or without predilatation [59], the two stents are placed into LMCA and respective branches and deployed by simultaneous inflation (Figure 5). The author is not a proponent of SKS that allows a variable amount of protrusion creating rather long double barrel. V stenting is relatively easy and fast and thus ideal in emergencies. It is indicated in patients with a short LMCA free disease and critical disease of both the LAD and LCx ostia.

Application of Intracoronary Imaging

IVUS is the ideal method for confirming the presence of significant LMCA lesion and also for stent size, assessing the presence of calcification, and documenting the involvement of the distal LMCA and its branches. Knowledge of reference lumen diameter, plaque composition, position of the carina in relation to the major portion of the plaque volume is critical prior to PCI of LMCA [54]. It is also considered to be a useful modality in selecting treatment strategy, and helpful in optimally expanding the stent, with or without post-stent balloon dilatation, to avoid under- or overstretch of the stent diameter, and might contribute to better long-term outcomes as compared with conventional angiography guidance [60]. The cut-off values for MLA after stenting in the LMCA bifurcation segments predicting in-stent restenosis are: ostial LCx - 5.0 mm^2, ostial LAD - 6.3 mm^2, LMCA bifurcation segment - 7.2 mm^2, and LMCA - 8.2 mm^2 [61].

The present IVUS catheters have a higher crossing profile and provide lower resolution compared to OCT (optical coherence tomography), and that OCT may increase use of contrast and does not

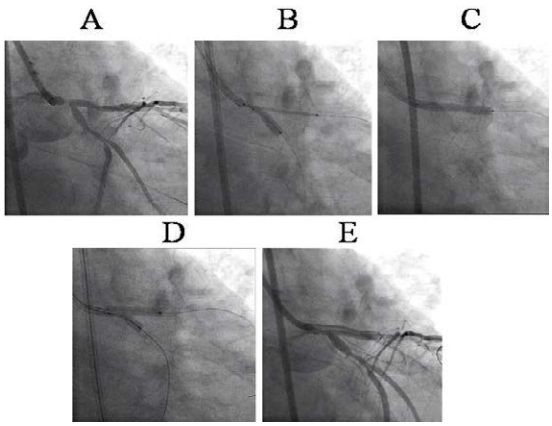

Figure 3: Mini-crush technique: **A)** Baseline coronary angiogram revealing significant stenosis of LMCA bifurcation involving proximal LAD and LCx; **B)** Deployment of LCx stent with mild protrusion into LAD following balloon dilatation; **C)** Deployment of LMCA-LAD stent crushing LCx stent; **D)** Rewiring of LCx followed by final kissing balloon inflation; **E)** Final angiographic result.

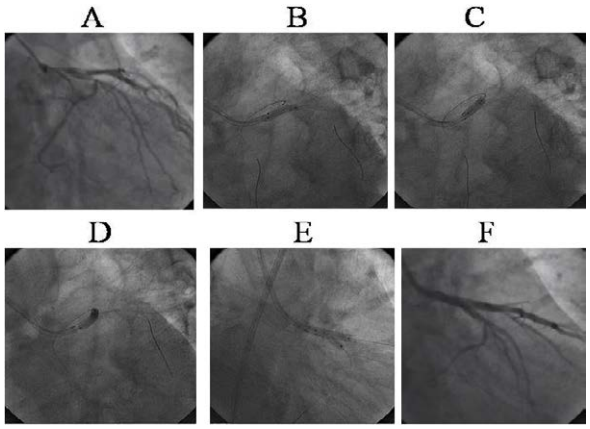

Figure 4: Double kiss crush technique: **A)** Baseline coronary angiogram showing significant distal LMCA, proximal LAD and ostio-proximal LCx lesions; **B)** Stenting of LMCA-LCx after predilation; **C)** Crushing of LCx stent with non-compliant balloon placed in LMCA-LAD; **D)** Deployment of stent in LMCA-LAD with second crushing of LCx stent after first kising balloon inflation; **E)** Second kissing balloon inflation; F) Final result.

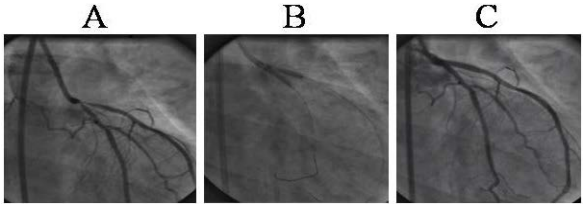

Figure 5: V stent technique: **A)** Baseline coronary angiogram showing significant bifurcation at short LMCA; **B)** Implantation of two stents in LAD and LCx simultaneously; **C)** Final result after kissing balloon inflation.

allow for aorto-ostial assessments [62]. As of today, crossing into a jailed SB using IVUS or OCT wire is not recommended, as they might distort or fracture [63]. Like IVUS, OCT may be used for assessing lesion composition and distribution, results of predilatation, reference sizing and evaluation of adequate vessel expansion after stenting [64,65]. OCT often is an excellent tool for assessment of evaluation of thin-cap fibroatheromas, thrombus and small dissections [64]. After stenting, both IVUS and OCT may be used to evaluate vessel expansion, stent distortion and malapposition. OCT is capable of detecting lower grades of malapposition than IVUS [66]. 3D OCT is of paramount importance in evaluating bifurcation treatment [67].

Application of FFR

It may be reasonable to defer LMCA revascularization in patients with an FFR >0.80. However, FFR for LMCA assessment is not without drawbacks. In presence of concomitant lesions in both the LAD and LCx without repairing the downstream lesions, the FFR may underestimate the true significance of the LMCA lesion [7]. Furthermore, in ostial lesions with catheter-induced damping upon engagement, uncomfortable maneuvers are sometimes repetitively required to engage, inject intracoronary adenosine and disengage the guide catheter. The administration of intravenous adenosine should be considered under these circumstances. There may be a discrepancy between angiographic percent diameter stenosis and FFR in jailed LCx lesions after LMCA-LAD stenting. One study reports that the need for revascularization of the ostial LCX after LMCA-LAD crossover stenting may be reduced, if the additional procedure is guided by FFR [68]. Given the nearly identical one-year MACE rates with both approaches in DKCRUSH-VI trial, either the angiography-guided or FFR-guided technique may be recommended for provisional side branch stenting of true bifurcation lesions [69]. However, further studies are needed to evaluate the efficacy of this strategy.

Adjunctive Management

Debulking

After the introduction of DES, the role of debulking is diminished due to the benefit of restenosis reduction significantly. There is no evidence to show debulking prior to stenting with DES can further improve the long-term outcomes. Directional atherectomy may be preferable in LMCA bifurcations to aid the provisional single-stenting strategy. Similarly rotablator is used when calcification prevents stent delivery or calcified target lesion is not significantly dilated [7].

Hemodynamic support

Patients with unstable hemodynamic condition need pharmacologic or device-based hemodynamic support. LMCA lesions with old age, MI, cardiogenic shock, and decreased LV EF are common conditions requiring elective or provisional hemodynamic support. Out of many support devices, IABP has been used most extensively. Its elective use needs to be considered for high-risk conditions, having multivessel disease, complex LMCA anatomy, low EF or unstable presentations. Other new support devices, such as Impella LP 2.5 and LP 5.0 (Abiomed) may be a preliminary answer to the need for a minimally invasive and easily deployable mechanical assist device that provides superior hemodynamic support compared to IABP. During LMCA manipulation, the support devices maintain perfusion limiting ischemic cycles and hemodynamic stability allowing operator tranquility.

Antithrombotics

Careful administration of antiplatelet agents is important to prevent the occurrence of stent thrombosis. Despite the lack of evidence, many clinicians have suggested indefinite use of dual antiplatelet therapy (DAPT) for patients of LMCA treated with DES in high-risk patients (diabetes mellitus, multiple stents, chronic renal failure, or presentation with MI). Park et al reported that continuing DAPT therapy beyond one year was no more effective in reducing major adverse events than aspirin monotherapy [70]. Another study suggested routine use of platelet function testing with recommendation to increase to increase clopidogrel dose to 150 mg if platelet aggregation is more than 50% [71]. The new anti-platelet agents (prasugrel and ticgrelor) should be evaluated in patients with complex LMCA intervention. Even, the additive role of glycoprotein IIb/IIIa inhibitor, cilostazole, low-molecular-weight heparin, direct thrombin inhibitor, or new drugs need to be investigated in future studies [7].

Conclusion

CABG remains the optimal treatment for majority of LMCA lesions. However, there have been emerging indications and growing trend in favour of PCI in the past few years. This has been supported by current evidences from clinical trials and large off-label experience updating current guideline for LMCA revascularization. Stenting of ostial and shaft of LMCA can be achieved without major technical difficulties and with good immediate- and long-term results. LMCA bifurcational lesions continue to pose considerable challenges and require expertise and performance of unique approaches for optimal results. An integrated approach that combines advanced devices, specialized techniques, adjunctive imaging support, as well as adjunctive pharmacologic agents would continue to improve PCI success rate and long-term outcomes for these complex subsets. The EXCEL trial will demonstrate whether PCI with new generation of DES will compete with CABG as regards to safety endpoint. Even if LMCA stenting is a different animal, the interventional cardiologists have discovered the light at the end of the tunnel.

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