Left Main Bifurcation Stenting in Primary PCI: Conventional Technique

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KEYWORDS

Left Main Bifurcation Stenting, Primary PCI, Intracoronary Imaging, T-Stenting and Small Protrusion

ABSTRACT:

Bifurcation lesions are common and often linked to a higher chance of restenosis. It is recommended to consider using a two-stent approach in patients with complex anatomy or a large myocardial area supplied by the side branch, in certain cases, using a temporary stent technique might be more appropriate. Here, the left main (LM) bifurcation was treated with primary PCI without the need for intracoronary imaging.

1. Introduction

Bifurcation lesions make up about 20% of the cases treated with percutaneous coronary intervention (PCI). Bifurcation lesions present a significant obstacle during PCI and are linked to a greater occurrence of significant negative heart-related incidents (MACE) as opposed to lesions that are not bifurcated. In complex bifurcation cases, particularly those involving the left main (LM) artery, a two-stent strategy may be a valuable approach to optimize outcomes.

2. Case Study

A man of 55 years came to the clinic with chest discomfort, marked as 5/10 on the Visual Analogue Scale (VAS). lasting approximately 15 minutes. The pain was accompanied by heavy breathing during sleep and cold sweats. The left-sided chest pain initially subsided but later reappeared and worsened (VAS 7/10), prompting the patient to seek medical attention.

The patient has a background of high blood pressure and heart disease affecting the coronary arteries (CHD) and has been receiving routine treatment for the past year. He has a smoking history of one pack every three days for the past three years. There was no history of exertional dyspnea, orthopnea, or paroxysmal nocturnal dyspnea.

During the examination, it was observed that the patient's blood pressure was at 105/67 mmHg, with a consistent pulse rate of 103 beats per minute, breathing at a rate of 21 breaths per minute, and peripheral oxygen saturation level at 98%. Examination of the head and neck showed no jugular venous distension. Cardiac examination revealed single and regular heart sounds (S1 and S2) with no murmurs. The extremities were warm and dry, with no evidence of edema.

ECG examination revealed sinus tachycardia (107 bpm), normal axis, ST elevation in aVR and V1–V3, and ST depression in I, II, aVF, V5, and V6. Left ventricular hypertrophy (LVH) was also noted

(Fig. 1). A chest X-ray in the anteroposterior (AP) position (overexposed) demonstrated cardiomegaly and pulmonary congestion, with both phrenicocostal sinuses appearing sharp (Fig. 2). Laboratory investigation showed elevated hs-Troponin (56553). Transthoracic echocardiography revealed eccentric LVH and Left ventricular systolic function is diminished, with an ejection fraction of 32% (biplane method). Regional wall motion abnormalities were observed, including anteroseptal hypokinesia (B-M), septal hypokinesia (A), and anterior hypokinesia (B-M-A), while other segments remained normokinetic.

The individual received a PPCI procedure through the femoral artery using a 7 Fr sheath for access. DCA revealed a healthy RCA and collateral arteries connecting the RPDA to the LAD. The left main coronary artery (LMCA) exhibited severe blockage of 95% at the opening of LM and widespread disease extending from the opening to the end of LM. Left anterior descending artery (LAD) showed diffuse disease with significant stenosis of 80-90% in the LAD. Left circumflex (LCx) showed high obtuse marginal (OM1) (Fig. 3).

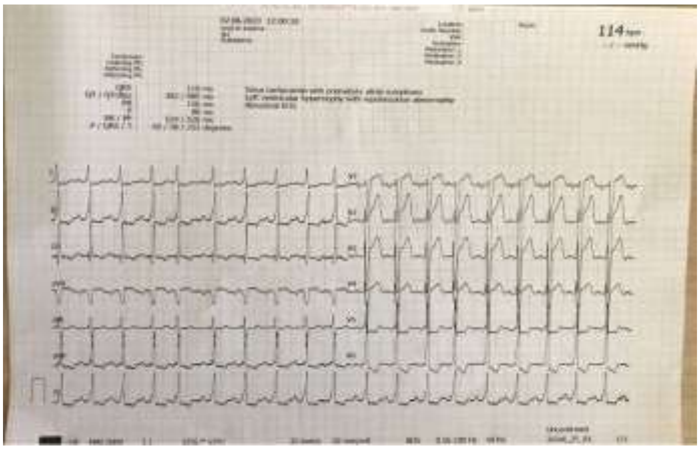

Figure 1. Electrocardiography

Figure 2. Chest X-Ray AP Position

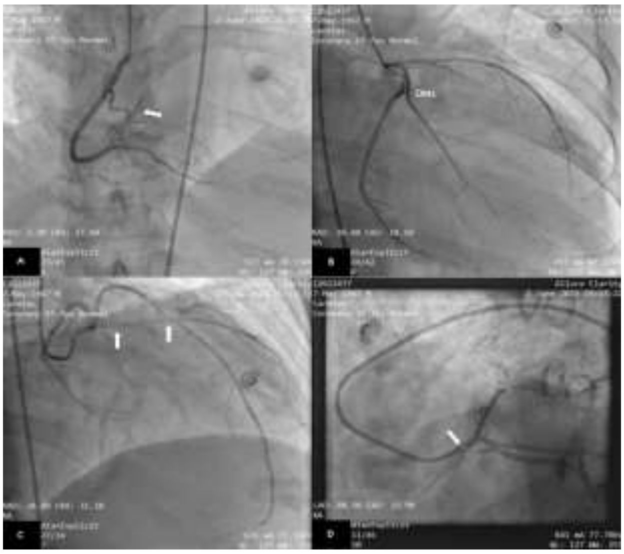

Figure 3. Diagnostic Coronary Angiography: (A) Collateral circulation from the RPDA to the LAD (arrow). (B) High obtuse marginal branch (OM1). (C) Diffuse disease (arrow) with significant 80–90% stenosis in the LAD. (D) Subtotal 95% stenosis (arrow) at the ostial LM, with diffuse disease extending from the ostium to the distal LM.

Based on the DCA findings, PPCI was performed. Using a 6 Fr EBU 3.0 guiding catheter (GC), the Runthrough NS floppy guidewire (GW) was advanced across the lesion to the distal LAD, while the Runthrough NS Hypercoat GW was positioned in the distal OM1 as a protective wire. A drug-eluting stent measuring 3.0 × 15 mm with Everolimus was inserted into the upper to middle part of the left anterior descending artery (LAD) and dilated at 12 atm for 17 seconds (Fig. 4). After that, a 3.0 × 16 mm Everolimus DES was inserted into the proximal LAD, with the new stent overlapping the old one, and then expanded at 14 atm pressure for 8 seconds (Fig. 5). Subsequently, a drug-eluting stent measuring 3.5 × 16 mm, Everolimus, in particular, was placed from the origin of the left main artery to the beginning of the left anterior descending artery, overlapping distally and protruding 1 mm into the aorta, with dilation at 14 atm for 16 seconds. Final angiography demonstrated TIMI 3 flow in the LM and LAD; however, ostial LCx pinching was observed due to plaque shift (Fig. 6).

Figure 4. A drug-eluting stent coated with Everolimus, measuring 3.0 × 15 mm, was placed in the LAD artery extending from the beginning to the middle section

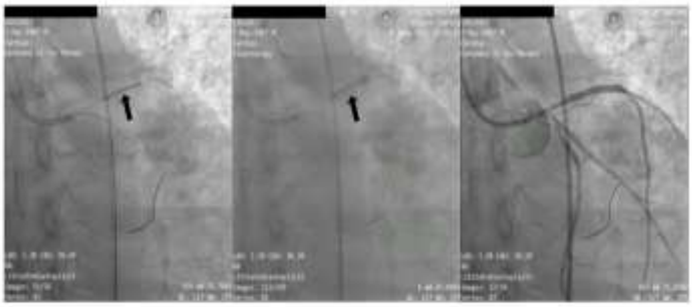

Figure 5. A 3.0 × 16 mm Everolimus-coated stent was placed in the proximal LAD artery, slightly overlapping with the stent that was previously inserted

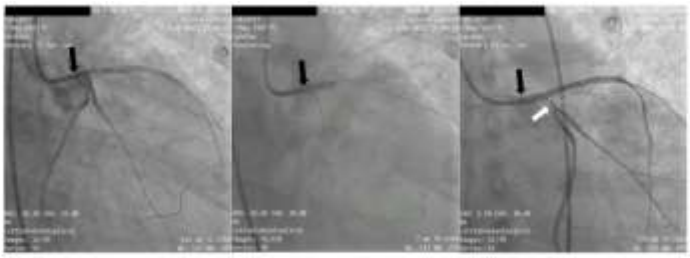

Figure 6. "A drug-eluting stent measuring 3.5 × 16 mm coated with Everolimus was inserted from the opening of the left main artery to the beginning of the left anterior descending artery, overlapping distally with the previous stent and protruding 1 mm into the aorta. Pinching of the ostial LCx was observed (white arrow).

A two-stent strategy was selected. To begin with, the Runthrough NS Hypercoat guidewire (GW) was inserted into the distal LCx through the distal strut of the stent in the main vessel. The TAP method was utilized in placing a 2.75 x 12 mm Amphilimus-eluting stent from the ostium to the proximal LCx (Fig. 7). Following that, they proceeded to perform Kissing Balloon Inflation (KBI) by using a stent delivery balloon measuring 2.75 × 12 mm in the LCx and a 3.5 × 16 mm balloon in the LAD. (Fig. 8a). Finally, the Proximal Optimization Technique (POT) involved utilizing a 4.0 × 16 mm non-compliant (NC) balloon in the ostial LM to the proximal LAD (Fig. 8b). In the angiographic outcome, the LCx demonstrated optimal flow according to the TIMI 3 scale (Fig. 9).

Figure 7. The Runthrough NS Hypercoat guidewire was advanced to the distal LCx (white arrow). A 2.75 × 12 mm Amphilimus-eluting drug-eluting stent (DES) was deployed from the ostium to the proximal LCx using the T and small protrusion (TAP) technique (black arrow).

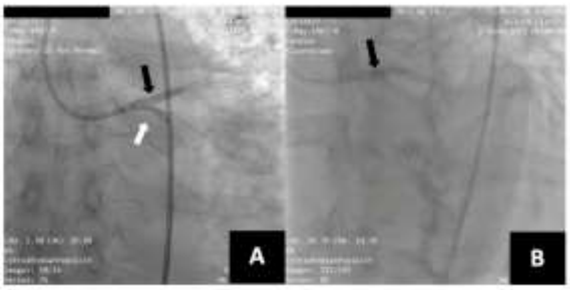

Figure 8. Kissing Balloon Inflation (KBI) and Proximal Optimization Technique (POT) in Coronary Intervention

Kissing Balloon Inflation (KBI) involved the use of a 2.75 × 12 mm stent delivery balloon in the LCx (marked by a white arrow) and a 3.5 × 16 mm balloon in the LAD (black arrow) (Fig. 8a). The Proximal Optimization Technique (POT) was then implemented in the ostial left main coronary artery (LM) to the proximal left anterior descending artery (LAD) using a 4.0 × 16 mm non-compliant (NC) balloon (Fig. 8b).

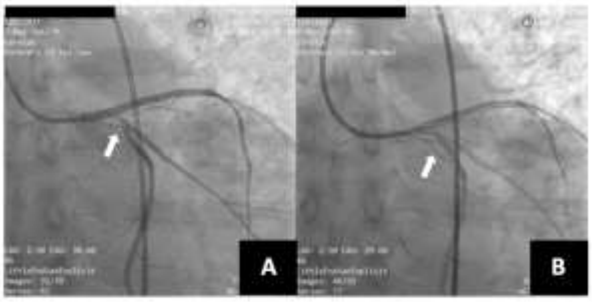

Figure 9. Pre-procedure (a) and post-procedure (b) images of the T and small protrusion (TAP) technique on the LCx.

3. Discussion

Left Main

The significant role of the heart's function can be attributed to the large size of the left main coronary artery, wide angle of branching, and significant supply of blood to the heart muscle (Chen, 2023). Thus, restenosis or stent thrombosis in the left main coronary artery can have serious consequences. The main treatment for LM lesions is typically coronary artery bypass grafting (CABG) (Neumann et al., 2018), however, with advancements in percutaneous coronary intervention (PCI) techniques and the development of new pharmacological treatments, re-evaluating the criteria for optimal LM disease revascularization becomes essential. While PCI is a viable option for most LM lesions, certain high-risk anatomical features, such as distal LM bifurcation lesions, present unique technical difficulties (Chen, 2023).

Coronary bifurcation

The coronary artery has a division known as the coronary bifurcation, consisting of the proximal main vessel, the distal main vessel, and side branches. At the bifurcation, there is *a Point of Bifurcation*

(POB) and *a Polygon of Confluence* (POC) (Fig. 10). Serving as a connection point, the carina links the distal main vessel to the side branches (Lunardi et al., 2022).

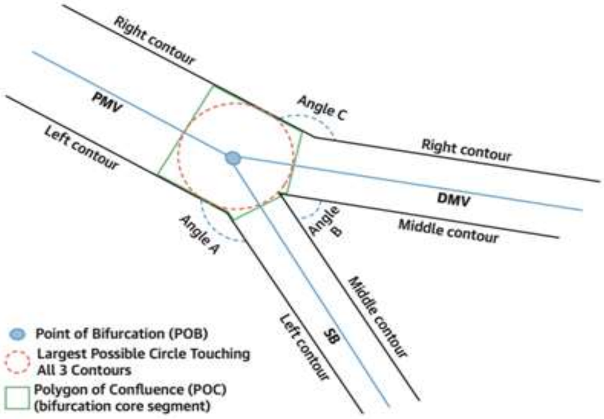

Figure 10. Diagram of coronary bifurcation components

The POB is where the largest circle can be found within the bifurcation, crossing paths with the proximal main vessel, the distal main vessel, and the side branches' contours. This point is where the diameter of the three vessels meets. In contrast, the POC is defined in 2D radiography as the area encompassing the beginning and end of the bifurcation area. The boundaries of the POC are determined by the intersection of the largest circle with the diameter of each vessel. Given the limitations of 2D angiography, it is essential to identify this entity from an optimal angiographic angle that minimizes overlap and shortening of the distal branches, and displays the widest bifurcation angle (Lunardi et al., 2022). The recommended angiographic view for bifurcated LM lesions is the Left Anterior Oblique (LAO)- Caudal ("Spider") or Postero Anterior (PA)- Caudal position (Green et al., 2016) (Fig. 11).

Angiographic guidelines specify that a bifurcation lesion refers to a blockage in a coronary artery that is located near or impacts a significant branch off the main artery, with a reference diameter of at least 2.0 mm. A bifurcation lesion is classified as significant when the narrowing surpasses 50% and the Minimum Lumen Diameter (MLD) is found to be less than or equal to 4 mm from the Point of Bolus (POB) in at least one of the three segments. A side branch is considered significant if it has a reference diameter ≥ 2.0 mm and is a branch that must be maintained for several reasons (causing ischemic symptoms, viability, collateral vessels, supplying extensive myocardium) (Louvard & Medina, 2015; Lunardi et al., 2022).

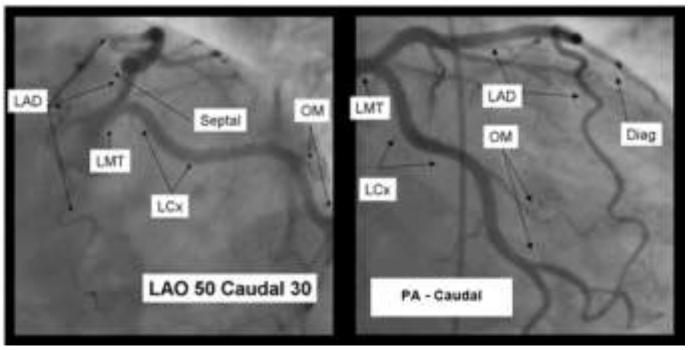

Figure 11. Angiographic view for bifurcated LM lesion

Bifurcation lesions are classified using the Medina criteria. Segments with significant lesions (stenosis > 50%) are assigned a value of 1, and segments with insignificant lesions are assigned a value of 0. Segments are analyzed sequentially in this order: proximal main vessel, distal main vessel, and side branches (Fig. 12) (Louvard & Medina, 2015). A lesion is considered a "true" bifurcation lesion when both the primary vessel opening and the side branch opening are severely narrowed. Thus, the subcategories of Medina's classification, such as (1,1,1), (1,0,1), and (0,1,1), are included in the category of bifurcation lesions known as "true." Other than these three Medina criteria, they fall into the “non-true” bifurcation lesion group (Park et al., 2015).

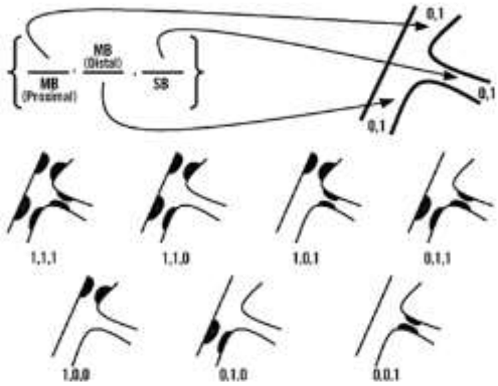

Figure 12. Medina Classification

Patients with a true bifurcation lesion have shown increased rates of the risk of death from any cause and serious cardiovascular incidents over a 36-month period compared to those without a true lesion (Table 1) (Hildick-Smith et al., 2022; Park et al., 2015).

Table 1. Outcomes of percutaneous coronary intervention in patients with bifurcation lesions categorized as "True" or "Non-True" were examined in the study

	True bifurcation (n=1,502)	Non-true bifurcation (n=1,395)	Unadjusted HR (95% CI)	P value	Adjusted HR† (95% CI)	P value
MACE*	181 (12.1)	115 (8.2)	1.52 (1.20–1.92)	<0.001	1.39 (1.08–1.80)	0.01
Cardiac death or MI	57 (3.8)	33 (2.4)	1.63 (1.06–2.50)	0.03	1.66 (1.03–2.67)	0.04
Death	75 (5.0)	43 (3.1)	1.63 (1.12–2.37)	0.01	1.56 (1.03–2.36)	0.04
Cardiac death	28 (1.9)	14 (1.0)	1.87 (0.98–3.55)	0.06	2.08 (0.98–4.39)	0.06
MI	31 (2.1)	22 (1.6)	1.33 (0.77–2.30)	0.31	1.26 (0.69–2.32)	0.46
Definite or probable ST	21 (1.4)	6 (0.4)	3.27 (1.32–8.10)	0.01	2.82 (1.03–7.67)	0.04
TLR	136 (9.1)	94 (6.7)	1.39 (1.07–1.81)	0.02	1.24 (0.93–1.65)	0.14

"True" bifurcation lesions are easily identified by the large buildup of plaque in both the main artery and its branching offshoots, which significantly increases the likelihood of blockages in the smaller side branches. Plaque displacement from the proximal main vessel or carina can lead to obstruction of the side branch ostium, blood flow in the side branch will be compromised (Gwon et al., 2015).

The mechanism of side branch occlusion is caused by, among other things, shifting of the carina or shifting of plaque (Pan et al., 2023). There are five independent predictors of side branch occlusion, namely: significant side branch ostial disease, length of side branch lesion, left main lesion, acute coronary syndrome, and significant proximal main vessel stenosis. Plaque shift associated with large plaque burden is thought to be the mechanism that occurs in the last two predictors (Gwon et al., 2015).

Provisional vs two stent strategy

The complex nature of bifurcation lesions during percutaneous coronary intervention (PCI) is said to be the main reason for the frequent occurrence of in-stent restenosis (ISR), the most common location experiencing ISR is the osteal side branch (Eltelbany et al., 2024). A major challenge in performing bifurcation PCI is the difficulty in using existing tools and techniques for the coronary anatomy to open up vessels while also keeping the bifurcation's shape intact. This requires a two-step approach: first, determining the ideal stenting strategy based on lesion and patient characteristics; second, optimizing the stent post-placement (Chieffo & Beneduce, 2021).

Until now, the provisional stent technique continues to be the fundamental strategy for left main bifurcation lesions, but more intricate cases may demand a different approach, a two-stent technique is often required.

The DEFINITION criteria, consisting of 2 main criteria and 6 secondary criteria listed in Table 2, are not only utilized for the purpose of classifying bifurcation lesions as either straightforward or intricate but also to determine the appropriate procedural approach. If a bifurcation lesion fulfills one major and two minor criteria, it is considered complex. In these cases, the provisional technique is linked to an increased risk of cardiac death and MACE compared to the two-stent strategy (Chen, 2023).

Table 2. DEFINITION Criteria

Major criteria	Minor criteria
For left main distal bifurcation lesions 1. SB lesion length ≥10 mm AND 2. SB diameter stenosis ≥70%	Moderate to severe calcification Multiple lesions Bifurcation angle <45° or >70°
For non-left main distal bifurcation lesions 3. SB lesion length ≥10 mm AND 4. SB diameter stenosis ≥90%	Main vessel reference vessel diameter <2.5 mm Thrombus-containing lesions Main vessel lesion length ≥25 mm

T and small protrusion (TAP)

Different types of two-stent procedures exist with varying degrees of difficulty and recommended uses. When main vessel stenting is completed, it may be necessary to also perform stenting on side branches using techniques such as T-stenting or TAP (T with a small projection), or culotte techniques can be chosen (Fig. 13) (Burzotta et al., 2020).

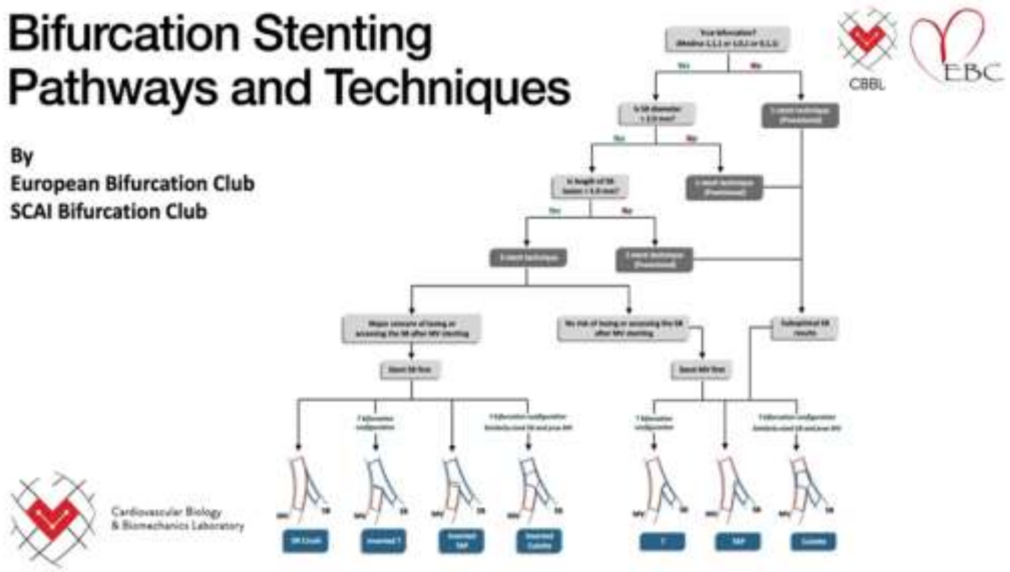

Figure 13. Flow of choosing two-stent technique in bifurcation lesion

The TAP technique offers the benefit of being able to work with 6 Fr GC, as well as providing comprehensive stent coverage for the ostium of the side branch (Burzotta et al., 2015), it can be applied to bifurcation lesions with angles between 70°–90°. Furthermore, it acts as a rescue method in cases of side branch narrowing after a stent is implanted in the primary vessel (Eltelbany et al., 2024).

The stent in the side branch is deployed using a deflated balloon within the main vessel close to the opening of the side branch to minimize its effect on the primary artery (Fig. 14). Kissing balloon inflation (KBI) is carried out immediately following the placement of the stent in the side branch, utilizing both the balloon from the stent and the balloon from the main vessel implanted earlier. A notable consideration with the TAP technique is the formation of a "neo-carina," formed when the stent struts from the side branch extend into the primary vessel at the point where it divides (Burzotta et al., 2015).

While performing the TAP procedure, the operator needs to make sure that the stent in the side branch only slightly sticks out into the main vessel, as this can affect the length of the neocarina. The length of the neocarina is partially dictated by the take-off angle of the side branch. In case the side branch features a take-off in the shape of the letter "T," the stent must fully cover the ostium of the side branch, a small side branch stent protrution is required. At a sharp side branch take-off angle (Y shape), the side branch ostium is longer and oval in shape, thus requiring a wider side branch stent protrution in the MV, which results in a longer neocarina. Rerouting the side branch by passing through the end of the stent in the main artery allows for this procedure to take place (GW in the main vessel is directed slightly distal to the carina and then retracted slightly and directed to the side branch), followed by KBI (Burzotta et al., 2015).

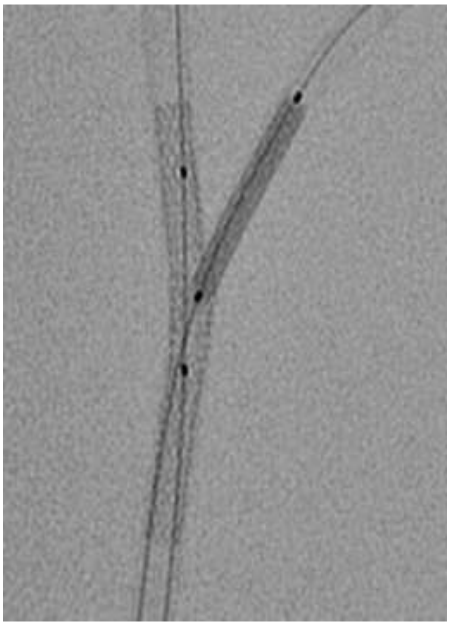

Figure 14. The side branch stent is carefully placed with minimal extension into the main vessel, and an uninflated balloon is positioned in the main vessel across the side branch take-off

Kissing Balloon Inflation (KBI)

In the two-stent strategy, IBC must be performed to produce good clinical outcomes (Burzotta et al., 2021). To prevent carinal shift during the KBI procedure, the balloon used in the main vessel must have a diameter equal to that of the distal main vessel (Murasato et al., 2015).

Proximal Optimization Technique (POT)

The extension of the main vessel induced by the IBC procedure causes a non-circumferential proximal diameter. This occurs due to the overlap of the balloon diameter used during KBI can exceed the reference diameter of the main blood vessel (Mitsudo Formula) (Fig. 15), which can increase the risk of stent malposition proximal to the main blood vessel (Murasato et al., 2015). To prevent these complications, it is very important to perform POT on the main blood vessel after KBI (Burzotta et al., 2024).

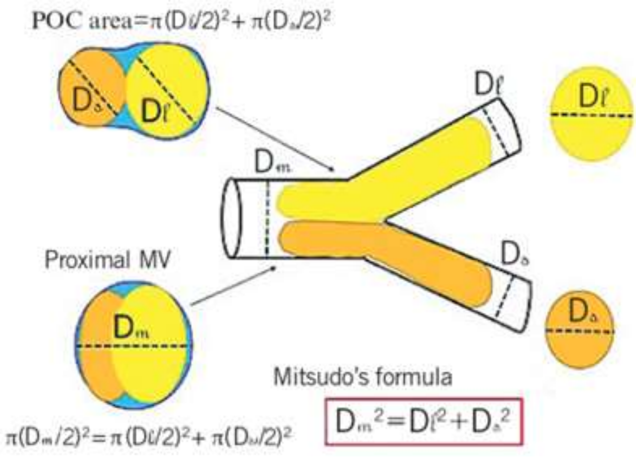

Figure 15. Mitsudo Formula

Intracoronary imaging in PPCI acute coronary syndrome

Optical coherence tomography (OCT) and intravascular ultrasound (IVUS) are used as imaging techniques within the coronary artery to examine and address cases of acute coronary syndrome (ACS). This modality provides better visualization of the plaque compared to traditional coronary angiography, allowing for more precise diagnosis and intervention strategies (Petrossian et al., 2022). The American College of Cardiology/American Heart Association (2021) guidelines endorse intracoronary imaging as a tool for procedural guidance, especially for complex coronary stent placement (Lawton et al., 2022). However, the use of intracoronary imaging remains low, especially in STEMI patients, possibly due to factors such as operator experience and concerns about procedural delay (Karamasis et al., 2023; Zaman et al., 2023).

Current consensus highlights the crucial role of intracoronary imaging in detecting lesions, elucidating the mechanisms of ACS, and informing management strategies (Karamasis et al., 2023). This imaging technique not only helps in recognizing plaque composition but also informs stent selection and optimization during PCI (Karamasis et al., 2023; Petrossian et al., 2022). Findings from multiple randomized controlled trials (RCTs) confirm that PCI guided by intracoronary imaging helps decrease MACE (Karamasis et al., 2023). However, the lack of data specifically addressing the STEMI population has limited the use of intracoronary imaging in PPCI. The European Society of Cardiology's 2023 guidelines reinforce the role of intracoronary imaging in optimizing PCI outcomes for ACS, but they do not specifically explain the use of OCT and IVUS in STEMI and NSTEMI (Byrne et al., 2024).

4. Conclusion

In ACS patients, PPCI for LM bifurcation is particularly challenging due to the heightened risk of restenosis and stent thrombosis. However, PPCI at the LM bifurcation can be safely and effectively performed when executed by a skilled operator following a well-defined strategy. Careful procedural planning, optimal stent selection, and meticulous technique are crucial to minimizing complications and ensuring the best possible outcomes.

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