__Original Research Article__

The Role of Intracoronary Imaging in Bifurcation Percutaneous Coronary Intervention

Abstract

In the most recent recommendations of the European Society of Cardiology and European Association of Cardio-Thoracic Surgery, both Optical Coherence Tomography (OCT) and Intravascular ultrasound (IVUS) are classified as class IIa for procedural optimization. In a comparison of OCT and IVUS measurement in the phantom model, OCT data corresponded to the real lumen area of the model, but IVUS readings were inflated and less repeatable.

Keywords: Optical Coherence Tomography, Intravascular ultrasound, Intracoronary Imaging, Coronary Bifurcation, Percutaneous Coronary Intervention

Introduction

Defining coronary bifurcation

Coronary bifurcation (CB) comprised of three distinctive parts: the proximal main artery (containing the bifurcation carina), the distal main vessel (MV), and the side branch (SB). The bifurcation carina (or MV- SB "transition zone") is regarded as the center of CB structure and is proximally limited by the area where the MV and SB meet, and distally limited by the area where the two distal branches begin.

There is an underlying functional/anatomical link between each coronary tree. The function ensures a uniform delivery of oxygenated blood throughout the myocardial space in accordance with its requirements.[2] The construction of corona trees is based on the principle of minimal cost of energy. A distributing epicardial part and a delivering intra-myocardial part compose them. The latter is distinguished by an increase in bifurcations. In the distributive component, mean blood flow velocity and the sum of all blood vessels remain unchanged. As one moves further downstream, the total vascular surface expands, and the flow velocity slows, creating a conducive environment for capillary exchange. The velocity of instantaneous flow of blood is greatest during diastole and modest or even reversed during systole. The CBs in the arteries of the heart's epicardium follow a pattern that is consistent with the fractal and the self-similarity principle.[3]

According to Murray's rule, the cardiac tree has recursive asymmetric bifurcations: $(\text{Diameter proximal main})^{3} = (\text{Diameter distal main})^{3} + (\text{Diameter side branch})^{3}$.[4] Regarding the law's exponent, which is now known to be 2.3 for human coronary arteries, modifications were made.[5] Intravascular ultrasound (IVUS) validation in normal human coronary arteries shows that Finet's approach is far less complicated and may be utilised in routine clinical settings: $(\text{Diameter proximal main}) = (\text{Diameter distal main} + \text{Diameter side branch}) \times 0.678$

These formulas are equivalent to the continuity formula applied to flow. Therefore, a CB isn't separated into an MV and an SB; it comprises of three parts, each with a specific diameter (proximal MV; distal MV; and SB) (proximal MV; distal MV; and SB). Also, the diameter of a coronary artery is constant between two bifurcations, rather than decreasing linearly from proximal to distal.

Multiple uses exist for this anatomical/functional structure. The distal MV segment is the longest and/or largest segment according to the diameter-to-length ratio. There are linear correlations between the flow of the corona and diameter, diameter and distal length, length/flow and diameter, and length/flow and perfused myocardial mass. [2, 5, 6]

Flow in coronary bifurcations:

In straight, non-bifurcated segments, intracoronary flow is laminar. It produces frictional force, called wall shear stress (WSS), on the vessel wall.[7] A low WSS is a well-established and widely acknowledged proatherogenic factor.[8] Weak WSS is the result of slow, turbulent, or reversed flow, especially in the vicinity of bifurcations, along the inner wall of a curve, or behind an obstruction (atheroma plaque, stent, etc.). In bifurcations, the flow is high and laminar at the carina, but turbulent and recirculating on the arterial wall facing the flow divider.

Pathology of coronary bifurcation lesions

A bifurcation is characterised by a transition from high, laminar flow at the carina to turbulent, recirculating flow on the arterial wall opposite the flow separator.[9, 10] Anatomopathological and IVUS studies have shown repeatedly that atheroma is more common in bifurcations. For example, atheroma develops on the artery wall opposite the flow divider.[11, 12] However, the atheroma forms because of the disturbance in blood flow caused by the plaque's anterograde and circling extension of the original plaque.[13] Several IVUS studies have shown evidence of atheroma at the flow divider in as much as 30% of cases, and this may be the possible root cause.[14] After therapy has effectively restored the bifurcation to its pre-treatment anatomical form, neointimal proliferation occurs at the location of the original plaque, resulting in in-stent restenosis [15]

Histopathological studies revealed that larger accumulations of elastic tissue were observed around the SB-ostium compared to other places in the coronary tree, which may explain the high incidence of elastic recoil and spasms at this point.[15]

In general, each CB has a distinct anatomy characterised by (a) connection between the proximal and distal ends in a conical form.; (b) segment-specific differences in vessel sizes, such as a greater proximal MV reference diameter and lower distal branch reference diameters.; (c) negative remodelling at the SB ostium; (d) proximal to distal vessel diameter thinning; and (e) Atherosclerosis's irregular geometric scattering.[15]

Role of imaging

IVUS-guided percutaneous coronary intervention (PCI) for bifurcation lesions.

Pre-intervention IVUS may aid in the correct selection of the bifurcation PCI procedure by analyzing the plaque morphology and distribution at the SB ostium. Recent propensity-matched study of patients undergoing PCI of non-LM bifurcations with DES using mostly a single-stent procedure found that IVUS-guided PCI (n = 487) was associated with bigger post-stent lumen widths in both the MV and SB (n 487).[16] Significantly, IVUS guidance was linked with lower mortality or MI rates than angiography advice (3.8% versus 7.0%, p = 0.03). Pre-intervention IVUS of the SB ostium may also be useful for predicting the likelihood of SB impairment when a single stent is implanted in the main branch due to plaque and/or carina shift.[17]

Kang et al. analysed 90 bifurcation lesions and found that a pre-intervention minimal lumen area (MLA) of 2.4 mm^2 in the SB reliably predicted a nonischemic post-intervention fractional flow reserve (FFR) of 0.80 in the SB (predictive value of 98%) following main branch stent implantation. MLA 2.4 mm^2 was unable to properly predict SB compromise leading to an ischemic FFR (predictive value of 40%).

Currently, IVUS guidance is recommended for drug-eluting stent (DES)-based PCI of bifurcation lesions. If the SB MLA before intervention is 2,4 mm^2, provisional SB PCI is often postponed. Nevertheless, if the SB MLA is 2,4 mm^2, clinical judgement and/or SB FFR must be used to guide interim SB action.

Optical Coherence Tomography (OCT)-guided PCI for bifurcation lesions

Since the debut of frequency domain-OCT, it has been utilized increasingly often in PCI guiding because to the creation of high-resolution pictures, rapid pullback, and user-friendliness. In the most recent recommendations of the European Society of Cardiology and European Association of Cardio-Thoracic Surgery, both OCT and IVUS are classified as class IIa for procedural optimization.

In a comparison of OCT and IVUS measurement in the phantom model, OCT data corresponded to the real lumen area of the model, but IVUS readings were inflated and less repeatable.[18] Consequently, factors such as stent length, landing zone, balloon size, and the requirement for distal protection may be used to determine the ideal stent parameters. [19] For example, OCT can more precisely identify plaque components such as lipid-rich or calcified plaque, allowing us to avoid placing stents in susceptible plaque areas. [20] Additionally, a modern angio-coregistration system that displays the position of the OCT camera on the coronary angiography is useful for determining the stent landing zone and minimizing geographic miss. Previous bench investigations shown that guidewire (GW) repeated crossing to the distal cell next to the carina resulted in a large SB opening with reduced mal-apposition following KBI, whereas the projection of the confined struts into the MV was a result of GW's recurrent crossing to the more proximal cell.[21]

Precise assessment of optimal GW recrossing is aided by clear imaging of the GW and stent strut in the 3-dimensional (3D) OCT image, which in turn significantly reduces stent malposition. (9.5% vs.42.3% in the angiography-guided group, p>0.001). In 33-50% of cases, initial angiography guidance for recrossing to the optimal GW cell failed. whereas OCT guidance boosted the success rate to 95%. The 3D-OCT bifurcation registry showed that 3D-OCT guidance improved distal GW recrossing compared to traditional 2D-OCT guidance with no necessarily increase in contrast dye volume or surgical time. [22]

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