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Review – *Special issue: Novel methods in interventional cardiology and cardiac surgery*

Percutaneous coronary interventions in bifurcation lesions: From theory to practical approach

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ABSTRACT

Coronary bifurcation lesions including unprotected distal left main stenosis remains challenging for percutaneous coronary interventions. This review will summarize the classification, histopathology and physiology of bifurcation lesions, as well as lessons learned from bench testing, different stenting strategies and two stent techniques including dedidated bifurcation devices.

Due to the variety of anatomical configurations the Medina classification of bifurcation lesions is widely accepted. Lessons from histopathology reveals location of the atherosclerotic plaques most frequently in the lateral walls of both main vessel and side branches in the areas of low shear stress with turbulent flow. The diameter of the mother vessel is the sum of the daughter vessel diameters (distal main plus side) multiplied by 0.68 ($Dm=0.678\times/D1+D2/$). In vitro bench testing of bifurcation stenting allows visualization of stent deformations and lumen reductions after deployment of one or two stents. The role of final kissing inflation, proximal optimization technique, one or two stent strategy and different two-stent techniques are addressed (provisional T-stenting, TAP, crush, culotte, SKS, V-stenting). The role of imaging techniques is emphasized (IVUS, FFR and OCT) especially for the distal LMCA bifurcation lesions requiring the use of more advanced devices and specialized techniques as well as adjunctive pharmacologic agents.

Dedicated bifurcation devices and their potential indications are described. Practical tips and recommendations based on the European Bifurcation Club consensus are presented.

Contents

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1. Introduction

Percutaneous coronary intervention (PCI) is widely accepted method of myocardial revascularization, life-saving in acute myocardial infarction with ST segment elevation (STEMI), superior to medical treatment in acute coronary syndromes (ACS) and concurrent to coronary artery bypass graft surgery (CABG) in many stable patients. With increasing complexity of coronary artery disease long term results of PCI decline due to cummulative risk of restenosis, while CABG results are not affected by lesion complexity itself. Drug eluting stents led to dramatical decrease in restenosis within first year after the procedure, but some situations remains challenging for catheter treatment, namely bifurcation lesions, left main lesions and chronic total occlusions.

2. Definition of bifurcation

Anatomical definition: bifurcation lesion is a lesion occurring at, or adjacent to, a significant division of a major epicardial coronary artery. Simple description of bifurcation lesion is difficult due to the variety of anatomical configurations, sizes of the main vessel (MV) and side branch/es (SB), stenosis location and severity, presence of calcifications, angles between main branch and side branch/es. The main vessel is the largest and/or the longest vessel. Definition of significant side branch is related to the volume of vascularized myocardium or vessel diameter (in most cases 2.25 mm and bigger), while functional definition is related to the potential consequences of SB occlusion in the global context of a particular patient (symptoms, viability, collaterals, left ventricular function, etc.). The only classification which indicates the position of lesions and is easy to use in everyday life is the Medina classification [1]. It is comprised of three numbers and two commas. The first number represents the proximal main vessel segment, the middle number is the distal main vessel segment and the third number represents the SB. “1” accounts for the presence and “0” for the absence of >50% stenosis. This classification was accepted by the general consensus from the second meeting of the European Bifurcation Club.

2.1. *Pathology and physiology*

Pathologic examination of coronary arteries and intravascular ultrasound studies reveals that location of the atherosclerotic plaques most frequently occurs in the lateral walls of both main vessel and side branches, while it is uncommon in the carina region [2].

Endothelial shear stress (ESS) is the tangential force exerted on the endothelial surface which results from the friction of the flowing blood. The pattern of fluid flow depends on the flow velocity and the presence of irregularities or obstructions. Flow is either laminar or turbulent. In a straight segment flow is laminar and undisturbed, and pulsatile ESS is varying between 15 and 70 dyne/cm^2 over the cardiac cycle. In irregular regions, like bifurcations, disturbed laminar flow (with areas of flow separation and recirculation) generate low and/or oscillatory ESS (<10–12 dyne/cm^2). Low ESS typically occurs at the inner areas of curvatures and upstream of stenoses. Oscillatory ESS occurs primarily downstream of stenoses, at the lateral walls of bifurcations and in the vicinity of branch points. The wide angulation of the side branch take-off intensifies flow perturbations, increases the spatial ESS variations and low ESS in the lateral wall, thereby augmenting the atherogenesis. The ESS variations are augmented by pulsatile flow, which generates an oscillatory ESS and constitutes a proatherogenic factor. High heart rate prolongs the exposure of the coronary endothelium to the impaired systolic flow conditions of low and/or oscillatory ESS [3]. Regions exposed to the non-uniform and low shear stresses develops early atherosclerotic lesions (areas of minimum shear stress are mainly along the inner side of the curved coronary arteries) while areas exposed to uniform shear stresses (flow dividers) are usually, but not always, protected. Atherosclerotic plaque usually develops opposite of the side branch and the same mechanism stimulate intimal hyperplasia and in-stent restenosis following stent implantation. Thus, high restenosis rates are expected with bare metal stents, which could be offset by drug eluting stent placement.

Although there is a correlation between the stenosis severity of the side branch (SB) and its physiological significance following stent implantation in the main vessel (MV), Koo has shown that about 70% of ostial SB lesions following MV stenting are not functionally significant. In this study [4], no lesion with <75% SB stenosis by QCA had a fractional flow