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Original Article

Dedicated bifurcation stents – Mechanistic, hardware, and technical aspects

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ABSTRACT

Aim: Percutaneous coronary intervention (PCI) in bifurcation lesions is associated with lower success rate, higher acute complication rates and higher event rates in follow-up.
Methods: The reason for this higher than usual complication rate relates to the relationship between anatomy, flow, and atheroma distribution in bifurcation lesions.
Results: Further, stenting these lesions can be a prolonged procedure and can be technically more demanding. The most common complication is the loss of significant side branch (SB). Main vessel (MV) stenting may enhance the carina displacement and atheroma shift across the SB ostium leading to SB ostium narrowing.
Conclusion: Finally, complications, if they occur, are more difficult to manage. Dedicated bifurcation stent has been developed to overcome the number of limitations associated with conventional bifurcation PCI. The main advantage of most dedicated bifurcation stents is to allow the operator to perform the procedure on a bifurcation lesion without the need to rewire the SB.

1. How bifurcation lesion is mechanistically different from other lesions?

Blood flow through a bifurcation vessel is governed by the ramification law of the epicardial coronary tree which simply means that there is a good correlation between side branch (SB) diameter and length and the mass supplied by this vessel. Thus, longer and larger diameter vessels have more blood flowing through them.[2]

Three diameters rule: The size of a vessel (as also the flow through it) is dictated by the three-diameter rule which states that the relation between true size of the main branch (MV) and distal main branch (DMV) and SB can be dictated by scaling laws like *Murrays's Law* ($\{MV\}^3 = \{DMV\}^3 + \{SB\}$,[3] or simplistically by Law of Finet which states that size of MV is 2/3rd of sum of both the distal branches (MV = 0.678{DMV + SB})[1,2] (Fig. 1).

Atheroma distribution and thrombus formation in bifurcation lesion: The atheroma distribution in bifurcation situation is also different from non-bifurcation areas. Physiologically atheroma is distributed in the areas of: (a) low endothelial shear stress (inner areas of curvatures, upstream of stenosis) and (b) oscillatory endothelial shear stress (lateral wall of bifurcation, downstream of stenosis, irregular arterial regions, branch points: plaques are located opposite the SB take-off and are more concentric proximal to the SB and more eccentric just distal to side-branch). The plaques are also influenced by the angle of SB take-off, it being deposited preferentially toward acute angle (toward an inner radius of curvature) and away from obtuse angle. Atheroma is less common in the region of

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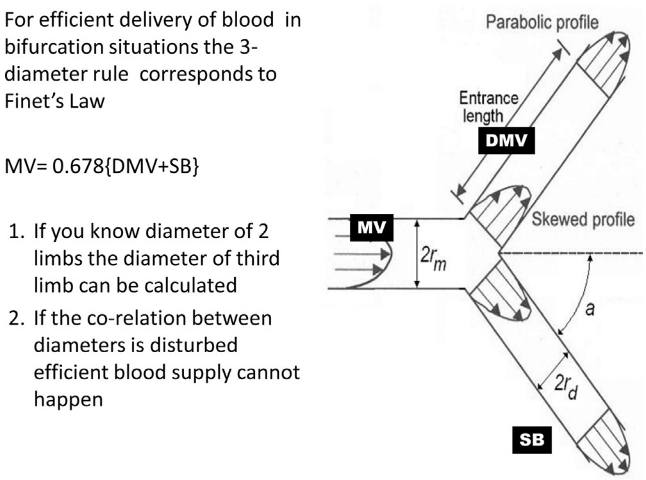

Fig. 1 – Finet's Law.

carina but more common when there is wide bifurcation angle, increased ratio of SB dimension in relation to main branch, or increased bifurcation tortuosity (Fig. 2). On the other hand, late stent thrombosis (ST) is more common in the areas of high shear stress where less re-endothelisation occurs such as carina.

As a consequence of all these mechanistic differences, the outcomes of percutaneous coronary intervention (PCI) in these subset of patients may be much different than non-bifurcated lesions.

1.1. *Correlates of clinical outcomes in bifurcation lesions*

1. Final angiographic result in main vessel (MV): this is generally the single most important predictor of the clinical outcome. Thus, many 2-stent strategies which lead to a high metal mass at carina (which actually requires least scaffolding because carina is the flow divider with high shear stress and therefore generally free of plaques), as also alter the flow dynamics but also go against the 3-diameter rule. That is why most studies demonstrate that irrespective of type of stents used and in all types of lesion classifications (except for Medina 0, 0, 1, i.e. isolated SB stenosis or those lesions with diffuse involvement of the SB), a single stent strategy is nearly always better than a 2-stent strategy.[3] The superiority lies in lower peri-procedural MI and possibly lower MACE, restenosis and ST rates as also in lower procedural time, contrast volume and radiation exposure with provisional SB stenting strategy. The 2-stent strategy is especially associated with a worse outcome if bifurcation angle is $>50^\circ$.
2. Result in the ostium of SB while not co-relative of major events is still responsible for minor events. Thus, when SB is important and diffusely diseased, it does increase requirement of re-intervention. Further, in some cases with a single stent strategy, the SB may be irretrievably lost. In those cases 2-stent strategy, which provides definitive scaffolding of SB ostium may be useful.

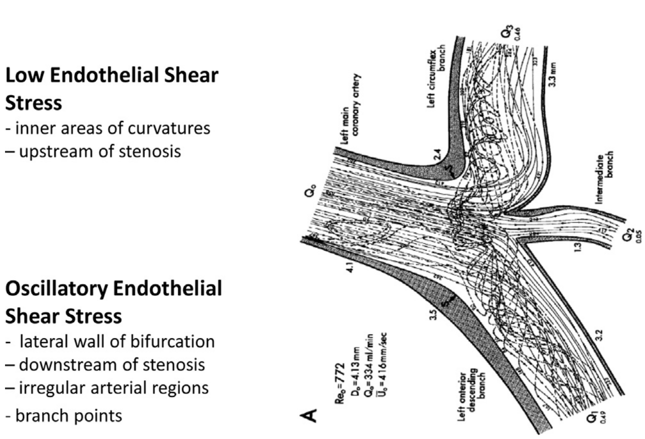

Fig. 2 – Atheroma distribution in bifurcation lesion.

1.2. *When to use 2 stent strategies?*

The major limitation of a single stent strategy is an inability to provide enough scaffolding to the ostium of the SB, which can lead to higher restenosis rate and higher need for target lesion revascularization (TLR). Therefore, in those cases, where SB is very important and likely to get compromised with 1-stent only strategy, a 2-stent strategy may be required initially ($\approx$10% of cases). Possible situations where a 2-stent strategy can be recommended to begin with are:

1. SB is large in diameter (>2.5 mm) and territory of distribution and there is a risk of hemodynamic deterioration, if SB is lost (poor LVEF, distal left main).
2. SB has severe disease (>50%) that extends beyond the ostium (10–20 mm or more).
3. Have an unfavorable angle (narrow angle A: the angle between proximal MV and SB) for re-crossing after MV stent implantation.N.B. Remember that when angle A is narrow ($<120^\circ$), insertion of guidewire increases the angle by an average of 33°.

1.3. *How to choose 2 stent strategies?*

1. Strategies with minimal metal overlap of 2 stents are the best: Mini-crush is better than classical crush because metal overlap is less, residual metallic stenosis at ostium is less, and there is a better scaffolding of ostium. The long-term re-endothelization is also better, which may translate into lower restenosis and late ST (most serious limitations of classical crush). T stenting with minimal protrusion (TAP) is better than classical T stenting, because there are fewer gaps in ostial coverage (better scaffolding) leading to lower restenosis.
2. If angle between the distal MV and SB (Angle B) is wide, a T stenting type of strategy like TAP technique may be preferable.
3. If angle between the distal MV and SB is narrow ($<50^\circ$), a V type of strategy like Culottes or Mini Crush may be preferable.
4. Culottes technique may be superior to classical crush technique because of lesser risk of SB restenosis and can be

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