Numerical simulations of coronary bifurcation stenting for the assessment of side branch compromise

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Introduction

The treatment of **coronary bifurcation lesions** remains a challenge for interventional cardiologists due to technical difficulties and associated high event rates [1]. Nowadays, the **provisional side branch (PSB) stenting technique**, which involves stent deployment in the main branch (MB), is the routine procedure to treat bifurcation lesions [1].

A major procedural complication of PSB is the **side branch (SB) compromise** (Fig. 1), which is induced by **the plaque/carina shift** towards the SB after stent implantation [2]. The exact contribution of bifurcation and lesion characteristics to SB compromise has not been fully clarified and the results are contradictory. The aim of this study is to investigate the **impact of plaque composition and distal angle** on SB compromise using a virtual implantation environment.

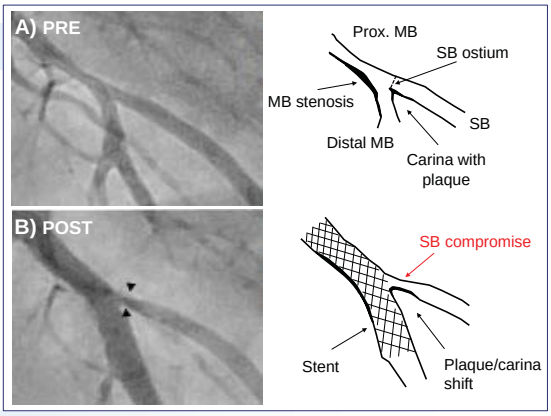

Fig. 1 - SB compromise after PSB stenting. A) Pre-operative and B) post-operative angiographic views of a patient with lesions at the proximal MB and at the bifurcation carina, who was treated with a single stent in the MB. SB ostium narrowing is clearly visible after stenting (black arrows).

Methods

A parametric model of a **diseased left anterior descending (LAD) coronary bifurcation** was created with a stenosis of 60% in each branch. Realistic diameters, plaque burden, and curvature values were included. Material properties of the tissues were retrieved from *ex vivo* data. **Eight models** were generated with **two different angles** (i.e. 45° and 70°) and **four different plaque scenarios** (i.e. fully lipid, fully fibrous, lipid with a half calcified ring in the distal MB, and lipid with a full calcified ring in the distal MB – Fig. 2). A Multi-Link 8 stent (Abbott Lab., USA) was virtually implanted in all models following the PSB technique (Fig. 3). Simulations were performed using ABAQUS/Explicit (Simulia Corp., USA) with a similar procedure as described by Mortier et al. [3].

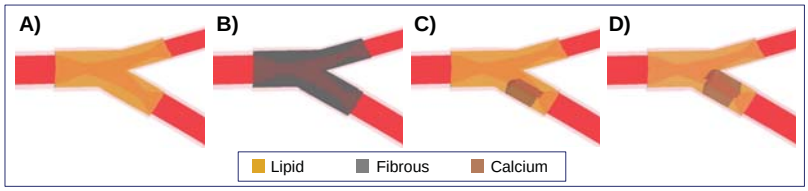

Fig. 2 - Parametric model of the diseased coronary bifurcation with four different plaque scenarios: A) fully lipid; B) fully fibrous; C) lipid with a 4 mm long half-calcified ring distal to the carina; D) lipid with a 4 mm long calcified ring distal to the carina, wrapping the distal MB.

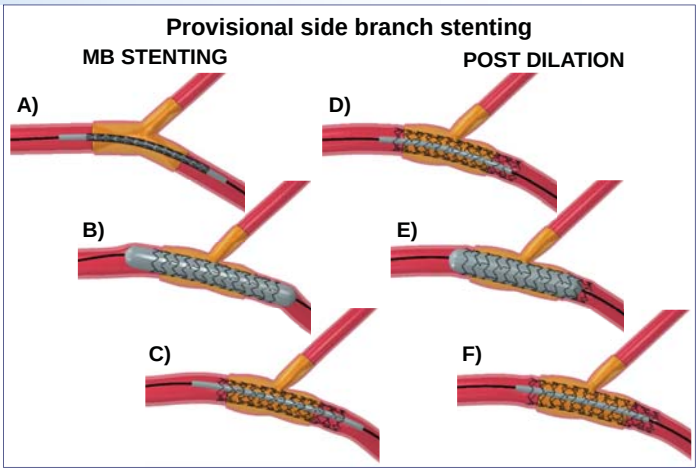

Fig. 3 - Provisional side branch stenting technique in the 70° bifurcation model with fully lipid plaque: (left panels) MB stenting followed by (right panels) post-dilation. Each step consists of (A, D) balloon positioning, (B, E) expansion, and (C, F) release.

Results and Discussion

The main impact of the PSB procedure is an ovalization of the SB ostium (Fig. 4A) that might appear as a significant stenosis in 2D angiography, without causing a marked reduction of the SB ostium area in all cases, except those with calcified plaque. Lumen ovalization was confirmed by a significant increase in ellipticity (101.9±73.1%, $p<0.05$). Ovalization was even more evident in the presence of calcifications, which showed the highest increase of ellipticity (164.4±17.3%). SB compromise, assessed as changes in SB lumen volume [2], was negligible for cases with fully lipid and fibrous plaques while it became severe in presence of calcifications (Fig. 4B). The distal angle did not influence SB compromise except for the cases with fully calcified ring.

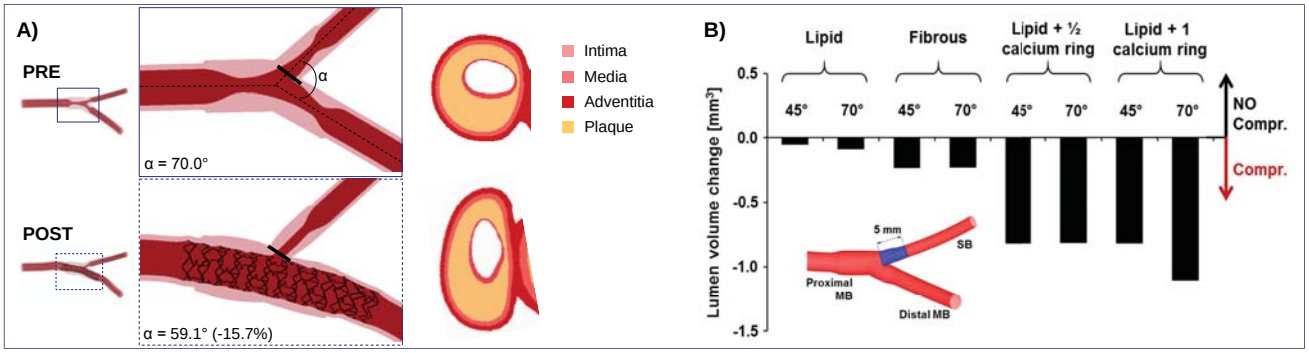

Fig. 4 – A) Pre- and post-procedural first cross-section of the 70° bifurcation model with lipid plaque. B) SB compromise after PSB stenting. Negative volume change is indicative of SB narrowing. The SB segment for the lumen volume calculation is indicated in blue in the bifurcation schematic.

Conclusion

The 3D numerical strategy here presented can help to understand the mechanisms of coronary bifurcation stenting in a reproducible environment and provides information that can be missed based on conventional angiography. The results showed geometrical changes of the SB ostium because of PSB stenting. The most important finding was the ovalization of the SB ostium, generally without significant lumen compromise. PSB stenting in the presence of calcifications resulted in a more severe outcome for the SB ostium.

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References:
[1] Lassen, JF et al. EuroIntervention, 10:545-560, 2014. [2] Xu JY et al. Circ Cardiovasc Interv, 5: 657-662, 2012. [3] Mortier, P et al. JACC Cardiovas Interv, 7:325-333, 2014.