Effect of bifurcation angle on the functional impact of coronary bifurcation lesions

Catherine Pagiatakis*1,2, Jean-Claude Tardif2, and Rosaire Mongrain1,2

Introduction. Myocardial ischemia is induced when blood flow is critically reduced as a result of a stenosis. The treatment of bifurcation lesions is associated with high peri- and post-procedural clinical events; overall, their dynamics and functional impact are complex and still not well understood. The objective was to study different bifurcation lesion topologies in a geometric multiscale (MS) framework so as to investigate the effect of bifurcation angle on their functional impact.

Methods. Four multilesional planar, 3D synthetic lesion topologies (41-68% diameter reduction) within the bifurcation of the left main coronary artery (LMCA) into the left anterior descending artery (LAD) and the left circumflex artery (LCX) were used. More specifically, based on the Medina classification, the (0,1,1), (1,0,1), (1,1,0) and (1,1,1) configurations were modelled. The LAD-LMCA and LCX-LMCA angles were varied between 0°-20° and 50°-73° respectively. The 3D geometries were coupled to a closed-loop, electrical analog lumped-parameter model (LPM) of the heart, systemic and pulmonary circulations and the downstream myocardium, in order to account for the global dynamics of the entire cardiovascular system. Transient, incompressible and Newtonian blood flow simulations (at maximum hyperaemia) were executed for the 3D geometries using the commercial software package ANSYS Fluent (Canonsburg, PA, USA). A partitioned, geometric MS approach was utilized to couple the 3D model to the LPM.

Results. The use of the geometric MS modelling algorithm allowed for accurate pressure and flow fields to be obtained for each case. It enabled the calculation of the flow-derived fractional flow reserve (FFR), defined as the ratio of the diseased to normal flow, which elucidated the functional impact of each lesion configuration based on topology, stenosis severity and bifurcation angle. The main finding of the study was that bifurcation angle did not have a significant effect on the functionality of the different configurations. Furthermore, it was found that the (1,0,1) configuration has the greatest overall flow reduction and that the (1,0,1) and (1,1,0) configurations, which showed significant differences in their dynamics, generated the lowest FFR values in the LCX and LAD respectively.

Discussion. The results of the study have important clinical implications. The fact that bifurcation angle does not influence the FFR is significant because the bifurcation angle affects the difficulty of the procedure (type of stent and corresponding technique). As such, unnecessary high-risk procedures could be avoided. Furthermore, due to the fact that the (1,0,1) and (1,1,0) configurations, and not the (1,1,1) topology induced the greatest flow reductions, it was made clear that coronary branch steal plays a significant role in the functionality of these types of lesions. Through the differences in the dynamics of the aforementioned configurations, it was clear that the branch steal phenomenon is complex and could even present the possibility of false negatives in diagnosis. Overall, the complexity of these configurations is evident and thus warrants further investigation.

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Department of Mechanical Engineering1, McGill University, Montreal Heart Institute2