A NOVEL APPROACH TO PATIENT-SPECIFIC HEXAHEDRAL MESHING : HEXAHEDRAL VS TETRAHEDRAL MESH REQUIREMENTS IN CORONARY CFD

De Santis G. , Mortier P. , De Beule M. , Segers P. , Verdonck P. , Verhegghe B.

bioMMeda, IBiTech, Ghent University, Gent, Belgium, gianluca.desantis@ugent.be

Introduction

Patient-specific simulations require generation of computational meshes reproducing the patient-specific geometry. Because of complex geometry (curved, stenosed and bifurcating vessels) most of the computational investigation has been carried out using automatic meshing tools which often provide a sub-optimal discretization [1]. pyFormex, which is an open-source software for generating and/or manipulating large geometrical models of 3D structures by script-based sequences of mathematical transformations, offers useful tools for fast and parametric structured mesh generation and has been tested for flow simulation in a left coronary artery geometry acquired by bi-plane angiography.

Materials and methods

The coronary artery 3D reconstruction consisted of a series of circles representing the vessel cross sections. This complex geometry was first partitioned into bifurcations and straight vessels and then reconstructed using Bezier splines in order to approximate the lumen surface (Fig. 1).

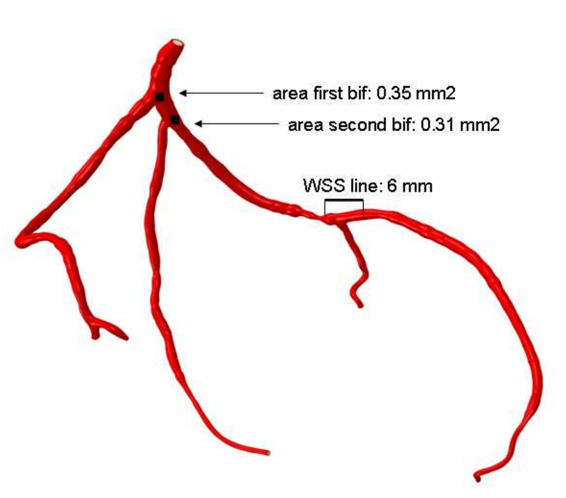

Fig. 1: left coronary tree

Separately, two parallelepipeds have been parametrically meshed and used as mapping-blocks for a cubic iso-parametric transformation. As a result, a structured conformal hexahedral mesh has been obtained for the whole left coronary artery and was imported into Fluent for steady state blood flow simulation. A series of structured meshes (HEX) has been generated and compared to a series of unstructured tetrahedral meshes with a prismatic boundary layer (TET) generated with Gambit. Grid-sensitivity analysis has performed on the HEX and TET (50,000 to 3,000,000 cells), in order to evaluate the number of cells required to reach grid-independent wall shear stress (WSS).

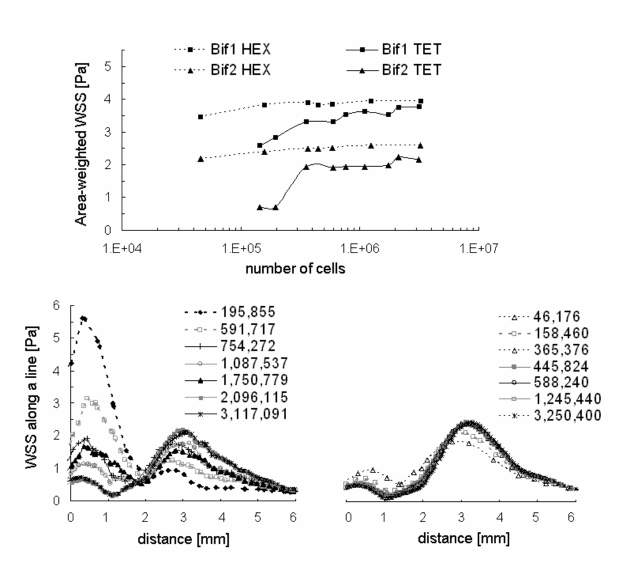

Fig. 2: WSS values for TET and HEX series

Results and discussion

Area-weighted-WSS values on two bifurcations (indicated in Fig. 1) show that the HEX series converges faster than the TET series (Fig. 2 top panel). Stronger difference has been found on the local hemodynamics, evaluated by measuring the WSS along a line as indicated in Fig. 1. The WSS predicted with TET meshes up to 1,000,000 cells is quantitatively but also qualitatively wrong (Fig. 2, bottom panel). The minimum number of cells needed to reach grid–independent WSS values (relative difference relative to the finest mesh < 5 %) were 300,000 and 2,000,000 for the HEX and the TET series respectively, requiring 14-fold longer CPU time for the TET series on the same computing infrastructure.

Conclusion

Hexahedral meshes provides more accurate WSS values with a lower number of cells, therefore saving computational resources and time, and should be preferred to unstructured meshes.

References

[1] Prakash S., Ethier C.R. (2001)., J Biomech Eng 123:134-44
[2] http://pyformex.org