Fluid–Structure Interaction Analysis of Human Coronary Arteries with Cardiac-Induced Motion

Ryo Torii*, Kenji Takizawa†, Takafumi Sasaki† and Tayfun E. Tezduyar‡

* Department of Mechanical Engineering, University College London
Torrington Place, London WC1E 7JE, UK
Email: r.torii@ucl.ac.uk

† Department of Modern Mechanical Engineering, Waseda University, Tokyo 169-8050, Japan
Email: Kenji.Takizawa@tafsm.org, Website: http://www.jp.tafsm.org/en/

‡ Mechanical Engineering, Rice University, Houston, TX 77005, USA
Email: tezduyar@tafsm.org, Website: http://www.tafsm.org/~tezduyar/

ABSTRACT

Coronary blood flow is subjected to substantial cardiac-induced wall motion in addition to the interaction between the blood flow and compliant arterial wall. Despite recent developments in medical imaging, due to its size and motion, it is still difficult to image detailed cross-sectional deformation of the coronary artery [1]. In this study, aiming to investigate biomechanical factors contributing to coronary atherosclerosis, we examine the effects of coronary-artery deformation on the heamodynamics. We do that by an approach that integrates cardiac CT and computational fluid–structure interaction (FSI). Pulsatile flow in 3D moving vascular models of coronary arteries is computed with the Space–Time Variational Multiscale (ST-VMS) method [2]. Displacement for part of the arterial wall is prescribed (on lumenal surface), with the displacement estimated from cine-CT images. Displacement for the other parts of the wall is determined through the interaction with the blood flow. The structural mechanics model of the arterial wall includes the estimated element-based zero-stress state [3-5]. Representative pulsatile flow and pressure waveforms are specified at the inlet and outlet. The 3D flow fields computed with and without the wall motion are compared to determine the effect of the wall motion on haemodynamics parameters. We previously reported that cardiac-induced wall motion enhances oscillatory nature of the flow, which is primarily caused by the pulsatile inflow [1]. The combined effect of FSI accounting for wall compliance and cardiac-induced motion is currently being investigated and our findings will be included in the presentation.

REFERENCES

[1] R Torii, J. Keegan, N.B. Wood, A.W. Dowsey, A.D. Hughes, G-Z. Yang, D.N. Firmin, S.A.M. Thom, and X.Y. Xu, "MR Image-Based Geometric and Hemodynamic Investigation of the Right Coronary Artery with Dynamic Vessel Motion", *Annals of Biomedical Engineering*, **38** (2010): 2606–2620.

[2] K. Takizawa and T.E. Tezduyar, "Space–time fluid–structure interaction methods", *Mathematical Models and Methods in Applied Sciences*, **22** (2012) 1230001, doi: 10.1142/S0218202512300013

[3] K. Takizawa, H. Takagi, T.E. Tezduyar, and R. Torii, "Estimation of element-based zero-stress state for arterial FSI computations", *Computational Mechanics*, **54** (2014) 895–910, doi: 10.1007/s00466-013-0919-7.

[4] K. Takizawa, R. Torii, H. Takagi, T.E. Tezduyar, and X.Y. Xu, "Coronary arterial dynamics computation with medical-image-based time-dependent anatomical models and element-based zero-stress state estimates", *Computational Mechanics*, **54** (2014) 1047–1053, doi: 10.1007/s00466-014-1049-6.

[5] K. Takizawa, T.E. Tezduyar, and T. Sasaki, "Aorta modeling with the element-based zero-stress state and isogeometric discretization", *Computational Mechanics*, doi: 10.1007/s00466-016-1344-5, 2016.