Image-based modeling and multi-scale simulation for cardiovascular diseases

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ABSTRACT

The cardiovascular diseases such as atherosclerosis or cerebral aneurysms are caused by the degeneration of blood vessel wall, which is initiated by hemodynamic forces, particularly wall shear stress (WSS) [1]. The WSS is known as one of the mechanical forces induced by blood flow causing damages on endothelial cells. The hemodynamic simulation combined with medical images can estimate WSS as well as flow features quantitatively, in a patient-specific manner, if an appropriate initial- and boundary conditions are estimated. Especially the fluid-structure interaction simulation is very sensitive regarding those conditions. Therefore it is important to simulate the dynamics of blood flow and the blood vessel wall as well as the interaction between them.

In order to achieve a realistic in-vivo simulation, modeling of appropriate boundary conditions is a crucial issue. The aim of the present research is to develop a numerical simulation system, which considers the interaction between the blood flow and the arterial wall and the effects of the blood vessels network of the entire circulatory system. The entire circulatory system consists of 1D and 0D models [2,3] and then the results of 1D-0D simulation is applied as outflow boundary conditions to the 3D simulation of patient specific model.

The present multi-scale simulation is applied to a patient using the medical images before and after the stent surgery as a treatment for the atherosclerosis in the carotid artery. This is an on-going project with neurosurgeons. In the workshop, the preliminary results for both before and after surgery are compared to examine and discuss the present method.

REFERENCES

[1] H. J. Steiger. Pathophysiology of development and rupture of cerebral aneurysms. Acta Neurochirurgica Supplement, 8,1–57, 1990.

[2] M. S. Olufsen, C. S. Peskin, W. Y. Kim, E. M. Perdersen, A. Nadim, and J. Larsen. Numerical simulation and experimental validation of blood flow in arteries with structured-tree outflow conditions. Annals of Biomedical Engineering, 28,1281–1299, 2000.

[3] Oshima, M., Torii, R., Tokuda, S., Yamada, S., Koizumi, A., ‘’Patient-Specific Modeling and Multi-Scale Blood Simulation for Computational Hemodynamic Study on the Human Cerebrovascular System’’, to be submitted to Current Pharmaceutical Biotechnology