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Numerical Simulation of the Interaction between Blood Flow and Arterial Wall with the Peripheral Network

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The formation and growth of cerebral aneurysm depends on hemodynamic factors, particularly WSS (Wall Shear Stress) induced by blood flow[1]. The WSS is known to cause damages on endothelial cells, which leads to degeneration of blood vessels. Therefore it is important to obtain information on the location and the magnitude of local high and low shear stresses to be able to predict consequences.

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 to those conditions. The peripheral vasuclar network of cerebral artery plays an important role in determining the flow distributions and the outflow pressure in the aritrial circle of Willis. Since the small vessels in the perophera vasucular network cannot be resolved by medical images, it is necessary to develop a numerical model that predicts the effect of the peripheral network on the 3D outflow boundary.

Based on models introduced by Olufsen et al[2], the peripheral network is modeled as the binary symmetric tree attached to the outlet of the 3D model as shown in Fig.1. The small arteries are modeled using 1D model, whereas the arterioles or one smaller than 100μm down to 5 μm are modeled using 0D models using the analogy of the electirc circuit.

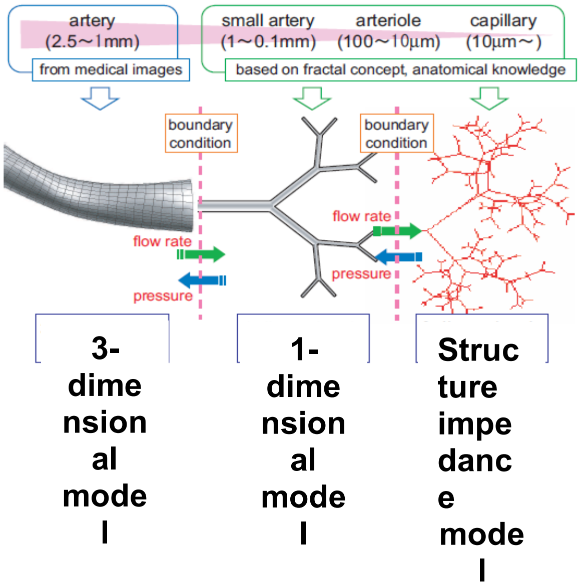

Fig.1 Schematic illustration of the multi-scale outflow boundary model.

The paper aims to develop a multi-scale model (1D -0D) for the cerebral peripheral network, and is applied as an outflow boundary condition for a 3D model for the region of interest. After the instablity at the interface between 1D and 3D models are resolved, the presnet FSI simulation is applied to a 49 year-old patient. The 3D geometry of the middle cerebral artery with the aneurysm is extracted by our in-house program as shown in Fig.2.

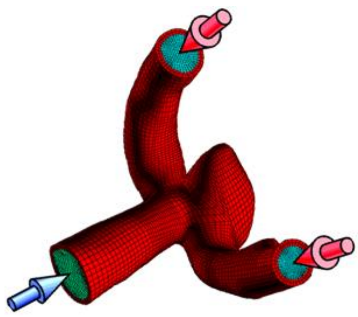

Fig.2 3D model of middle cerebral aneurysm

There are two types of the numerical instability in the inerface between 3D and 1D simulations. Thus, new numerical methods have been implemented to solve the numerical instability.

The simulations are conducted for four diffrent types to compare the effects of FSI as well as those of the pheripheral cerebral network. Since the mechanical properties of the cerebral artery tend to be stiff, the defomation is not siginificantly large. However, dispite a small deformation, there is a large difference between FSI and flow simulations. The detials will be presented at the conference.

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