脳動脈瘤内の流動不安定性と破裂の相関：流入低調波の影響

EXPLORING ASSOCIATION BETWEEN FLOW INSTABILITY AND RUPTURE IN MULTIPLE INTRACRANIAL ANEURYSMS: LOW HARMONIC INFLOW EFFECTS

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1. Introduction

Multiple intracranial aneurysms are observed in 15% to 35% of patients with aneurysms who present with SAH [1]. For SAH patients with multiple aneurysms, it is very crucial for doctors to determine the cause of SAH [2].

2. Methods

A patient was confirmed to have two aneurysms with one located in the anterior communicating artery (ACA) and the other in the basilar artery (BA). Patient-specific geometries of the cerebral aneurysm and vessels were extracted using a gradient-based level set segmentation algorithm. The reconstructed surface model was then smoothened by a Taubin filter. We included the vessel's geometric features as much as possible but added some artificially extended vessels at inlet and outlet with a length of eight diameters so as to damp out the numerical reflective waves at boundaries.

・Mesh

Unstructured grids composed of tetrahedral and prism elements were generated by ANSYS ICEM 15.0with a minimum element size of 0.035 mm and maximum element size of 0.14 mm. A total number of 0.81 ~ 1.28 million elements were used in different aneurysm models. Three prism layers were employed to resolve the near-wall regions.

・Boundary conditions

At inlet a prescribed fully developed Womersley velocity profile was imposed on the basis of a flow rate waveform [3], which has a cycle-averaged velocity of 0.5 m/s and a period of 0.75s.

・Computational fluid dynamic modeling

Blood is modeled as an incompressible and Newtonian fluid. The governing equations for the fluid are unsteady and incompressible three-dimensional Navier-Stokes equations. Transient flow simulations were performed using ANSYS CFX 15.0, which utilizes a finite volume approach to discretize in space, and a high-resolution scheme for the stabilization of the convective term.

3. Results

Both the ACA and BA models show a stable flow pattern with a single vortex in the aneurysm. The BA aneurysm experiences more significant temporal WSS fluctuations than the ACA aneurysm at the feature points under the same boundary conditions. However, there also exists a combination of high OSI and low WSS at the blebs of the ACA aneurysm and neck of the BA aneurysm, which is more significant in the ACA aneurysm. The ACA aneurysm is more likely to rupture than the BA aneurysm based on the low-WSS theory.

4. Conclusion

The present study investigated the flow instabilities and hemodynamics in multiple intracranial aneurysms. The ACA aneurysm is more likely to rupture than the BA aneurysm considering that it exhibits an obvious characteristic of high OSI and low WSS at the bleb.

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References

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