PARAMETRIC MODELING OF CEREBRAL ANEURYSMS

Zijing Zeng*†, Mike Durka†, Howard Yonas††, Akira Takahashi†††, Hasballah Zakaria††††, Anne M. Robertson†

*†Department of Mechanical Engineering and Materials Science, University of Pittsburgh, USA
E-mail: rbertson@pitt.edu
††Department of Neurosurgery, School of Medicine, University of New Mexico, USA
†††School of Medicine, Tohoku University, Japan
††††Biomedical Engineering Program, Institute Technology Bandung, Indonesia

ABSTRACT

Background and purpose:
Localized hemodynamic loads play an important role in normal homeostasis of arterial wall and in vascular diseases such as atherosclerosis and cerebral aneurysms. Patient specific 3D geometries are routinely reconstructed from clinical imaging data and widely used in biomechanical studies of these diseases. However, it is not possible to perform parametric studies using the models. Idealized arteries and aneurysms have been created and used for parametric studies, but are highly simplified. The goal of this work is to develop and validate a more realistic parametric model for intracranial aneurysms (ICA) and the surrounding vasculature. A parametric study on the influence of aneurysm aspect ratio (sac height/sac width) is used to demonstrate the value of parametric models of this kind.

Materials and Methods:
Four human cerebral aneurysm cases were selected for developing parametric models. We considered two classes of ICA: side wall and bifurcation aneurysms with aspect ratios (AR) ranging from 0.9 to 2.8. The side wall aneurysms were located at the internal carotid artery. Surface geometries were reconstructed for the aneurysm and surrounding vessels using 3D DSA data. Geometric information including vessel and aneurysm centerlines, cross sectional area and aneurysm sac centroid were measured and extracted from 3D reconstructed model. Building on our previous work for arterial bifurcations [1], a parametric model was then created for the surrounding arteries, bifurcation region and aneurysm sac. After model creation, the parametric model was validated by comparing results of CFD analyses of blood flow in the parametric and 3D reconstructed geometries. A parametric study to investigate the effects of AR on the blood flow pattern inside the aneurysm sac for sidewall aneurysms was then conducted.

Results:
The geometric error in the parametric model relative to the 3D reconstructed geometry was always less than 10% of the local cross sectional diameters. The CFD results show a good match between parametric models and 3D reconstructed models in hemodynamic features. The magnitude and distribution of time averaged wall shear stress, oscillatory shear index and velocity fields were reproduced well in the parametric models. The parametric study on sidewall aneurysms showed two dinstinct flow patterns in low and high AR aneurysms. For low AR models, only a single vortex was observed. A second, transient recirculation pattern appeared in the the dome for aneurysms with AR larger than 2.2.

Conclusion:
This parametric model can be used to create realistic idealized models for parametric study. Such models will be valuable for studies of ICA pathology and evaluation of novel treatment strategies. We anticipate their usefulness for guiding 3D reconstruction of poor quality clinical data.

Reference

[1] Zakaria, H., Robertson, A. M., and Kerber, C. W., 2008, A parametric model for studies of flow in arterial bifurcations. *Ann Biomed Eng*, **36**(9), pp. 1515-1530.