Hemodynamic Features of Cerebral Aneurysms that Influence to Rupture

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Abstract—Cerebrovascular diseases are one of the three major mortalities, such as the rupture of cerebral aneurysm. Currently, however, there is no certain quantitative method to evaluate risk of rupture. We utilized Computational fluid dynamic (CFD) technology to understand difference of hemodynamic condition between stable unruptured aneurysms and those that ruptured during the observation that followed. The hemodynamic characteristics; energy losses (EL), were calculated under 100 aneurysms and the results indicated that there are more than five times difference from ruptured and unruptured aneurysms. According to flow visualization, the flow inside ruptured aneurysms appeared stronger impact on the aneurysm wall. These results indicate that EL and recirculation time may be an useful parameter to quantitatively estimate the risks of ruptured of cerebral aneurysm.

I. INTRODUCTION

The hemodynamic analysis of cerebral aneurysms have been developed using numerical and experimental methods [1]. However, there are no quantitative expression and are difficult for use in predicting rupture. Therefore, the challenge for aneurysm’s hemodynamic analysis using the computational numerical methods are; validation with large numbers and specific geometries of aneurysms from clinical records, specification the blood flow boundary conditions at performing vessel domain, and availability to create a predicting criterion to recognize the risk of cerebral aneurysm before rupture.

Our studies are to develop an efficient transfer system to convert the clinical image data into computational available vessel shape geometries, to computationally validate blood flow patterns, and as well to analyse flow characteristics (see figure 1).

II. METHODS

Patient specific image data was segmented by using image DICOM format clinical image into three dimensional vessel surface format data. Image segmentation software was developed based on Insight Toolkit (ITK) and open source software 3DSlicer. The STL format geometry was transferred into mesh generation software ICEM (ANSYS®) to generate volume mesh for fluid simulation. Navier-Stokes governing equations solved basing on Finite Volume Method (FVM), was introduced as a main solver. All simulations were performed under a personal computer.

The energy loss (EL) was proposed to estimate the power loss calculated follow equation. The simulations of the non-aneurysm cases were carried out with the same flow conditions as that of the with-aneurysm cases [2]. The EL was calculated by difference between with and non-aneurysm.

\[
EL = 
\left( \frac{P_i + \frac{1}{2} \rho v_i^2 + \rho g h_i}{Q} \right) \quad \left( \frac{P_o + \frac{1}{2} \rho v_o^2 + \rho g h_o}{Q'} \right)
\]

where, \(i\) is inlet, \(o\) indicates outlet.

III. RESULTS

The EL for ruptured aneurysms was around 5 times \((P < 0.001, N=100)\) higher than for unruptured. (Figure 2). The energy loss might be transferred into physical stimulus, force and stress, to load on the pathological aneurysm surfaces.

IV. CONCLUSION

A new approach using EL to estimate the risk of aneurysm rupture was performed by hemodynamic simulation. Flow energy loss in aneurysms was significantly different between ruptured aneurysm and unruptured aneurysm.

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