3 차원적으로 재구성된 대뇌 동맥류 모델과 유동해석
Three-dimensionally Reconstructed Model of the Cerebral Aneurysms and Fluid Analysis

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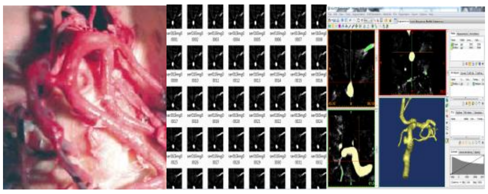
1. Introduction

The cerebral aneurysms is a very serious disease and gains more and more attention of researchers. When the cerebral aneurysms rupture, it will lead to human's death. According to recent studies, the basic reason for rupturing is the wall shear stress of the aneurysms sac which can not endure the flow shear stress. There are various factors to induce the rupture and hemodynamics has been considered as the key role in the wall shear stress distribution. The advanced computational fluid dynamics (CFD) method supply researchers a great help on the relative researching work by simulating the condition in aneurysms, such as predicting velocity fields and other hemodynamic parameters contributing to the rupture of the arterial wall. While simulating, the reconstruction of high accuracy 3-D aneurysms model is a key prerequisite for good finite element analysis. As Juan C. Lasheras described in his paper [1], the three-dimensional shape of abdominal aortic aneurysms and other fusiform large aneurysms can be reconstructed with relatively good accuracy because of its large size and relatively simple geometry. However, it is difficult to establish a good accurate 3-D model according to the previous studies when accounting for the exact curvature of the intracranial aneurysm.

In this paper, we have proposed a good method which could reconstruct the three-dimensional model of cerebral aneurysms quickly and accurately based on CT date. Firstly, a 3-D model could be built from 245 cross-sectional CT images obtained from an volunteer cerebral aneurysms patient by the medical reconstructed software working with the CAD software. Then the file (IGES form) was imported to the CFD software to simulate these hemodynamics factors contributing to the rupture.

2. Reconstructing the 3-D aneurysms model

Nowadays, there are four main methods for reconstruction: directly modeling, coordinate point modeling, tissue slice modeling, and medical image-based modeling. However, the complexity of these modeling methods restrict the application in clinic. We used a convenient and accurate modeling method as follow: firstly, we used the medical reconstruction software (MRS) to draw the contour date of the aneurysms and established the entity model including interior structure information, and then treated the model in CAD software. The 245 cross-sectional CT images with the 256 x 256 pixel obtained from an volunteer cerebral aneurysms patient and the sliced distance between two adjacent images was 0.5mm (Fig. 1). The reconstruction model of the blood vessel is shown in Fig. 2. In order to focus analysis on the aneurysms area, we cut these branches in MRS.



(a) (b) (c)

Fig. 1. The cerebral aneurysms reconstruction. (a) blood vessel with aneurysms, (b) CT images, and (c) reconstructed model in MRS.

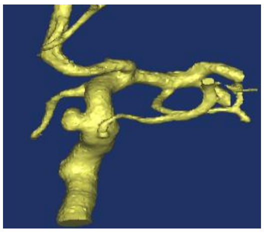


Fig. 2. The reconstructed aneurysms model.

3. CFD simulation

After cutting the branches of the blood vessel the model was treated in CAD software. The IGES file was imported to the CFD-ICEM software to create the boundary (inlet, outlet and wall) and set boundary conditions. Next, we transferred the surface geometry to 3-D volume model and then calculated the volume mesh to generate grids for the CFD simulation (Fig. 3). The quality of the grids is crucial important for the accuracy of the simulation results.

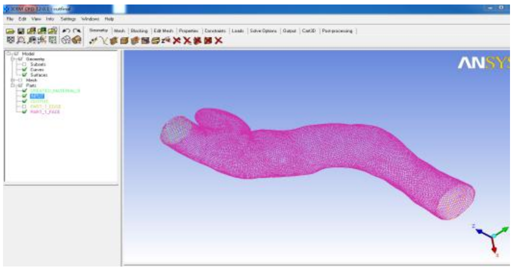
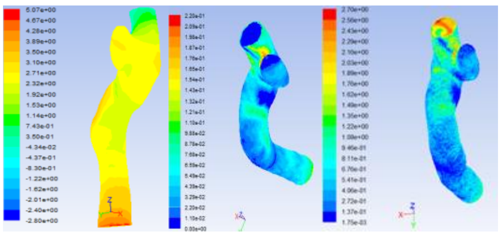


Fig. 3. Pre-processing in CFD-ICEM.

The simulation for blood flow was assumed as incompressible Newtonian fluid. For blood the density is ρ = 1.105 g/cm^3 and the viscosity is μ = 0.04 poise. No slip boundary conditions was prescribed at the blood vessel walls. We used the blood flow waveform given by Holdsworth DW and the mean blood velocity at the inlet was 39.7cm/s[2]. The outlet was set to be pressure-outlet with 0 Pa of the gauge pressure.

4. Results and discussion

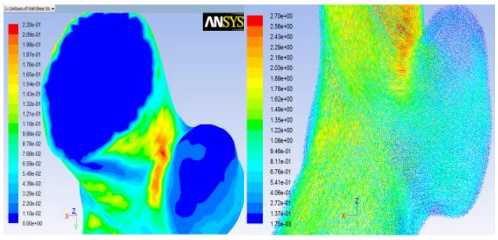
The residuals converged at the iteration number of 350. These hemodynamics factors, such as wall shear stress (WSS), pressure, and the velocity could be calculated by the CFD method as shown in Fig. 4.



(a) (b) (c)

Fig. 4. The CFD simulation results. (a) wall pressure (b) WSS, and (c) velocity vectors distribution.

The pressure is high at the inlet and decrease along the vessel, but a special high pressure area on the aneurysms sac is appeared. The outlet has the high velocity and vortex.



(a) (b)

Fig. 5. Hemodynamics factors around sac. (a) WSS and (b) velocity vectors.

The WSS and velocity vectors around aneurysms sac are shown in Fig. 5. The WSS is exactly low around the aneurysms sac but high at the location of aneurysms contacting area. The velocity shows a small vortex inside of the aneurysms sac. In result, the low WSS, high pressure, and vortex flow contribute to the rupture together[3], by which we can make sure the concrete expecting rupture area.

5. Conclusion and future work

In this article, a good method of quickly and accurately reconstructing the three-dimensional model of cerebral aneurysms has been presented. The process and the result of CFD simulation have also been showed. In future, we would like to do some simulation on real aneurysms date and compare with the clinical observation to make sure the exact location of the rupture.

Reference

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