Preliminary Study: FSI Modeling of Blood Flow Simulation on Different Cerebral Aneurysms Geometries

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ABSTRACT – A ruptured aneurysm can immediately become life-threatening and requires prompt medical treatment. Previous practices depended on medical image prediction and physicians' experiences. Nowadays, the development of computational technology such as numerical and modeling simulation has enabled good prediction to be done onto cerebral aneurysm patients. This paper focuses on modeling the blood flow simulations in different simplified aneurysms models. Fluid Structure Interaction (FSI) method was used to simulate these models. The results resonated well with the current studies on wall shear stress (WSS) distribution and pressure differences between geometry A, B and C.

1. INTRODUCTION

Cerebral aneurysm is also known as intracranial aneurysm. It is a cerebrovascular disorder due to the weakness of cerebral artery or vein walls that can lead to a localized dilation or ballooning of the blood vessel. Cerebral aneurysms are classified into terminal, lateral or bifurcation aneurysms depending on their relationships with the parent artery. Aneurysms are either acquired later in life or due to genetic condition (since born). Unhealthy lifestyles such as hypertension, smoking, excessive alcoholism and obesity are highly associated with the development of brain aneurysms. Cerebral aneurysms are generally found in the anterior and posterior regions of the circle of Willis. The rupture of cerebral aneurysm can cause subarachnoid hemorrhage (SAH) with potentially severe neurologic complications [10]. Location of cerebral aneurysms' wall shear stress (WSS), pressure, particle residence time and flow impingement play important roles in the growth and rupture of cerebral aneurysms [2,3,8]. High WSS has been regarded as the major factor in the development and growth of cerebral aneurysms [3].

Current limitation in aneurysms detection is, it only depends on MRI and CT scans to obtain the geometry and fluid flow information. Fluid Structure Interaction (FSI) has then been introduced to detect the hemodynamic in the artery to overcome the limitation. The application of coupled FSI simulation that combines Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA), is becoming a popular tool for understanding the interaction of the arterial hemodynamics [1-6,15]. Particularly, Torii et. al. [11-13] and Valencia et. al. [1-2] studies demonstrated that FSI simulations have the ability to provide information on the magnitude of vessel wall motion and visualize its characteristics that current in vivo methods and imaging techniques unable to accurately provide [7,9,14]. It can be concluded that, CFD simulations without FSI are not reliable. Furthermore, the mechanical behavior of cerebral aneurysms under fluid dynamics load can be obtained only with CFD considering FSI.

In this paper, we investigate the wall shear stress (hemodynamic factor) and pressure distribution between different simplified aneurysms geometries.

2. METHODOLOGY

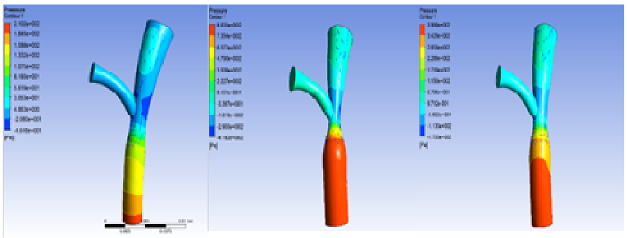
FSI method was used to simulate blood flow within patient-specific cerebral aneurysms to predict the hemodynamics flow pattern and properties such as velocity, pressure and wall shear stress. In this study, the Arbitrary Lagrangian Eulerian (ALE) method and Navier-Stroke equation were used as the governing equations to solve problems with FSI. The density of blood was assumed to be constant, ρ = 1050 kg/m^2, the dynamic viscosity μ = 0.0035Pa and Poisson's ratio = 0.45. The Reynold number normally in the range of $1 \leq Re \leq 400$ for the flow.

Table 1 ANSYS Parameter Setup

Properties	Data
Inlet of the artery wall	Rigid
Outlet of the artery wall	Rigid
Material	Blood
Blood density	1035 kg/m^3
Blood viscosity	0.00035 kg/ms
Specific heat, Cp	3513 j/kg.k
Thermal conductivity	0.44w/m.k.
Velocity magnitude	0.3
Temperature	310k

3. RESULT AND DISCUSSION

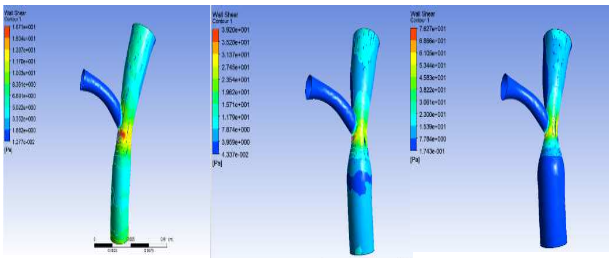
The different geometries of the vascular model exerted high impact on intra-aneurismal pressure and hemodynamic flow characteristics. These derived quantities thought to be the key parameters for the better understanding of aneurysms disease and potentially useful in predicting aneurysm rapture. The results in Figure 1 and Figure 2 show that geometry C has larger inlet and outlet diameters compared to geometry B, while geometry B has larger inlet and outlet diameters compared to geometry A. The differences in these diameters affected the pressure differences and WSS experienced by the arteries.



A B C

Figure 1 Pressure differences between geometry A, B and C

In Figure 1, the highest pressure difference (863Pa) was experienced by geometry C while geometry A and B experienced 210Pa and 398Pa pressure differences respectively. Larger diameters of the inlet and outlet produced higher pressure.



A B C

Figure 2 Wall shear stress (WSS) differences between geometry A, B and C

The average value of WSS at the highest region increased ascendingly from geometry A to C. Figure 2 shows that WSS distribution for geometries A, B and C are 6Pa, 9Pa and 11Pa respectively. Based on the WSS analysis, a sensitive measure of changes in the flow pattern and vessel geometry can interact to produce WSS error larger than predicted.

4. CONCLUSIONS

The conclusion from this preliminary study, arteries with larger diameters, have higher tendency to develop cerebral aneurysm and the development of extensive analysis of modeling simulation may help to reduce the effect of the reconstructed geometries.

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