Applying Hemodynamics in Treatment Planning for Aneurysms

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Introduction

Intracranial aneurysms are a condition where weak areas of blood vessels in the brain can expand and create blood-filled sacs. Rupture of these aneurysms leads to subarachnoid hemorrhages, a life-threatening condition, which affects approximately 30,000 individuals each year in the United States. While surgical clipping and endovascular coiling are common treatment options, flow diversion devices are a newer option. Flow Diversion Devices (FDD) are fine-mesh tubular stents, that limit the blood flow into the aneurysm and can alter the blood flow patterns inside of the aneurysm. By analyzing the hemodynamics of the blood flow in the aneurysm, specific hemodynamic parameters can be identified in order to predict which patients might respond well to stenting. This can also assist in determining why in some patients the aneurysm grows which is undesirable.

Methods

Four patients' aneurysms were analyzed pre- and post stenting. These patient geometries were analyzed with a fluid dynamics simulator, Palabos. This program allows for hemodynamic analysis by simulating the blood flow patterns within the aneurysm, and the corresponding hemodynamic parameters such as velocity distribution and wall shear stress within the aneurysm. The program Paraview was then used to visually show these simulation results in a 3-D image. By analyzing and comparing the hemodynamic parameters pre- and post-stenting, along with comparing the hemodynamics and geometries of each patient, specific parameters can be identified in order to predict patient response to stenting. Identifying these parameters can assist in developing a treatment plan for patients with aneurysms and predict if stenting will be beneficial.

Results

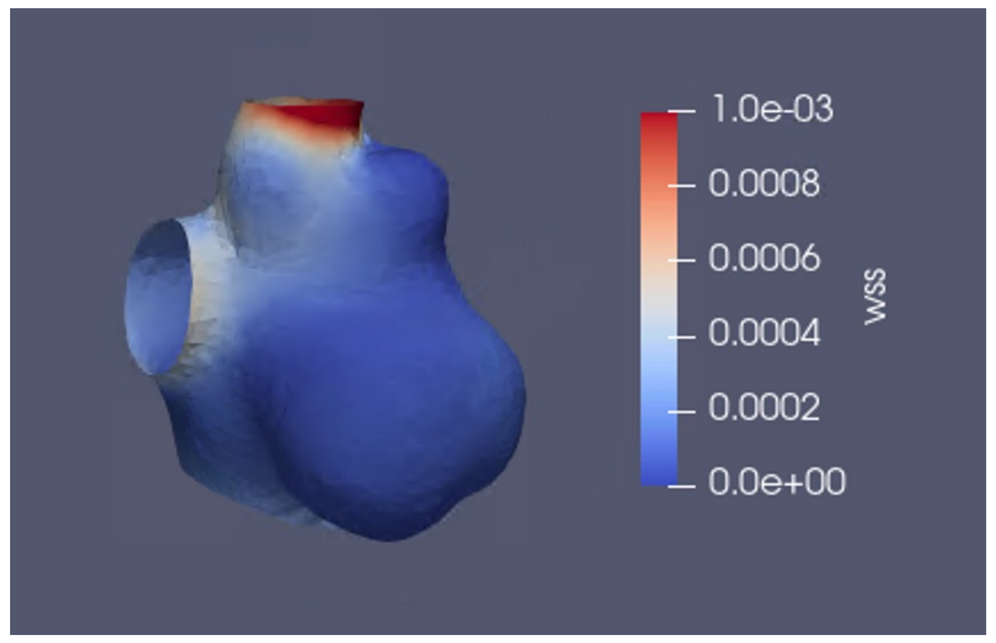

Figure 1: Patient geometry displayed in Paraview taken on November 5th, 2013

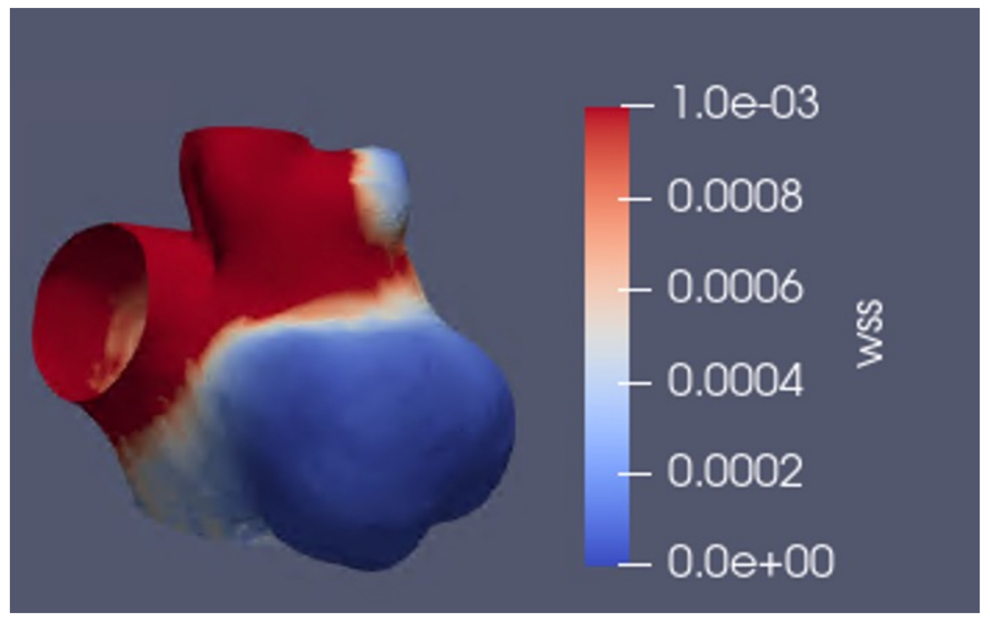

Figure 2: Patient geometry displayed in Paraview taken on November 6th, 2013

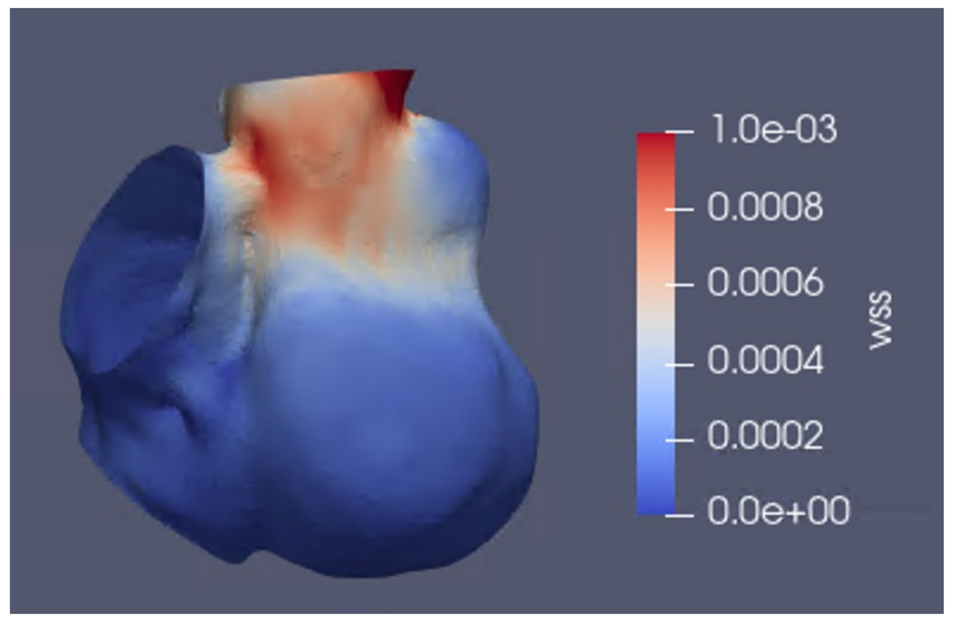

Figure 3: Patient geometry displayed in Paraview taken on May 19th, 2014

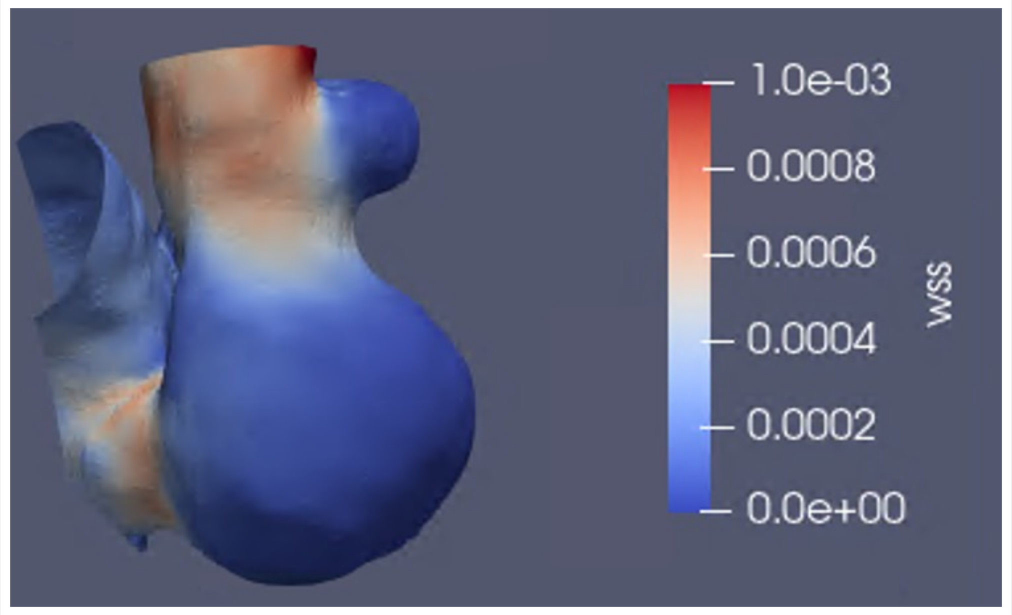

Figure 4: Patient geometry displayed in Paraview taken on June 22nd, 2015

- Our examination of the flow patterns and wall shear stress (WSS) within the aneurysm revealed changes in the anatomy of the aneurysm which impacts the areas of the aneurysm that experiences lower magnitudes of WSS. Here are our key findings:
  - Post-stenting size of aneurysm decreasing due to limited blood flow into aneurysm from stent
  - Wall shear stress has been identified as a hemodynamic parameter linked to aneurysm rupture
  - Early images(Figures 1 and 2) show areas with abruptly changing high to low shear stress, and these "sharp corners" of high to low wall shear stress greatly indicates risk of rupture
  - Later images(Figures 3 and 4) show overall lower levels of wall shear stress, along with more distribution of changing levels
  - The flow impingement zone is narrow in changes with the stent insertion. The flow impingement zone is associated with the region of elevated WSS because of the inflow stream.
  - Similar results in each patient in this study

Conclusions

The main purpose of this study is to examine the efficiency of stenting for cerebral aneurysms. Our main aim is to use the findings of this study to initiate criteria in predisposing the aneurysm response to the stenting. We investigated the mechanisms underpinning the aneurysm responses in four patient-specific cerebrovascular aneurysm models corresponding to one pre- and several post-stenting stages of the aneurysm. The computational fluid dynamics simulations performed with Palabos were utilized to study the hemodynamics in consecutive stages of a pre/post-stented aneurysm. Aneurysms are classified as not-responding to stenting if an increase in size (displacement) larger than 0.5 mm can be measured in any direction on at least 5% of the aneurysm, from the initiation examination in 9 months of follow up. When comparing the results for the hemodynamics and geometry shape for patients pre- and post-stenting, this method for assisting in treatment planning for aneurysms seems to be promising. The results show that aneurysm growth after stenting decreases, and then the aneurysm proceeds to shrink, which is desirable. Also, the results for analyzing changes in the hemodynamics for the aneurysm, show that key warning signs of aneurysm rupture decrease after stenting. Our finding show that computational modeling is a useful too in analyzing aneurysm growth and hemodynamic parameters within and can help determine which patients may respond well to treatment. Although the results for this research are limited in case number, further research in this area can greatly benefit aneurysm treatment plans.

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For further information

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