Biofluid-Structural Interaction in Abdominal Aortic Aneurysm for Predicting Timeline to Rupture: The Effect of Hypertension and Aorta Wall Material Properties

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Abstract

Background:
An abdominal aortic aneurysm (AAA) occurs when there is a bulge formed in the large blood vessels that supply blood to the abdomen, pelvis, and legs. Abdominal aortic aneurysms pose a serious risk of rupture and can be life-threatening. Diagnosis of a life-threatening AAA is based on measuring the diameter of the enlarged aorta. Current treatment options includes open surgery and endovascular stent grafting. However, the estimated time to rupture of an enlarged aorta is unknown. Medical image (CT-scan) of a hypertension patient with an AAA prior to surgery has been analyzed. Combining medical imaging and computational fluid dynamics (CFD) in a time dependent study allows the determination of wall stress, deformation, and fluid flow dynamics over a certain period of time. This model can be used by physicians to predict the estimated time to rupture based on the fluid properties and aorta wall material properties.

Methods:
The CT scan was reconstructed into a three-dimensional renderings using 3D image rendering software, then imported into COMSOL Multiphysics® software as a finite element mesh, followed by a fluid structure interaction simulation. Pulsatile blood-flow was simulated in the aorta wall with layers of collagen, elastin fibers and the endothelial cells. Degraded levels of elastin and collagen were modeled in aneurysm prone areas of the aortic wall to estimate the time to rupture. The deformation in the wall was measured using a time dependent study to predict the timeline for the enlarged diameter. A typical aneurysm rupture will occur once the diameter enlarges to 5-7 cm. Combining the results of wall deformation along with wall stress and blood velocity with respect to time, a physician will a have a better estimate of the time it will take for the aneurysm to rupture.

Results and Conclusion:
The results show that deformation increases over time with high blood pressure in the diseased aortic wall. Figure 3 and Figure 4 show that high displacement and high wall stress take place at the bifurcation of the aortic artery. High blood velocity for a long period of time will increase

degradation of elastin and collagen fibrous materials in the aortic wall which results in increased deformation and likelihood of a rupture. Combining the results of wall deformation and wall stress in a time dependent study will give a time estimate for the aneurysm to rupture.

Figures used in the abstract

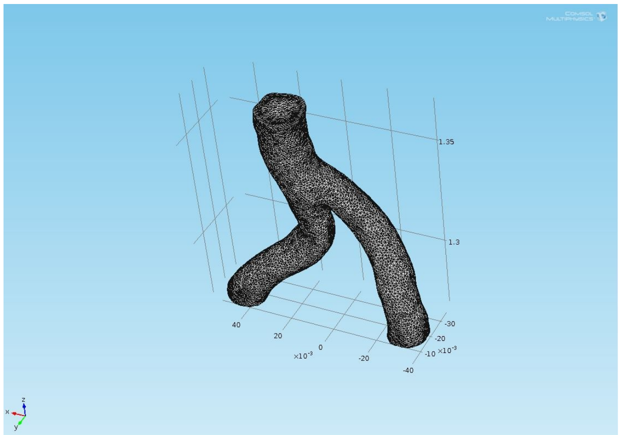

Figure 1: Meshed Geometry of Aorta.

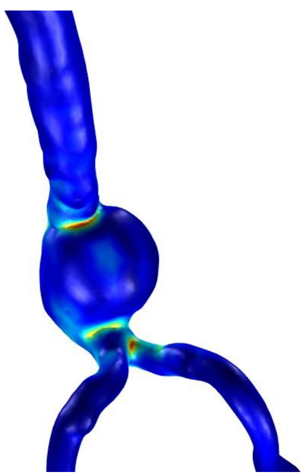

Figure 2: Von Mises Stress in abdominal aortic aneurysm (AAA).

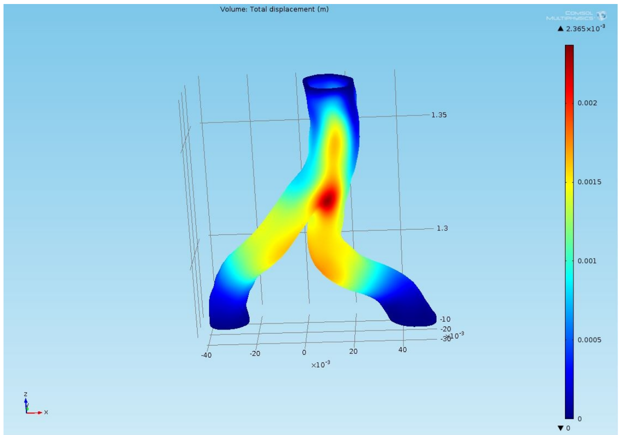

Figure 3: Surface Total Displacement in the Aorta Wall.

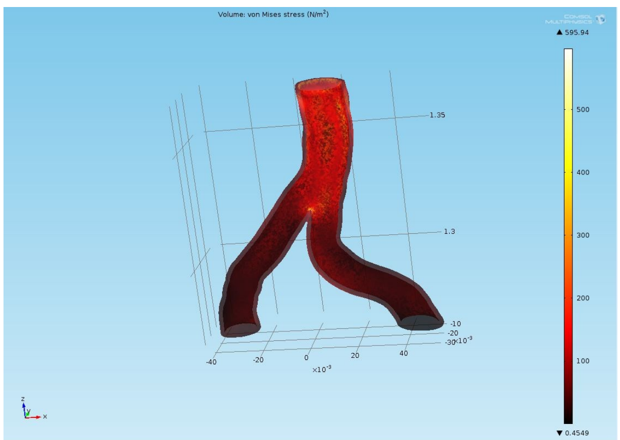

Figure 4: Surface Von Mises Stress in the Aorta Wall.