Senior Honors Thesis Prospectus

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Background

**Coronary Atherosclerosis - Stents - Oscillatory Wall Shear Stress**

The use of coronary stents has become standard practice in the treatment of atherosclerosis, generally known as the blockage of arterial flow by fatty build up. This can occur for a variety of reasons ranging from diet, lifestyle and genetic predisposition. Atherosclerosis and other related pulmonary disorders are ranked as the number one cause of death in the United States. [1]

Arthroscopically, a small cylindrical coiled stent is fed into the region of the plaque. When the stent is released, it either self inflates or is inflated via a small balloon. This stent then provides a mechanism for holding open the artery and restoring regular blood flow.

Arteries by definition involve flow moving away from the heart and therefore experience relatively high pressures. The cyclic nature of the pumping heart imposes a range of velocities which in turn can impose a range of complex oscillatory wall shear stresses onto the arterial wall. [2] This is thought to be one factor that can contribute to the initial formation of atherosclerotic plaque as well as restenosis. [3]

**Intracranial Aneurysm - Flow Patterns**

The development of an intracranial aneurysm is thought to be a complex and multifaceted process. One widely accepted belief is that
hemodynamic stimulus on the arterial wall is an important factor. [4] For this reason understanding and studying the flow patterns in diseased arteries is integral in developing an understanding of this process. The geometry of the artery can be captured by using medical scanning technology, then aneurysm can be digitally removed. This presents an estimate of the structure of the artery before the formation of the aneurysm. Flow simulations can then describe the hemodynamic conditions that were present during the initial formation of the aneurysm.

The danger associated with intracranial aneurysms is that of rupture. Infrequently the aneurysm will make its presence known before rupturing by affecting the cognitive abilities. In this scenario the dangers associated with surgical intervention must be weighed against the probability of rupture. To predict rupture, expansion rate and diameter are used with little reliability. Key in understanding this phenomenon is the hemodynamic force exerted by the flow inside the aneurysm.

**Thesis Description**

*Hemodynamic Computational Fluid Simulations*

I will perform hemodynamic flow simulations on stented coronary arteries and intracranial arteries suffering from aneurysm. These simulations will provide insight into such factors as oscillatory wall shear stress and its location throughout the artery. The Process will begin with thousands of two dimensional DICOM images (digital imaging and
communication in medicine), taken from a CT scan (computed tomography). These will be compiled in a software package called Gambit. Any artifacts or blooming effects that are present will be removed. These generally result from the high reflectivity of the stent material.

This data will then be exported into Fluent where simulations will be run to determine the nature of the flow in the artery. In the case of the stented coronary artery, the effects of the stent on the hemodynamics of the artery will be of concern. In the case of the intracranial aneurysm the flow inside the aneurysm will be studied. The aneurysm will be removed using Gambit and the flow reexamined. This will provide insight into the conditions that were present during the formation of the aneurysm. These simulations will yield valuable information such as wall shear stress and will allow particle tracking in the region.

**Particle Tracking - 3 Dimensional Animations**

The software being used is capable of tracking particles throughout their lifetime in the artery. The path taken by each particle can become increasingly complicated with tortuous arteries containing aneurysms. For this reason, two dimensional imaging of this information yields limited benefit. This is why three dimensional viewing techniques will be applied to examine these arteries. Facilities in the University of Houston Texas Learning Center will be used for this purpose. This requires exporting VRML data from Fluent to Amira which can be compiled to create three dimensional animations of the path lines taken by each particle. Matlab will
also be utilized to help in understanding the particle tracking information. By exporting a history of the position of each particle, Matlab will be used to generate images visualizing the particle and a tail recounting its path.

**Unwrapping of stented coronary arteries**

Visualizing the results of the flow simulations on stented coronary arteries can also be a difficult and confusing task. The results are normally graphed onto a cylindrical mesh. While viewing the information this way on a computer or on paper, the data becomes quite complex and confusing. For this reason I will write a Matlab code which will mathematically unwrap the artery while still maintaining the three dimensional structure of the image. The mathematical process is physically analogous to cutting the artery along its axis and laying it flat. This novel imaging technique will be very useful in visualizing the results of the computational analysis.

The images obtained in Matlab will also be helpful in visualizing the deployment of the stent. Occasionally the stent doesn't expand properly in all areas resulting in a bunching effect. The non-uniform dispersion of the mesh is difficult to detect when examining the stent in its cylindrical shape. In this way the flattened image can be very useful in elucidating this potentially problematic occurrence.

A data set containing the nodal points that define the stent and artery wall will be exported into Matlab via a plain text file along with information describing the wall shear stress at each node. The data set will be fed into the novel imagine code in Matlab that performs manipulations
on each data point to mathematically unwrap the stent. Once the surface is unwrapped the results will be exported to Amira via the PSI file format. This requires augmenting the text file to allow Amira to recognize and import the file correctly. Once in Amira, the data will be used to create a surface using the 2D Delaunay algorithm.

Exporting a smooth mesh created by the 3D Delaunay function in Matlab which accurately represent the geometry of the stent into Amira is an objective that will be pursued if time is allowed. This is because of the complications in dealing with the cumbersome Matlab visualization software and the unrealistic geometry created by the 2D Delaunay algorithm in Amira. Unwrapping a stent which has been placed in a highly tortuous artery is another goal that will be pursued if time is allowed. This would require finding a center reference point and diameter that is changing throughout the artery.
Conclusion

This is an area that I am highly interested in, and am considering pursuing throughout my career. A thesis would be an exceptional opportunity for me to begin building a knowledge base in this field, upon which I will build in graduate school.
Bibliography


