NON-NEWTONIAN STUDIES OF PATIENT-BASED CARDIOVASCULAR MODELS USING A STABILIZED FINITE ELEMENT FLOW SOLVER

By

Victor Luis Marrero Ortiz

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Mechanical Engineering

Examining Committee:

Dr. Kenneth Jansen, Thesis Adviser
Dr. John Tichy, Thesis Adviser
Dr. Natacha DePaola, Member
Dr. Luciano Castillo, Member
Dr. Benyebka Bou-Saïd, Member

Rensselaer Polytechnic Institute
Troy, New York

September 2009
(For Graduation in December 2009)

ABSTRACT

Computational methods can provide a detailed description of blood flow in virtual models of the cardiovascular system, helping vascular surgeons make better individualized treatment decisions. It is well known that blood has non-Newtonian properties, but it is generally accepted that blood behaves as a Newtonian fluid at shear rates above 100 s^{-1}. However, in transient conditions there are periods of time where the shear rate is below 100 s^{-1} and it is reasonable to infer that non-Newtonian effects could become important. A question that is important to address is; to what extent are these effects important over an entire cardiac cycle?

In this study, we incorporate the non-Newtonian properties of blood into the simulation based framework for cardiovascular surgery planning developed by Taylor *et al.* . This framework seeks to guide vascular surgeons to select the best procedure for a patient in a clinically-relevant time frame. We solved the blood flow in a patient-based abdominal aorta aneurysm model under steady and physiological flow conditions. It was found that using the non-Newtonian viscosity modifies the solution in subtle ways that yield a mesh independent solution with fewer degrees of freedom than the Newtonian counterpart. This was first studied and demonstrated on a steady problem to isolate the effects of unsteadiness. It appears that, in separated regions, the lower shear regions produce higher viscosity with the non-Newtonian model that reduce both the vorticity and its associated resolution needs. Furthermore, when considering the real case of pulsatile flow, these same high vorticity layers lead to greater unsteadiness in the Newtonian case relative to the non-Newtonian case. This results in a tendency for the non-Newtonian model to need less computational resources even though it has to perform additional calculations for the viscosity. In this way, this work suggests that the use of non-Newtonian viscosity models may be more attractive to solve cardiovascular flows since they can provide a solution with less computational effort for a given level of accuracy in comparison with the Newtonian model. To the best of our knowledge this is a new finding in using non-Newtonian viscosity model in cardiovascular flows. It is also shown that in both viscosity models a similar wall shear stress distribution is attained.