Computational Study of Blood Flow through the Carotid Artery Bifurcation

M. Soltani[1], P. Chen[1], and A. L. Bauer[2]

***Short Abstract* — we investigated the ability of non-Newtonian models of the carotid bifurcation to capture shear rates. We simulated blood flow through 3D geometries of the carotid artery using the finite volume method in a steady and unsteady flow algorithm. Because the most used model for non-Newtonian blood flow is only accurate in a very specific range, in the present study, four different blood flow models were used to simulate the flow of the human carotid bifurcation.**

Motivated by arterial diseases, such as atherosclerosis, early research on flow through the carotid artery bifurcation was based solely on experimental observation. With the development of computational methods and software programs for flow simulation, computational fluid dynamics simulations have become a primary tool for study in this field. Over three decades, numerical computation of flow through the carotid artery bifurcation has seen spectacular progress both in using more sophisticated simulation methods and in capturing more realistic physics of flow through the carotid artery.

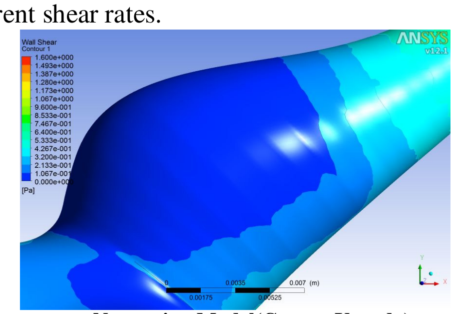
Despite great advancements in imaging techniques and simulation methods, there is no definite conclusion about the relation between geometrical and hemodynamical parameters and the risk of vascular disease. Hemodynamic factors such as flow separation, vortex formation, and shear stresses influence atherogenesis. Many computational studies suggest that the atherosclerotic process is strongly correlated with the local wall shear stress (WSS) and it is believed that the rheology of blood flow plays an important role in hemodynamic phenomena. However, many of these computational studies treat blood flow as an incompressible, Newtonian fluid. Recent numerical studies establish the necessity of using more anatomically correct arterial geometries and more accurate flow physics to capture realistic flow physics through the carotid artery. Steps toward a predictive model of arterial flow that can be used to prevent diseases including atherosclerosis must include more accurate modeling of flow physics, such as two-phase flow of non-Newtonian model, and modeling the interaction between the fluid and the vessel wall.

[1]Waterloo Institute for Nanotechnology, Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1. E-mail: msoltani@uwaterloo.ca

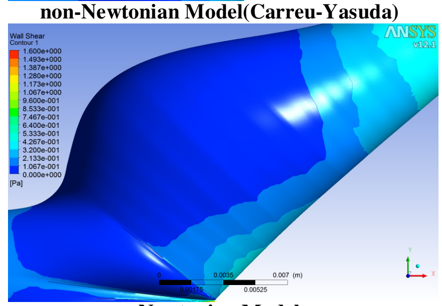
[2]X Theoretical Design Division (XTD-4), Los Alamos National Laboratory, Los Alamos, New Mexico, 87545, USA. E-mail: albauer@lanl.gov

In this study, we investigated the ability of non-Newtonian models of the carotid bifurcation to capture shear rates. We simulated blood flow through 3D geometries of the carotid artery using the finite volume method in a steady and unsteady flow algorithm (to capture pulsatile blood flow). In simulations of steady flow with Re= 300 and Re=800, results show that there is not a significant difference between Newtonian and non-Newtonian treatments when the shear rate is high because the blood behaves like a classical Newtonian flow (see Figure 1). In the case of low shear rate, the results show different values of wall shear stress and velocity profiles within the sinus region of the carotid. Results from the unsteady simulation with Newtonian blood flow, show that a wide range of shear rates are present in the flow field of the carotid bifurcation. Because the most used model for non-Newtonian blood flow is only accurate in a very specific range, in the present study, four different blood flow models, namely, the Newtonian, the Casson, the modified Casson and Yasuda-Bird, and modified power law models were used to simulate the flow of the human carotid bifurcation.

As non-Newtonian models strongly depend on the shear rate changes, we concluded that to have a more accurate solution we have to implement a combination of non-Newtonian models to calculate viscosity through the whole domain. This hybrid model considers conventional models for different shear rates.



non-Newtonian Model(Carreu-Yasuda)



Newtonian Model

Figure 1: Simulation results show that there is no significant difference between Newtonian and non-Newtonian model