# Numerical study of hemodynamics in healthy and diseased arteries under different physiological conditions


## Abstract

Arterial stenosis poses a high cardiovascular risk as it restricts the normal flow of blood. Arterial location subjected to low and oscillating wall shear stress (WSS) is prone to atherosclerosis and consequent stenosis progression. Flow features like reversed flow, shear layer instabilities, non-axial circulation, etc., influence the WSS levels. Hemodynamic flow in the arteries strongly depends on geometrical parameters like arterial curvature, bend angle, bifurcation, stenosis size, etc., as well as on inflow waveform and blood viscosity. Therefore, it is important to predict the susceptible locations in complex arterial domains during different flow conditions arising from the physiological situation. The present work uses an immersed boundary (IB) based computational method to study hemodynamics in physiologically realistic arterial domains and predict the deviation in the WSS levels and flow features due to stenosis formation. The present IB solver is accelerated on graphics processing unit platforms using OpenACC, and more than 100X speedup is reported. At first, the flow structures in an S-bend arterial geometry with different levels of stenosis are investigated. It is observed an onset of Kelvin-Helmholtz-type vortex roll-up for higher degrees of stenoses. A comparison of vortex structures and WSS levels in Newtonian and non-Newtonian Carreau models is also reported. Next, the impact of exercise-induced elevated heart rate on arterial flow is reported for healthy and stenosed carotid arteries. WSS behavior and the pressure drop across the stenotic region of the carotid arteries at different heart rates are also studied. Blood viscosity may significantly change as red blood cell volume fraction or hematocrit (Hct) level may vary due to diseases like anemia, chronic obstructive pulmonary disease (COPD), etc. The effects of high and low Hct levels on the flow features of different arterial models are thoroughly investigated, and their impact on WSS-based parameters is reported. Overall, this study gives an assessment of flow behavior and stress levels in normal and diseased human arteries during different physiological conditions. The present framework may aid clinicians in better understanding the arterial flow for different patients.



**Keywords:** Atherosclerosis, Hemodynamics, S-bend artery, Kelvin-Helmholtz instability, Carotid stenosis, Elevated heart rate, Hematocrit level, Non-Newtonian flow, Immersed boundary method