Abstract

Khalid M Saqr

Evidence for non-Newtonian behavior of intracranial blood flow from Doppler ultrasonography measurements

Computational fluid dynamics (CFD) studies of intracranial hemodynamics often use Newtonian viscosity model to close the shear rate term in the Navier-Stokes equation. This is based on a commonly accepted hypothesis which state that non-Newtonian effects can be neglected in intracranial blood flow. This study aims to examine the validity of such hypothesis to guide future CFD studies of intracranial hemodynamics. Doppler ultrasonography (DUS) measurements of systolic and diastolic vessel diameter and blood velocity were conducted on 16 subjects (mean age 50.6). The measurements were conducted on the internal carotid (ICA), middle cerebral (MCA), and anterior communicating (AComA) arteries. Systolic and diastolic wall shear stress (WSS) values were calculated via the Hagen-Poiseuille exact solution using Newtonian and three different non-Newtonian models: namely Carreau, power-law and Herschel-Bulkley models. The Weissenberg-Rabinowitsch correction for blood shear-thinning viscosity was applied to the non-Newtonian models. The error percentage between the two sets of models was calculated and discussed. The Newtonian hypothesis was tested statistically and discussed using paired t tests. Significant differences (P<0.0001) were found between the Newtonian and non-Newtonian WSS in ICA. In MCA and AComA, similar differences were found except in the systole and diastole for the Herschel-Bulkley and power-law models (P=0.0669, P=0.7298), respectively. The error between the Newtonian and non-Newtonian models ranged from 27 to 30% (0.2 to 2.2 Pa). These values could affect the physical interpretation of IA CFD studies. Evidence suggests that the Newtonian assumption may be inappropriate to investigate intracranial hemodynamics.