Experimental and CFD flow studies in an intracranial aneurysm model with Newtonian and non-Newtonian fluids.

According to the clinical data, flow conditions play a major role in the genesis of intracranial aneurysms. The disorder of the flow structure is the cause of damage of the inner layer of the vessel wall, which leads to the development of cerebral aneurysms. Knowledge of the alteration of the flow field in the aneurysm region is important for treatment. The aim is to study quantitatively the flow structure in an patient-specific aneurysm model of the internal carotid artery using both experimental and computational fluid dynamics (CFD) methods with Newtonian and non-Newtonian fluids. A patient-specific geometry of aneurysm of the internal carotid artery was used. Patient data was segmented and smoothed to obtain geometrical model. An elastic true-to-scale silicone model was created with stereolithography. For initial investigation of the blood flow, the flow was visualized by adding particles into the silicone model. The precise flow velocity measurements were done using 1D Laser Doppler Anemometer with a spatial resolution of 50 μm and a temporal resolution of 1 ms. The local velocity measurements were done at a distance of 4 mm to each other. A fluid with non-Newtonian properties was used in the experiment. The CFD simulations for unsteady-state problem were done using constructed hexahedral mesh for Newtonian and non-Newtonian fluids. Using 1D laser Doppler Anemometer the minimum velocity magnitude at the end of
systole -0.01 m/s was obtained in the aneurysm dome while the maximum velocity 1 m/s was at the center of the outlet segment. On central cross section of the aneurysm the maximum velocity value is only 20% of the average inlet velocity. The average velocity on the cross-section is only 11% of the inlet axial velocity. Using the CFD simulation the wall shear stresses for Newtonian and non-Newtonian fluid at the end of systolic phase (t= 0.25 s) were computed. The wall shear stress varies from 3.52 mPa (minimum value) to 10.21 Pa (maximum value) for the Newtonian fluid. For the non-Newtonian fluid the wall shear stress minimum is 2.94 mPa; the maximum is 9.14 Pa. The lowest value of the wall shear stress for both fluids was obtained at the dome of the aneurysm while the highest wall shear stress was at the beginning of the outlet segment. The vortex in the aneurysm region is unstable during the cardiac cycle. The clockwise rotation of the streamlines at the inlet segment for Newtonian and non-Newtonian fluid is shown. The results of the present study are in agreement with the hemodynamics theory of aneurysm genesis. Low value of wall shear stress is observed at the aneurysm dome which can cause a rupture of an aneurysm.