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COMPUTER SIMULATION OF NON-NEWTONIAN EFFECTS ON BLOOD FLOW IN A COMPLETE 3D BYPASS MODEL

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ABSTRACT

The development of intimal hyperplasia at the distal anastomosis is one of the reasons for late failure of implanted bypass grafts. Beside the surgery injury, the non-uniform hemodynamics is hypothesized to be the main triggering factor in the gradual patency loss leading to the graft stenosis. Therefore, a better understanding of bypass flow has become one of the topical problems in biomechanics. On our part, some results regarding the investigation of Newtonian blood flow inside a complete idealized 3D bypass model were introduced in [5]. The main objective of the study presented here is to improve our existing computational model with the consideration of blood's non-Newtonian behavior. Regarding the varying fluid viscosity, several investigations and non-Newtonian models were introduced in connection with bypass hemodynamics. For example in [2], the blood flow through the distal part of the bypass is simulated using the power-law model. Although the assumption of blood as a power-law fluid is one of the most often used, problems with high gradients and infinite viscosity predictions make power-law model unsuitable for our applied bypass geometry. The Carreau-Yasuda model as another shear-thinning viscosity model was used in [1], where different graft positions to the stenosis (distance of grafting) and various inlet flow rates are investigated in a bypass model with 75% stenosis.

Compared to the usual practice to model only the distal part of the bypass, we present a complete idealized bypass model, which includes both the proximal and distal parts of the damaged native artery and the end-to-side bypass graft. The diameters of both tubes are set equal, whereas two types of the host artery are modelled with corresponding diameters and mean inlet Reynolds numbers (the coronary artery: $D_{artery} = 0.0033$ m, $Re_{inlet} = 230$; the femoral artery: $D_{artery} = 0.0068$ m, $Re_{inlet} = 125$). Considering the negligible elastic properties of venous and synthetic bypass grafts, the model walls are assumed to be impermeable and rigid. In order to describe the shear-dependent viscosity, two macroscopic non-Newtonian models are applied: the Carreau-Yasuda model, the parameters were taken from [3], and the modified Cross model, for parameters see [4]. All numerical simulations are performed by own developed computational software written in Fortran 90, which is based on the cell-centred finite

volume formulation of the central explicit fourth order Runge-Kutta time stepping scheme defined on unstructured hexahedral computational grid. Following boundary conditions are applied: at the inlet a fully developed velocity profile, at the outlet a constant pressure (p_2 = 12 kPa) and at the walls the non-slip boundary condition.

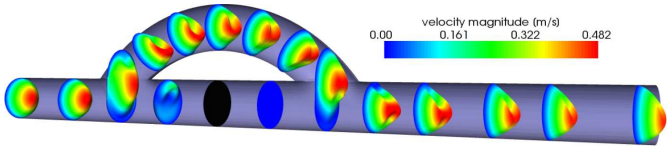

Fig. 1. Velocity profiles at selected cross-sections for Newtonian blood flow ($\rho = 1050$ kg m^{-3}, $\eta = 0.00345$ Pa s), coronary occluded bypass.

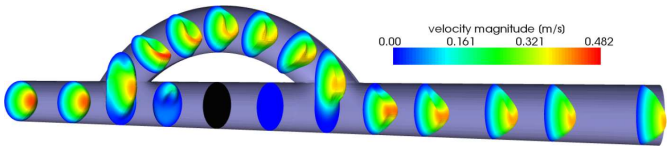

Fig. 2. Velocity profiles at selected cross-sections for non-Newtonian blood flow simulation (Carreau-Yasuda model), coronary occluded bypass tube.

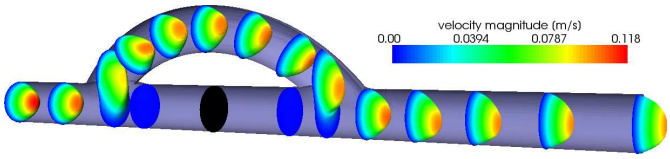

Fig. 3. Velocity profiles at selected cross-sections for non-Newtonian blood flow simulation (Carreau-Yasuda model), femoral occluded bypass tube.

All results, see for example Fig. 2, obtained by the application of a non-Newtonian model in comparison with the Newtonian flow, Fig. 1, imply the importance of variable viscosity when dealing with blood flow in medium-sized arteries. The differences in velocity and wall shear stress distribution become more apparent in the case of the femoral bypass, Fig. 3, where the inlet Reynolds number is lower then by the coronary bypass. Our conclusions indicate a significant role of blood's non-Newtonian behaviour by the analysis of bypass hemodynamics in connection with intimal hyperplasia.

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