Numerical and Experimental Evaluation of Platelet Reaction in Blood Vessels

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Aims: Blood flow through human blood vessels is numerically analyzed. We investigated flow conditions in the aorta and in coronary arteries. Both steady and pulsatile blood flow is analyzed. Pathological cases of a stenosed coronary artery and the formation of an abdominal aortic aneurysm are studied. In the case of stenosed vessels and for aneurysms the formation of a thrombus is typically observed.

Thrombotic complications due to activation of platelets and plasmatic clotting factors belong still to the most investigated topics in the field of study of patho-physiological mechanisms. Mathematical modeling of thrombotic reactions is established and validated in test cases. Aim of this study is to experimentally evaluate and computationally simulate platelets under the influence of well-defined shear flow conditions as they occur in blood vessels under physiological and patho-physiological conditions. Platelet behaviour and reactions are experimentally reproduced, measured and used for validation of the numerical simulation.

Methods: A mathematical model of platelet activation, adhesion and aggregation has been implemented into a finite element CFD (Computational Fluid Dynamics) code. The approach is based on the advective and diffusive transport equations for resting platelets, activated platelets and platelet released agonists. Adhesion rates for the reactive surfaces depend on the hemocompatibility properties of the surface and the local shear rate. Experiments with citrate-anticoagulated freshly-drawn whole blood are performed in a perfusion flow chamber as well as in a system of rotating cylinders for Couette and Taylor-vortex flow. The activation, drop of platelet concentration, adhesion and aggregation are quantified using scanning electron microscopy (SEM) and flow cytometry.

Results: Regions and flow conditions with a high potential for thrombus growth within the blood vessels and for the experiments could be identified. The experiments clearly show the influence of the flow properties. By means of SEM diverse platelet adhesion patterns are observed. Numerical analysis can explain the patterns and the degree of thrombus formation.

Conclusion: The numerical method shows good agreement with experimental data indicating a possible prediction of initiation of activation and detection of the local adhesion areas in connection with the role of Von-Willebrand-Factor. Shear dependent platelet reactions in coronary arteries could be modeled and fitted to experimental data. A coupled model to describe the relationship between aneurysm and thrombus growth was established for further validation.