Advection-diffusion anisotropic model for platelet transport in intracranial saccular aneurysms

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Abstract

Intracranial aneurysms are dilatations of cerebral arteries walls, their rupture is the main cause for subarachnoid hemorrhage (SAH). SAH are relatively uncommon ($\cong 0.1$), but associated mortality and morbidity are extremely high. Endovascular alternatives to classic surgery have been developed with good results. Amongst them, the stent-based flow diversion approach. Aneurysms rupture risk is not easy to assess and little is known about their clotting-dependent healing mechanism. In silico computational fluid dynamics (CFD) may aid to further our understanding of the complex multiscale hemodynamic processes of healing. In addition, these methods could be applied in assisting medical practitioners in their treatment decisions as well as in the design of more efficient stents. Amongst other CFD techniques, the lattice Boltzmann methods (LBM) and the open source Palabos software library are well suited for that task. For instance, Palabos is used in the frame of the Thrombus-VPH project. This master's goal is to improve the existing Thrombus-VPH modeling of platelets transport, which plays a crucial role in the clotting mechanism. The full microscopic simulation of this rheology is extremely costly in computational resources. To improve this, we worked on a multiscale model treating platelets as particles. In practice, a Brownian anisotropic advection-diffusion model was established, then implemented in Python and validated. This model is at the core of this work, because it builds a bridge coupling microscopic and macroscopic phenomena by emulating advection-diffusion. It was then integrated in a LBM theoretical framework to solve the fluid using bi-directional communication. Red blood cells (RBCs) constitute typically 45% of the blood. Thus, they condition its non-newtonian behavior. Therefore, in this platelet transport model both platelets and RBCs particles where taken into account. The proof of concept implementation uses Palabos and was evaluated on a real aneurysm geometry from the THROMBUS project.