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Tentative topic of the invited talk

Modeling simplifications for blood flow in arterial channels – rheological and geometric reductions.

Abstract of the invited talk

Blood is a dense suspension of deformable, non-spherical red blood cells (RBC) in a non-Newtonian plasma, exhibiting a yield stress as well. For future digital twins of cardiovascular systems, such complications in rheology, coupled with those in the shape of flow channels, render computations prohibitive even with modern processors. In this talk, we discuss how two simplifications enable cheaper pulsatile-flow simulations, while retaining accuracy, for realistic blood flow calculations in patient-specific arterial channels. Firstly, we show how the rheology can be accurately captured by a single-phase model, where migration terms for RBCs are coupled with a non-Newtonian blood viscosity model. The results are in excellent agreement with highly detailed mesoscale simulations for blood flow in a channel, where each RBC is resolved by multiple connected beads using dissipative particle dynamics simulations. For patient-specific geometries, geometric details and complications is the other factor significantly increasing computational times. Thus, we investigate the effects of geometric model reduction on the predictions of blood flow field in patient-specific descending aorta using a range of rheological models, encompassing Newtonian and non-Newtonian ones. In contrast to idealized geometries, real arteries possess significant amounts of roughness, asymmetry, perturbations, and undulations. To understand their impact along with blood rheology, 3D simulation studies are performed with two levels of geometry reduction. The first level of reduction loses the local asymmetry but reasonably approximates various parameters, capturing patterns with the correct magnitude while showing significant computational speed-up. However, further simplification to an idealized smooth geometry loses all information about the vortex structures in the flow field. The flow recirculation zones near wall perturbations progressively weaken as the geometry is smoothed. Broadly, for blood rheology models, no significant differences are observed in trends predicted by the various types used in this study. However, the non-Newtonian models retain more accuracy than the Newtonian on geometric reductions, quantified using correlations defined in this study. We also show a speed-accuracy trade-off analysis useful for future applications. The number of iterations to convergence becomes progressively lower with geometry reduction, with nearly four times speed-up obtained with the first level of simplification. Interestingly, we show that wall shear stresses can be reliably estimated for such realistic arteries using simulations of the highly idealized geometry, for any blood rheology model. Further, we will discuss the extension and relevance of these observations to a more complicated geometry with an aneurysm.