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How the deformation of red blood cells affects hemolysis estimation for ventricular assist devices

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Ventricular assist devices (VADs) are small implantable axial or centrifugal pumps used to support chronically-ill heart disease patients. Due to unphysiological shear-stresses that the blood is exposed to, most VAD patients are suffering from partially damaged blood, leading to a high rate of adverse events. Even though the use of CFD significantly improved current VAD designs, the reliability of CFD models for hemolysis estimations is still not satisfying [1].

We are continuously improving a strain-based hemolysis model, where the viscoelastic deformation of red blood cells (RBCs) is computed by a morphology tensor. In contrast to the common stress-based model, which assumes instantaneous deformation of RBCs, the strain-based model is able to predict the time-dependent stress acting on the cell itself. In previous publications (e.g., Ref. [2]), we have already shown that the strain-based model identifies different critical regions in a blood pump if compared to the stress-based model.

We will discuss the numerical methods used to discretize the involved equations, in particular, multiscale stabilization and a logarithmic transformation for symmetric tensors. Furthermore, we will compare plasma-free hemoglobin generation for a simple power law and for a multiscale model for membrane poration. Simulations will be applied to a benchmark blood pump by the U.S. Food and Drug Administration as well as to state-of-the-art VADs.

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