

Mesoscale simulation of blood flow in microcapillaries

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Abstract

The collective behavior of several red blood cells (RBCs) in narrow capillaries determines their flow-induced morphology, arrangement in the flow, and effective viscosity. Furthermore, recent developments of microfluidic devices allows the investigation and manipulation of individual cells. Here, the relations between the flow behavior, the elasticity and deformability of the cells, the long-term hydrodynamic interactions in narrow channels, and the thermal undulations of the membrane are of fundamental interest. We study these mechanisms in a model, which combines a mesoscale simulation technique with explicit particles for the hydrodynamics of the fluid with a triangulation-based model for the membrane. The most essential control parameters in the model are the volume fraction of the RBCs', ie. the tube hematocrit, the flow velocity, and the viscosity contrast between the fluid inside and outside the cells.

Single red blood cells in capillary flow show a transition from the biconcave disk shape at low flow velocities to a parachute shape at high velocities for low volume fractions. A similar transition is also observed for higher hematocrits. In addition, hydrodynamic interactions are responsible for a strong deformation-mediated clustering tendency at low hematocrits, and the existence of several distinct flow phases at higher hematocrits. Of the latter, a zig-zag arrangement of slipper-shaped cells is particularly interesting.