Mesoscopic Simulation of Blood Flow in Small Tubes,

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In tube flow, blood is usually treated as a Newtonian fluid down to diameters of about 200 μm. By means of Dissipative Particle Dynamics (DPD) we investigate the flow of red blood-cell (RBC) suspensions driven through small tubes (**diameters 10-150 μm)** marking the transition from arterioles and venules to the largest capillary vessels. Previously our DPD suspension model (Fedosov DA, Pan W, Caswell B, Gompper G, and Karniadakis GE, Predicting human blood viscosity in silico, Proc. Nat. Acad. Sci. USA, 108(29):11772-11777(2011)) successfully predicted the measured values of the Couette viscosity (CV) of blood in homogeneous plane shear flow. In tube flow the cross-stream stress gradient induces an inhomogeneous distribution of RBCs. It features a centerline cell density peak, and a cell-free layer (CFL) at the wall whose inner edge is the point of maximum RBC distortion. For a neutrally buoyant suspension the imposed linear shear-stress distribution together with the differentiable velocity distribution allow the calculation of the local viscosity across the section. At constant tube hematocrit (Ht) and after suitable scaling, the viscosity across the section as function of the scaled strain rate is found to be similar; i.e. it becomes essentially independent of size for the larger tubes. From experimental CV values this function is found to be determined by the local Ht and shear rate, i.e. in every cylindrical annulus, dr, the suspension responds to the local shear rate as if it were a plane Couette flow at the local Ht. As the tube size decreases the viscosity departs from the similarity function. Analysis of cell orientation suggests that just beyond the CFL the hematocrit(H) is depleted to the point where cell orientations can approach their CV values. Conservation then requires H to increase towards the center; hence for smaller tubes (<100μm) this crowding hinders the cells from attaining their CV orientations and the viscosity departs from similarity. Hence for the smaller tubes the flow cannot be described in terms of the Couette viscosity, and thus the stress cannot be described as a continuum, even a heterogeneous one.