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Blood flow in microvascular networks. Experiments and simulation.

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Abstract

A theoretical model has been developed to simulate blood flow through large microcirculatory networks. The model takes into account the dependence of apparent viscosity of blood on vessel diameter and hematocrit (the Fahraeus-Lindqvist effect), the reduction of intravascular hematocrit relative to the inflow hematocrit of a vessel (the Fahraeus effect), and the disproportionate distribution of red blood cells and plasma at arteriolar bifurcations (phase separation). The model was used to simulate flow in three microvascular networks in the rat mesentery with 436,583, and 913 vessel segments, respectively, using experimental data (length, diameter, and topological organization) obtained from the same networks. Measurements of hematocrit and flow direction in all vessel segments of these networks tested the validity of model results. These tests demonstrate that the prediction of parameters for individual vessel segments in large networks exhibits a high degree of uncertainty; for example, the squared coefficient of correlation between predicted and measured hematocrit of single vessel segments ranges only between 0.15 and 0.33. In contrast, the simulation of integrated characteristics of the network hemodynamics, such as the mean segment hematocrit or the distribution of blood flow velocities, is very precise. In addition, the following conclusions were derived from the comparison of predicted and measured values: 1) The low capillary hematocrits found in mesenteric microcirculatory networks as well as their heterogeneity can be explained on the basis of the Fahraeus effect and phase-separation phenomena. 2) The apparent viscosity of blood in vessels of the investigated tissue with diameters less than 15 microns is substantially higher than expected compared with measurements in glass tubes with the same diameter.

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