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Simulation of Metabolic Blood Flow Regulation by Wall-Derived and Red-Blood-Cell-Derived Mechanisms: Responses to Hemodilution

Oxygen exchange between blood and tissue occurs primarily in the microcirculation, which has a heterogeneous structure with wide variation in vessel geometry and flow rates. Blood flow in the microcirculation is regulated according to local metabolic demands of the tissue; however, the mechanism for this regulation is not entirely known.

The purpose of this investigation is to analyze the effects of metabolic flow regulation by signals derived from the vessel wall and derived from red blood cells, in response to a reduction in systemic hematocrit (red blood cell volume fraction). A theoretical model is used to simulate blood flow, oxygen transport, and flow regulation in microvascular networks with realistic heterogeneous structures. Flow regulation is modeled based on length-tension characteristics of vascular smooth muscle, and includes myogenic, shear-dependent, and metabolic responses. If the hematocrit is reduced (hemodilution), the initial effects (before active diameter changes) are increased blood flow rates due to the reduction in apparent viscosity, but decreased red blood cell fluxes. If the metabolic signal is assumed to originate solely from a red-blood-cell-dependent mechanism, the model predicts that flow regulation will then cause a reduction in blood flows and further decreases in red blood cell fluxes. If the metabolic signal is assumed to originate instead from a vessel-wall-dependent mechanism, flow regulation causes a further increase in flow, such that the initial decrease in red blood cell flux is partially reversed. These findings suggest that a red-blood-cell-independent mechanism of metabolic flow regulation is required for an appropriate physiological response to hemodilution. Supported by NIH grant HL070657.