ROLES OF OXYGEN-DEPENDENT ATP RELEASE BY RED BLOOD CELLS AND CONDUCTED RESPONSES IN METABOLIC REGULATION OF BLOOD FLOW

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A proposed mechanism for metabolic flow regulation involves the oxygen-dependent release of ATP by red blood cells, which triggers an upstream conducted response signal and arteriolar vasodilation. To analyze this mechanism, a theoretical model is used to simulate the variation of oxygen and ATP levels along a pathway of seven representative segments, including two vasoactive arteriolar segments. An expression for the conducted response signal is defined by integrating the ATP concentration along the vascular pathway, taking into account exponential decay of the signal in the upstream direction. Arteriolar tone depends on the conducted metabolic signal and on local wall shear stress and wall tension. Arteriolar diameters vary according to changes in the passive characteristics and active responses of the vessel wall. In the model, tone and diameter are treated as time-dependent variables and are described by a system of ordinary differential equations. For some pressure and oxygen demand levels, vessel tone and diameter oscillate with time. This model prediction corresponds to vasomotion, a biological phenomenon in which vessels undergo slight rhythmic variations in their diameter. The model also predicts that combining the conducted, myogenic, and shear-dependent responses can account for a nearly 10-fold increase in perfusion in response to a 20-fold increase in oxygen demand.