

THEORETICAL ANALYSIS OF OXYGEN-DEPENDENT ATP RELEASE BY RED BLOOD CELLS IN THE MICROCIRCULATION Julia C. Arciero¹ and Timothy W. Secomb^{1,2} ¹Program in Applied Mathematics, ²Department of Physiology, University of Arizona, Tucson AZ 85721

Experimental evidence has shown that red blood cells (RBCs) release ATP at a rate dependent on their oxyhemoglobin saturation level and that this oxygen sensing mechanism may play a role in blood flow regulation. Here, a theoretical model is presented to predict the amount of ATP released in a capillary as a function of blood flow rate and tissue oxygen demand. A Krogh cylinder model is used to calculate the decline in saturation along a capillary. Release rate of ATP is expressed as a decreasing linear function of oxyhemoglobin saturation based on experimental data. Assuming uniform oxygen consumption gives the following quadratic variation of the increase of ATP level, C , with blood transit time, T : $C = aT + bMT^2$. Thus, ATP levels increase with oxygen consumption rate, M . The constants a and b depend on the rates of ATP release at 0% saturation (1.4×10^{-9} mol/s/cm³) and 100% saturation (1.53×10^{-10} mol/s/cm³), discharge hematocrit (0.4), tube hematocrit (0.3), initial saturation level (0.98), capillary diameter (6 μ m), and the oxygen capacity of RBCs (0.5 cm³ O₂/cm³). Evaluating this equation at these values and for $T = 1$ s predicts C values that vary from 0.1 M for a low consumption rate ($M = 1$ cm³ O₂/100 cm³/min) to 0.4 M for a high consumption rate ($M = 16.9$ cm³ O₂/100 cm³/min). C values in this range have been observed in human knee-extensor exercise and have been shown to cause diameter increases in upstream vessels via conducted responses. These results support the hypothesis that oxygen-dependent ATP release is a potential mechanism for the regulation of blood flow in response to varying metabolic demand in tissue.