Letter to the editor: “The plausibility of arterial-to-venous oxygen shunting in the kidney: it all depends on radial geometry”

Roger G. Evans,1 David W. Smith,2 Zohaib Khan,2 Jennifer P. Ngo,1 and Bruce S. Gardiner2

1Department of Physiology, Monash University, Melbourne, Australia; and 2School of Computer Science and Software Engineering, The University of Western Australia

TO THE EDITOR: We read with great interest the recent paper by Olgac and Kurtcuoglu (5) entitled “Renal oxygenation: preglomerular vasculature is an unlikely contributor to renal oxygen shunting.” We commend the authors on their careful approach to the problem of oxygen transport in the renal cortex. The authors’ model simulations support an important contribution of oxygen delivery to tissue from the pre-glomerular vasculature, particularly under conditions of hyperoxemia and hemodilution, or when oxygen consumption is high in relation to oxygen delivery. This phenomenon has been well documented in other tissues, but this appears to be the first attempt at the problem in the kidney. We also believe that the concept of advection-facilitated diffusion, which appears to allow the simulations of the model to be reconciled with the experimental observations of Schurek and colleagues (6) and Johannes and colleagues (1), represents an important concept to explore in the field.

The authors also conclude from their simulations that “the amount of pre-glomerular arterial-to-venous (AV) oxygen shunting is negligible.” We believe that the authors have overinterpreted their findings. It is not surprising to us that the authors’ model did not provide any evidence of AV oxygen shunting, since the “checkboard pattern” of arteries and veins adapted for the vascular geometry would be expected to preclude this phenomenon (Fig. 1). In our recent analysis of oxygen diffusion in the vicinity of artery-vein pairs, over a range of cross-sectional configurations, we concluded that the presence of oxygen sinks of any kind (e.g., tubules or capillaries) between an artery-vein pair should prevent AV oxygen shunting (4) and that shunting would be strongly dependent on the degree of wrapping by veins on arteries. Without wrapping, our models predicted little to no shunting. The model of Olgac and Kurtcuoglu (5) is generally based on an assumption that there are oxygen sinks between all artery-vein pairs. Yet, the critical feature of the renal cortical circulation, unlike the circulation of skeletal muscle, is that a proportion of arteries are partially wrapped by their associated vein, so that oxygen sinks (tubules and capillaries) are excluded from intervening space across which oxygen might diffuse and diffusion distances are very short (∼15 μm) (Fig. 1). The phenomenon of wrapping is particularly prominent in larger vessels (≥50 μm in diameter), although wrapped vessels can be observed, with variable frequency, throughout the cortical circulation (4). We propose that any model aimed toward testing the plausibility of AV oxygen shunting should include the phenomenon of wrapping, and certainly should not rely on a lumped average of diffusion distances between artery-vein pairs.

The seminal observations that relate to the concept of AV oxygen shunting were obtained more than 50 years ago by Matthew Levy and colleagues (3). They found that the transit time for oxygen across the renal circulation was considerably shorter than that for labelled erythrocytes. Olgac and Kurtcuoglu (5) state that “Levy and Saucedo pointed to either the peritubular capillaries in the cortex or the vasa recta in the medulla as the location of potential oxygen shunting, favoring the latter on the basis of their anatomic arrangement.” However, Levy and Imperial (2) later found that the difference in transit time between oxygen and labeled erythrocytes was maintained when the renal medulla was cooled, thus greatly reducing medullary perfusion and the driving force for oxygen shunting in the medulla, medullary oxygen consumption. Thus we maintain that the experimental findings of Levy and colleagues can only be satisfactorily explained by diffusive shunting of oxygen between arteries and veins in the renal cortex.

We believe the jury must remain out on the question of whether AV oxygen shunting is an important phenomenon in the regulation of intrarenal oxygenation. Two lines of research are required to resolve this issue. First, we must develop experimental methods, perhaps along the lines of Levy and colleagues’ pulse experiments, to quantify this phenomenon. At the very least, we need to quantify the cross-sectional geometry of the artery-vein pairs throughout the kidney. Second, we must develop computational models, based on realistic...
vascular geometry, to generate realistic estimates of the magnitude of AV oxygen shunting.

GRANTS
The authors’ work is funded by a grant from the Australian Research Council (DP140103045).

DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

REFERENCES