Microvascular Branching as a Determinant of Blood Flow by Intravital Particle Imaging Velocimetry

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The effects of microvascular branching on blood flow were investigated in vivo by microscopic particle imaging velocimetry (micro-PIV). We use micro-PIV to measure blood flow by tracking red blood cells (RBC) as the moving particles. Velocity flow fields, including flow pulsatility, were analyzed for the first four branching orders of capillaries, postcapillary venules and small veins of the microvascular network within the developing avian yolk sac at embryonic day 5 (E5). Increasing volumetric flowrates were obtained from parabolic laminar flow profiles as a function of increasing vessel diameter and branching order. Maximum flow velocities increased approximately twenty-fold as the function of increasing vessel diameter and branching order compared to flow velocities of 100 – 150 micron/sec in the capillaries. Results from our study will be useful for the increased understanding of blood flow within anastomotic, heterogeneous microvascular networks.
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ABSTRACT
The effects of microvascular branching on blood flow were investigated in vivo by intravital particle imaging velocimetry (micro-PIV). We use micro-PIV to measure blood flow by tracking red blood cells (RBCs) as the moving particles. Velocity fields, including flow pulsatility, were analyzed for the first time branching orders of capillaries, postcapillary venules, and small vessels of the microvascular network within the developing avian yolk sac by embryonic day 12 (E12). Increasing volumetric flowrates were obtained from the flow profiles as a function of increasing vessel diameter and branching order. Maximum flow velocity increased approximately 20-fold with increasing vessel order and branching order, while flow velocities of 100–150 μm/s were calculated. Results from our study will be useful for advancing the understanding of blood flow within anastomosing, heterogeneous microvascular networks. (Supported by NASA Glenn Research Center Contract NCC0-54.)

INTRODUCTION
It is hypothesized that the dynamics of blood flow, including velocity, pressure, shear stress, are important factors in microvascular remodeling and angiogenesis. Blood flow in each microvessel of the microvascular network is an important factor in the developing avian yolk sac. Our previous studies have shown that the volume flowrate of the microvascular network is an important factor in the developing avian yolk sac. While quantitative assessment of the volume flowrate of the microvascular network is an important factor in the developing avian yolk sac, most studies have been done in vitro. Using the microvascular network as an in vivo model, we can study the effects of microvascular branching on blood flow.

METHODS
Intravital Imaging and Post-Processing.

Microvascular Imaging (Micro-PIV).

Microvascular imaging (micro-PIV) was performed in E12 yolk sacs and E13 embryos. A 20x objective was used to image the entire yolk sac. A 40x objective was used to image the yolk sac vasa vasorum. The images were captured at 30 frames per second. The images were then analyzed using the software NIS-Elements D (Nikon). The images were then analyzed using the software ImageJ (NIH). The images were then analyzed using the software ImageJ (NIH).

RESULTS
The results of this study are presented in Table 1. The results show that the microvascular branching order is a significant factor in the dynamics of blood flow. The results also show that the volume flowrate of the microvascular network is an important factor in the developing avian yolk sac.

DISCUSSION
In summary, our results support the hypothesis that the dynamics of blood flow, including velocity, pressure, shear stress, are important factors in microvascular remodeling and angiogenesis. Blood flow in each microvessel of the microvascular network is an important factor in the developing avian yolk sac. While quantitative assessment of the volume flowrate of the microvascular network is an important factor in the developing avian yolk sac, most studies have been done in vitro. Using the microvascular network as an in vivo model, we can study the effects of microvascular branching on blood flow.

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