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 flow rates 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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Patricia Parsons-Wingerter,1 Terri L. McKay,1 Mary B. Vickerman,1 Mark F. Wernet,1 Jerry G. Myers, Jr.,1 and Krishnan Radhakrishnan2

1 NASA Glenn Research Center, Cleveland, OH 44135, 2 University of New Mexico, School of Medicine, Department of Pathology and The Cancer Research & Treatment Center, Albuquerque, NM 87131

ABSTRACT

The objective of this study was to investigate by intravital particle image velocimetry (PIV) the relationship between microvascular branching and blood flow in the rabbit ear. By combining PIV with intravital microscopy, we were able to resolve the complex three-dimensional architecture of the microvasculature. The results of this study indicate that microvascular branching is a determinant of blood flow in the rabbit ear.

INTRODUCTION

Blood flow in the microvasculature is a complex phenomenon that is determined by the interplay of several factors, including vessel geometry, blood viscosity, and blood pressure. The branching pattern of the microvasculature is an important determinant of blood flow, as it influences the distribution of blood flow and oxygen delivery to the tissue. Previous studies have shown that changes in microvascular branching can affect blood flow and oxygen delivery, but the exact relationship between branching and blood flow remains unclear. The objective of this study was to investigate the relationship between microvascular branching and blood flow using intravital particle image velocimetry (PIV).

METHODS

Intravital Imaging and Post-Processing. Fertilized zebrafish embryos (Columnaris sp.) were cultured in a 2.5-liter beaker containing embryo medium (E3). The yellow vessels, which transmit blood pumped by the embryonic heart, are visible to the naked eye. The embryos were then transferred to a petri dish containing embryo medium and placed on a stage of a confocal microscope. A Plan Apochromat 40x1.25 NA objective lens was used to acquire high-resolution images of the microvasculature. The images were then analyzed using a custom-written image analysis software to quantify the microvascular branching pattern.

Microvascular Particle Imaging Velocimetry (PIV). PIV was performed on live zebrafish embryos using the LaserScan PIV system. The PIV system consists of a laser, a high-speed camera, and a computer for data acquisition and analysis. The laser emits a sheet of light that is passed through a series of optical filters to create a spatially uniform laser sheet. The light sheet is then focused onto the sample using a high-numerical aperture objective lens. The light scattered by particles in the flow field is then captured by the camera, which is positioned perpendicular to the light sheet. The images are then analyzed using a custom-written image analysis software to quantify the microvascular branching pattern.

RESULTS

The results of this study indicate that microvascular branching is a determinant of blood flow in the zebrafish embryo. The velocity profiles measured in the microvasculature were found to be consistent with the theoretical predictions of laminar and turbulent flow. The results of this study provide important insights into the complex relationship between microvascular branching and blood flow, and suggest that microvascular branching is an important determinant of blood flow in the zebrafish embryo.