A high order DG scheme for one-dimensional blood flow in networks of human vessels

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Computational Fluid Dynamics (CFD) is emerging as a tool for better assessment and management of human vascular diseases. However, CFD calculations are often restricted to a small arterial zone and the solution is sensitive to boundary conditions prescribed. A 1D simulation of the complete vessel network, THINkS (Total Human Intravascular NetworK Simulation), is introduced to better describe the boundary conditions and to provide an overall flow information of the complex vessel network.

As the governing equations for the blood flow in human vessel system can be casted in the same form as the gas dynamic equations, the high order DG scheme can be modified to solve the hemodynamic equations. THINkS consists of a simulation of 85 major arteries, 158 major veins, 43 arterial and 77 venous junctions. Blood flow in arterioles, capillaries and venules is modeled using lumped parameter models, or the 0D models, which are modeled using the connection of a number of capacitors, resistors and inductors to represent the real physics. The model used a simple 0D model for 20 one-artery-to-one-vein micro circulations and 4 other 0D models for 7 complex arteries-to-veins micro circulations. Moreover, a 4-chamber 0D model for the heart is used to allow blood to pump from superior vena cava I and inferior vena cava I veins, through the pulmonary system, and discharge back to the ascending aorta artery. In addition to the 4 valves inside the heart, there are also 15 venous valves used in the venous system.

THINkS calculates the complete human blood network circulation and it indicated usefulness of the model in predicting the trends of cerebral flow patterns. The solutions of THINkS were validated with a number of in vitro and in vivo experimental data and the agreement was excellent. A comparison with experiments for the impact of incomplete circle of Willis (CoW) to the flow patterns was also made and the trend shows an excellent agreement with reported data. THINkS allows for more accurate boundary conditions for 3D zonal-based CFD calculations. Our aim is to use THINkS to generate accurate flow assessments, guide treatment plans, and more reliably predict risks associated with vascular lesions.