

A ONE-DIMENSIONAL FINITE ELEMENT METHOD COUPLED TO MORPHOMETRY-BASED DOWNSTREAM TREES FOR SIMULATION OF BLOOD FLOW IN PULMONARY ARTERIES

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The development of predictive models of the cardiovascular system for use in planning treatments of cardiovascular disease can be accomplished using subject-specific anatomic models created from medical imaging data and numerical methods to model blood flow in alternative surgical and medical procedures [1]. Challenges in this process include the limited spatial resolution of imaging techniques and the need for realistic outlet boundary conditions for flow simulations. We have developed an approach to define impedance boundary conditions for subject-specific models based on morphometric data, which include empirical lengths, radii, and connectivity of blood vessels of a vascular tree. Our method employs a stabilized, space-time finite element method to solve the nonlinear one-dimensional equations of blood flow in the major arteries subject to impedance outlet boundary conditions [2, 3]. This method is applied to model blood flow in the pulmonary arteries. A subject-specific anatomic model is created from contrast-enhanced magnetic resonance angiography data, and flow at the inlet is prescribed from cine phase-contrast MRI data. The radius of each outlet of the image-based model is used to initialize the construction of a downstream vascular tree. Morphometric data from a human lung is used to define the downstream trees to the pre-capillary level [4]. The input impedance of this tree is computed with a recursive method based on the characteristic impedance from Womersley's model of pulsatile flow in an elastic tube and published compliance coefficients [5]. Results of simulations of blood flow in porcine and human pulmonary arteries will be presented.

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References

- [1] C. Taylor, M. Draney, J. Ku, D. Parker, B. Steele, K. Wang, and C. Zarins, "Predictive Medicine: Computational Techniques in Therapeutic Decision-Making," *Computer Aided Surgery*, v. 4, p. 231-247, 1999.
- [2] J. Wan, B. Steele, S. Spicer, S. Strohsand, G. Feijoo, T. Hughes, and C. Taylor, "A One-Dimensional Finite Element Method for Simulation-Based Medical Planning for Cardiovascular Disease," *Computer Methods in Biomechanics & Biomedical Engineering*, v. 5, p. 195-206, 2002.
- [3] B. Steele, J. Wan, J. Ku, T. Hughes, and C. Taylor, "In Vivo Validation of a One-Dimensional Finite Element Method for Predicting Blood Flow in Cardiovascular Bypass Grafts," *IEEE Transactions on Biomedical Engineering*, v. 50, no. 6, 2003.
- [4] W. Huang, R. Yen, M. McLaurine, and G. Bledsoe, "Morphometry of the Human Pulmonary Vasculature," *Journal of Applied Physiology*, v. 81, p. 2123-2133, 1996.
- [5] W. Milnor, *Hemodynamics* (2nd ed.), Williams & Wilkins, Baltimore, 1989.