SIMULATION-BASED MEDICAL PLANNING FOR CARDIOVASCULAR DISEASE

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At every stage of the circulatory system, whether blood is swirling in the heart or streaming through the capillary vessels, a range of mathematical models have been employed to quantify fluid mechanical conditions. These models, ranging from lumped parameter, one-dimensional wave propagation, and three-dimensional numerical methods, can all be used with effect to describe velocity and pressure fields. Computational methods were first applied to compute velocity and pressure fields in idealized, generic models of vascular anatomy and physiology [1]. With the development of modern three-dimensional imaging techniques, especially Magnetic resonance imaging, it is now possible to quantify blood flow in subject-specific anatomic and physiologic models. The construction of subject-specific geometric models from medical imaging data has enabled an entirely new application of cardiovascular fluid mechanics, namely predicting changes in blood flow resulting from possible therapeutic interventions for individual patients [2-4]. To support predictive medicine applications in cardiovascular surgery we have developed a Simulation-Based Medical Planning system including techniques to: (i) construct geometric models from three-dimensional magnetic resonance imaging (MRI) and computed tomography (CT) data, (ii) extract preoperative physiologic data from cine phase contrast magnetic resonance imaging data, (iii) modify the preoperative model to incorporate an operative plan, (iv) assign boundary conditions appropriate for the postoperative state, (v) discretize these models using an automatic mesh generator, (vi) solve the governing 3D or 1D equations using finite element methods, and (vii) visualize and quantify resulting physiologic information. Recent progress in developing Simulation-Based Medical Planning tools for cardiovascular treatment planning is presented followed by a discussion of the challenges and opportunities that lie ahead. Experimental validation of numerical methods for modeling blood flow will be described [5].

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References

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