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MULTISCALE MODELING AND OPTIMAL TREATMENT PLANNING IN PEDIATRIC CARDIOLOGY

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Cardiovascular blood flow simulations offer a powerful, non-invasive means to augment the knowledge gained from medical imaging and clinical measurements to positively impact clinical decision-making. In particular, simulations fill two crucial gaps in current clinical capabilities. First, despite the enormous recent advances in medical imaging, leading to ever-increasing resolution, imaging alone is not a predictive tool. Simulations now offer a powerful means to systematically test and optimize new surgical and device concepts at no risk to the patient, and to customize designs for individual patients. Second, and perhaps equally importantly, simulations can be used to characterize the in vivo mechanical environment, providing missing data on hemodynamics and mechanical stimuli that are not directly attainable from medical imaging.

We will discuss our recent methodological advances that aim to increase the rigor and clinical utility of cardiovascular simulations, including (1) automated surrogate-based derivative-free optimization algorithms to customize treatments for individual patients, (2) incorporating uncertainty quantification to systematically quantify confidence in simulation predictions, and (3) developing multi scale modeling capabilities that couple lumped parameter networks with the 3D Navier Stokes solver to capture the dynamic interplay between local geometry and global physiologic response. We will then present examples from pediatric cardiology, namely single ventricle heart surgery, that illustrates the potential clinical impact of these tools. Single ventricle heart patients typically undergo a three-staged surgical repair to route the venous return directly to the pulmonary arteries, separating the systemic and pulmonary circulations. We will demonstrate application of the above tools on the complex three-staged (BT-shunt, Glenn, Fontan) single ventricle surgical palliation. Issues and goals related to clinical translation and validation will be discussed.

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