DFD11-2011-001698

Abstract for an Invited Paper
for the DFD11 Meeting of
the American Physical Society

Multiscale modeling and surgical planning for single ventricle heart patients

ALISON MARSDEN, Mechanical and Aerospace Engineering, University of California San Diego, CA, USA

Single ventricle heart patients are among the most challenging for pediatric cardiologists to treat, and typically undergo a palliative course of three open-heart surgeries starting immediately after birth. We will present recent tools for modeling blood flow in single ventricle heart patients using a multiscale approach that couples a 3D Navier-Stokes domain to a 0D closed loop lumped parameter network comprised of circuit elements. This coupling allows us to capture the effect of changes in local geometry, such as shunt sizes, on global circulatory dynamics, such as cardiac output. A semi-implicit numerical method is formulated to solve the coupled system in which flow and pressure information is passed between the two domains at the inlets and outlets of the model. A finite element method with outflow stabilization is applied in the 3D Navier-Stokes domain, and the LPN system of ordinary differential equations is solved numerically using a Runge-Kutta method. These tools are coupled via automated scripts to a derivative-free optimization method. Optimization is used to systematically explore surgical designs using clinically relevant cost functions for two stages of single ventricle repair. First, we will present results from optimization of the first stage Blalock Taussig Shunt. Second, we will present results from optimization of a new Y-graft design for the third stage of single ventricle repair called the Fontan surgery. The Y-graft is shown, in simulations, to successfully improve hepatic flow distribution, a known clinical problem. Preliminary clinical experience with the Y-graft will be discussed.