Title: A MULTISCALE MODEL OF THE NEONATAL CIRCULATORY SYSTEM FOLLOWING HYBRID NORWOOD PALLIATION

Hypoplastic left heart syndrome (HLHS) is a complex cardiac malformation in neonates suffering from congenital heart disease and occurs in nearly 1 per 5000 births. HLHS is uniformly fatal within the first hours or days after birth as the severely malformed anatomies of the left ventricle, mitral and aortic valves, and ascending aorta are not compatible with life. The regularly implemented treatment, the Norwood operation, is a complex open heart procedure that attempts to establish univentricular circulation by removing the atrial septum (communicating the right and left ventricles), reconstructing the malformed aortic arch, and connecting the main pulmonary artery into the reconstructed arch to allow direct perfusion from the right ventricle into the systemic circulation. A relatively new treatment being utilized, the Hybrid Norwood procedure, involves a less invasive strategy to establish univentricular circulation that avoids a cardiopulmonary bypass (heart-lung machine), deliberate cardiac arrest, and circulatory arrest of the patient during the procedure. The resulting systemic-pulmonary circulation is unconventional; blood is pumped simultaneously and in parallel to the systemic and pulmonary arteries after the procedure. Cardiac surgeons are deeply interested in understanding the global and local hemodynamics of this anatomical configuration. To this end, a multiscale model of the entire circulatory system was developed utilizing an electrical lumped parameter model for the peripheral or distal circulation coupled with a 3D Computational Fluid Dynamics (CFD) model to understand the local hemodynamics. The lumped parameter (LP) model is mainly a closed loop circuit comprised of RLC compartments that model cardiac function as well as the viscous drag, flow inertia, and compliance of the different arterial and venous beds in the body. A system of 32 first-order differential equations is formulated and solved for the LP model using a fourth-order adaptive Runge-Kutta solver. The output pressure and flow waveforms obtained from the LP model are imposed as boundary conditions on the CFD model. Coupling of the two models is done through an iterative process where the parameters in the LP model are adjusted to match the CFD solution. The CFD model domain is a representative HLHS anatomy of an infant after undergoing the Hybrid Norwood procedure and is comprised of the neo-aorta, pulmonary roots, aortic arch with branching arteries, and pulmonary arteries. The flow field is solved over several cardiac cycles using an implicit-unsteady RANS equation solver with the k-epsilon turbulence model.

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The public is welcome to attend.