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**Numerical methods for congenital cardiovascular treatment exploration  
of a new surgical option**

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Single ventricle heart defects including hypoplastic left heart syndrome (HLHS), pulmonary atresia/intact ventricular septum and tricuspid atresia are among the most severe congenital heart malformations. The patients uniformly die without treatment. Usually a three-staged surgery is performed. The first stage consists of establishing stable sources of aortic and pulmonary blood flow, in a Norwood procedure or variant thereof. In the second stage, the bidirectional Glenn procedure, the superior vena cava (SVC) is disconnected from the heart and reimplanted into the pulmonary arteries (PA). In the third and final stage, the Fontan procedure, the inferior vena cava (IVC) flow is channeled to the PAs via an extracardiac Gore-Tex graft or a lateral tunnel bypassing the right heart. Despite high early survival rates for the Fontan procedure, long term outcomes remain unsatisfactory. Previous studies have shown that the geometry plays an important role in the Fontan circulation. With the advances in numerical methods and medical imaging, computational fluid dynamics(CFD) has been widely used to study cardiovascular problems and improve surgical designs. Particularly, a Y-shaped graft has been proposed to replace the traditional tube-shaped graft. Simulation-based studies have shown that the Y-graft improves energy loss, hepatic flow distribution and the SVC pressure. In this talk, optimal designs for the Y-graft, which couple a derivative-free optimization algorithm to a 3D finite element flow solver, will be introduced. Then, postoperative validations and evaluations for a clinical pilot study using Y-graft will be presented and discussed. Our results emphasize that a customized optimal design is necessary to achieve the superiority of the Y-graft.

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