New technique to improve blood flow in children born with one functional ventricle shows promise in pilot study

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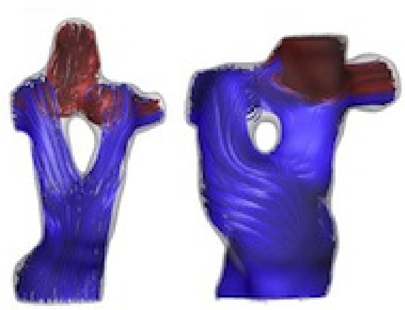

Fluid dynamics modeling of blood flow within two patients' reconstructed grafts, with structural data obtained via magnetic resonance imaging.

(Medical Xpress) -- Two in every thousand babies born in the United States start life with just one functional ventricle, or pumping chamber, instead of the normal two. These babies typically undergo a series of two or three open-heart surgeries, culminating in a “total cavopulmonary connection” (TCPC), which is known as the Fontan procedure. During this process, surgeons redirect the circulation to allow oxygen-poor blood to flow from the body directly to the lungs passively, without the benefit of a pumping chamber.

A team of surgeons and university researchers recently reported promising results from a novel surgical connection intended to streamline blood flow between the heart and lungs of such infants.

Typically, the final stage of the Fontan procedure is performed by connecting a cylindrical conduit to the pulmonary arteries, forming a 'T' shaped junction. In a pilot study, six patients at Children's Healthcare of Atlanta received a commercially available Y-shaped conduit for their Fontan procedure instead of the cylindrical conduit to create a smoother transition of the blood flow to the pulmonary arteries. Postoperative imaging data from five of the patients indicated improved blood flow distribution and similar energy efficiency when compared with computer simulations of two alternative connections the patients could have received instead of a Y-graft.

"Based on improved energy characteristics predicted by computer modeling for the Y-shaped conduit, we felt it was time to try it in the clinical realm," said Kirk Kanter, M.D., chief of cardiothoracic surgery at Children's Healthcare of Atlanta and professor of surgery at Emory University School of Medicine, who performed the operations. "The pilot study revealed that surgical implementation of a Y-graft for Fontan procedures is feasible and promising because early outcome was good in these patients."

The surgical procedure and the postoperative outcomes were detailed in two articles recently published online in the *Journal of Thoracic and Cardiovascular Surgery*. The research was funded by the National Institutes of Health and the American Heart Association.

Also involved in the study were Ajit Yoganathan, Ph.D., Regents' professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University; W. James Parks, M.D., associate professor of pediatrics and radiology at Emory University and Children's Healthcare of Atlanta at Egleston; Mark A. Fogel, M.D., director of cardiac magnetic resonance at The Children's

Hospital of Philadelphia; Georgia Tech School of Interactive Computing Professor Jarek Rossignac, Ph.D., and Coulter Department graduate student Christopher Haggerty.

The TCPC typically creates a four-way intersection. Blood from the upper half of the body enters the intersection from the top and blood from the lower body enters from the bottom. The blood flows collide and mix in the intersection before they are split and redirected 90 degrees toward the left or right pulmonary arteries. The collision of blood from the two veins at the intersection causes inefficient blood flow.

Because the blood flows passively from the body to the lungs without being pumped by the heart, it is assumed that any energy inefficiencies inherent in the construction of the Fontan pathway may translate into diminished life expectancy and quality of life.

Substituting a Y-shaped conduit should avoid the collision of blood in the intersection and enable a smooth and streamlined transition of the blood to the pulmonary arteries, which carry deoxygenated blood from the heart to the lungs.

For the pilot study, Kanter surgically implanted a commercially available Y-graft, made of a synthetic polymer called polytetrafluoroethylene, in each patient to direct flow from the lower half of the body to the left and right pulmonary arteries. This was a variation of a conduit design, called the Optiflo, which was patented by Yoganathan and colleagues for its ability to efficiently direct an even distribution of blood flow to the left and right pulmonary arteries.

After surgery, the researchers acquired cardiovascular images to evaluate the operative connections. The images allowed Yoganathan and Haggerty to evaluate the hemodynamic outcomes of the surgical procedures for five of the patients and compare them to the simulated outcomes of two alternative connections patients could have received instead of a Y-graft.

They used the images to model blood flow through the arteries under resting and exercise conditions. These simulations assessed the robustness of each connection geometry because small inefficiencies under resting conditions may be amplified with higher flows.

Results for the patients who received the Y-graft showed balanced distribution of flow to both pulmonary arteries with minimal flow disturbance. The resistance of the vessels to blood flow at the connections varied considerably among patients, but the Y-graft results demonstrated resistance levels similar to the alternative connections in four of the five patients and marked improvement in the remaining patient.

“We found desirable flow distribution characteristics using the Y-graft, but the flow efficiency performance fell short of the outcomes we previously predicted,” said Yoganathan. “The results suggest that the Y-graft performs as well as the standard procedure with a T-graft even when the Y-graft design is theoretically sub-optimal.”

The study allowed the researchers to identify ways of refining the surgical technique that should help them improve the theoretical efficiency of the conduit design. Before conducting future clinical trials, the research team plans to address two features of the Y-graft design that limited hemodynamic efficiency in the current study. They plan to introduce curvature to the Y-graft branches and extend the distance between the Y-graft branches to reduce continued interaction and mixing between the two blood streams.

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