Another step toward intelligent surgical planning

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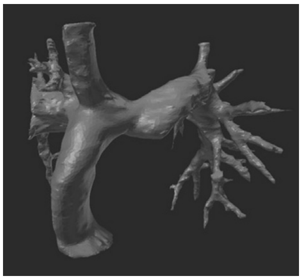

Can the surgeon reproduce a preoperatively designed Fontan model?

Central Message

Computational surgical planning can be especially useful in the performance of complex Fontan operations, with the hope of reducing the incidence of persistent arteriovenous malformations.

See Article page 1146.

The applications of computational fluid dynamics (CFD) to cardiovascular medicine and surgery just keep getting better. Trusty and colleagues[1] examine a way that CFD could be used to plan "complex" Fontan operations. These patients are those whose anatomy does not "guarantee" a relatively even distribution of hepatic blood flow (HBF) to both lungs with a conventional extracardiac conduit or lateral tunnel. The typical example would be an interrupted inferior vena cava with azygous continuation to a left superior vena cava and a right-sided hepatic veins-to-right pulmonary artery conduit. Inadequate HBF to a lung may result in pulmonary arteriovenous malformations, which cause cyanosis and are difficult to treat.

Trusty and colleagues[1] had each of 7 patients undergo preoperative magnetic resonance imaging (MRI) and catheterization, from which anatomic, flow, and pressure waveform data were used to construct an anatomic and physiologic computational model. The model was modified by the addition of a computer aided design–generated surgical reconstruction (with surgeon input) corresponding to the "best guess" of the optimal surgical approach to achieve adequate HBF to both lungs. The operation was then performed, the surgeon presumably trying to reproduce the optimal preoperative model. Postoperatively, MRI and catheterization were repeated, and another computational model was generated. The difference between the preoperatively and postoperatively calculated HBF to each lung was recorded. Trusty and colleagues[1] found a mean difference of −17% with a range from 0% to 45%. By running other simulations, they found that much of the difference was due to anatomic and not flow-related differences between the preoperative and postoperative models. The authors convincingly argued that CFD-based surgical planning can predict an acceptable postoperative result (adequate HBF) with reasonable fidelity.

The study by Trusty and colleagues[1] is important. Any surgeon who has performed enough Fontan operations has had the misfortune of experiencing the appearance or persistence of pulmonary arteriovenous malformations after a Fontan completion operation. Even an anastomosis of the hepatic conduit to the pulmonary bifurcation does not guarantee balanced, adequate hepatic flow to both lungs. CFD can predict this problem and, by simulating different models, can reveal a configuration that will work. If one thinks the solutions are intuitively obvious, consider patient number 3 in the authors' article. Although the hemodynamic details are not provided, it is probable that in this patient the azygous vein and Fontan (hepatic) conduit were nearly equally pressurized by the pulmonary resistance, resulting in little if any pressure gradient to drive flow through the hepatic-to-azygous graft. As the authors point out, CFD has the power to exactly calculate the complex interactions among multiple flows, and between the anatomy and these flows, to minimize the chance of acting on fallacious intuition.

The greatest challenge, as emphasized by Trusty and colleagues,[1] is for the surgeon to reproduce the recommended operation with good fidelity. The surgeon must be intimately involved in the preoperative modeling, because he/she knows best what configuration is surgically feasible. On the other hand, the imaging team must provide accurate representation of the directly relevant anatomic structures, including the *surrounding* anatomy, that is, any structure that may impede the optimal placement of the graft(s). The surgeon must then be committed to making measurements to place grafts in positions and angles that match those of the preoperative model.

Could this approach become standard of care? The approach requires protocolized measurements of the relevant quantities from MRI and catheterization, a standardized, well-validated CFD software program, personnel to supervise model generation, and surgeon commitment to both generate a priori models and execute the optimal configuration in the operating room. This "package" will take time to gain traction, but it holds a key to better clinical care and should be pursued.

Reference

1. Trusty PM, Wei ZA, Slesnick TC, Kanter KR, Spray TL, Fogel MA, et al. The first cohort of prospective Fontan surgical planning patients with follow up data: how accurate is surgical planning? *J Thorac Cardiovasc Surg*. 2019;157:1146-55.