Computer-aided Design and Computational Fluid Dynamics for Virtual Surgery of Tetralogy of Fallot: A Promising Virtual Surgery Framework

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1. Background

Due to the anatomical variability of the pulmonary arteries (PA) in patients with tetralogy of Fallot (TOF), the patch repair (PR) procedure varies[1] and is often performed based on individual experience. The need for scientific evidence to guide patient-specific PR procedures is imperative. With the advance of computer technology, computer-aided design (CAD) and computational fluid dynamics (CFD), as engineering tools, get the broader application in cardiovascular research[2), 3)]. However, efficiently boosting the adoption of these tools in clinical practice requires further investigation and advocacy.

2. Methods

We proposed a virtual surgery framework equipped with CAD and CFD techniques, divided into a 1st trial and a 2nd trial. Initially, engineers perform the initial surgical design for TOF patients based on clinicians' experiences, in the 1st trial. In this case, Operation 1 involved enlarging the diameter of the narrow region from 8 mm into 14.75 mm, followed by related simulations. In the 2nd trial, based on the simulated results, engineers adjust the surgical design multiple times, changing the angle or diameter in Operation 2, 3 and 4. CFD technique was employed to obtain the hemodynamic performance of these models for optimizing the surgical design, including velocity streamlines and pulmonary blood flow distribution (%).

3. Results

Operation 1 resulted in a low-velocity stagnation area on the enlarged patch in front of the main pulmonary artery. Operation 2 minimized the area by adjusting the patch size, but the blood flow distribution remained suboptimal, similar to Operation 1. Operation 3 and 4 increased the angle α gradually, blood flow distribution approaching the normal value of a healthy child consequently. The optimal value in Operation 4 was 43%: 57%, nearly close to the normal value, as shown in Fig.1.

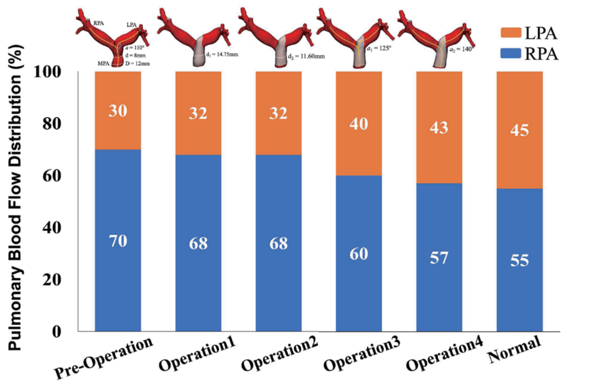

Fig 1　Pulmonary blood flow distribution of different surgical design

4. Conclusion and Originality

Integrating CAD with CFD techniques enables surgeons to explore various surgical designs and make informed decisions to improve the prognosis of TOF patients. Our virtual surgery framework, tailored for the PR procedure, enhances collaboration between doctors and engineers, thereby improving the decision- making process in clinical practice.

All authors have no COI to disclose.

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