The Role of Computational Modelling in Patients with Congenital Heart Disease

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Abstract

Interest in the application of engineering methods to problems in congenital heart disease (CHD) has gained increased popularity over the past decade. Computational fluid dynamics (CFD) is a technique of determining fluid flow by numerically solving its equations of motion. It has been a critical and invaluable tool in discovery, prediction, and validation of a wide variety of natural and artificial phenomena. In cardiovascular disease, CFD has been used to understand the contribution of flow disturbances to the evolution of atherosclerosis and risk factors for growth and rupture of aneurysms.

Increasingly, computational modelling and numerical simulations are used to help plan complex surgical and interventional cardiovascular procedures in children and young adults with CHD. It may aid in improving our understanding of the pathophysiology and mechanism of cardiovascular disease, in elucidating measures to treat these diseases, and in surgical planning [1].

From its origins, more than 30 years ago, surgical planning with analysis of flow hemodynamics and energy loss/efficiency has helped design and implement many modifications to existing techniques. The use of computational simulation to examine a broad range of congenital heart disease, including patients with single ventricle physiology and the associated surgical approaches ([2]-[8]), those with aortic coarctation ([9]-[14]), bicuspid aortic valve, Kawasaki disease [15], tetralogy of Fallot [16] or with double outlet right ventricle [17], as well as the effects of pacemaker implantation on vascular occlusion, or delineation of the biomechanical effects of implanted medical devices is now routinely

appearing in clinical journals within all paediatric cardiovascular subspecialties. Interventional planning is equally intriguing. Stent diameter, length, and location can be modelled preprocedurally, with finite element as well as CFD simulations performed to determine an ideal outcome [18],[19].

Over the last 15 years, considerable improvements were made in these calculations owing to (1) better resolution of magnetic resonance imaging, (2) improved computing power, and (3) the use of real patient data to configure the anatomy. Close collaboration between the clinicians and biomedical engineers is paramount to accurate representations and modelling. Despite the intensity of the work involved, surgical planning with computational modelling offers unique insights and tremendous potential for the care of patients with CHD, ultimately each patient's interventional procedure can be planned and analyzed preoperatively on the basis of their patient-specific characteristics to ensure optimal long-term outcomes.

In this presentation, we will review the techniques and principal finding of computational fluid dynamics studies as applied to a few representative forms of congenital heart disease.

Keywords: Hemodynamics, Computer modeling, Congenital heart disease.

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