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Computation of blood flow in the pulmonary bifurcation: towards a more effective treatment for adults with congenital heart disease

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Introduction

Adults with congenital heart disease represent an increasing population of patients that require repeated surgical interventions, most commonly for pulmonary valve replacement (PVR) and stenting [1]. Currently, the decision for treatment relies on symptoms, including arrhythmias and abnormal right ventricular volume and function [2], however the optimal timing for surgery remains unclear [3]. The aim of this work is to investigate the altered haemodynamic environment of the pulmonary bifurcation in adults with repaired tetralogy of Fallot, before and after pulmonary valve replacement. The overall objective is to derive a computational fluid dynamic metric to determine the optimal time for surgery. In this preliminary study, we present results in simplified geometries of the pulmonary trunk, focusing on the effects of geometry and flow conditions.

Methods

Blood flow simulations were performed in simplified models of the pulmonary bifurcation using a finite volume method solution. Physiological vessel dimensions and boundary conditions were used in the models, and blood flow was assumed steady, incompressible, and governed by the Newtonian Navier-Stokes equations. The effect of the bifurcation angle between the main pulmonary artery and its branches were studied and different Reynolds numbers were tested, representing healthy and diseased conditions.

Results & Discussion

Blood flow in the pulmonary bifurcation is strongly dependent on local geometric characteristics and haemodynamic conditions. Flow separation increases when the bifurcation angle and Reynolds number increase. In addition, the geometry has a significant effect on velocities and shear stresses developed on the vessel wall. Evaluation of these parameters can provide an insight into the underlying flow mechanisms of more complex 3D patient-specific geometries. Future work will involve time-dependent effects and anatomically-correct geometries, reconstructed from CT and MRI image data of adult patients with repaired tetralogy of Fallot that have or are about to undergo pulmonary valve replacement or stenting. Pre- and post- operative haemodynamic analysis is expected to establish new reliable metrics for a more accurate and timely assessment for PVR treatment in this particular group of patients and contribute towards better medical care.

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