P2427

The development of a computational fluid dynamics pipeline for the study of tetralogy of Fallot and coarctation of the aorta in a developing world context

L. Swanson[1], B. Owen[2], A. Revell[2], M. Ngoepe[1], A. Keshmiri[2], A. Deyranlou[2], T. Aldersley[3], J. Lawrenson[3], P. Human[4], R. De Decker[3], B. Fourie[5], G. Comitis[3], B. Mayosi[6], B. Keavney[7], L. Zuhlke[3]

[1]University of Cape Town, Mechanical Engineering, Cape Town, South Africa; [2]University of Manchester, School of Mechanical, Aerospace and Civil Engineering, Manchester, United Kingdom; [3]University of Cape Town, Department of Paediatrics & Child Health, Cape Town, South Africa; [4]University of Cape Town, Cardiovascular Research Unit, Cape Town, South Africa; [5]University of Stellenbosch, Department of Paediatrics & Child Health, Cape Town, South Africa; [6]University of Cape Town, Health Sciences Department, Cape Town, South Africa; [7]University of Manchester, Division of Cardiovascular Science, Manchester, United Kingdom

On behalf of Partnerships in Congenital Heart Disease in Africa (PROTEA)

Funding Acknowledgement: National Research Fund, British Heart Foundation, Newton Fund (UK MRC, South African Medical Research Council), University of Cape Town

Background: Tetralogy of Fallot (ToF) and coarctation of the aorta (CoA) each constitute approximately 7% of congenital heart disease (CHD) births worldwide. Compared to developed countries, developing countries have a disparate level of access to prompt diagnosis and treatment for these diseases. Computational fluid dynamics (CFD) approaches implemented on routinely available non-invasive imaging data may yield low-cost improvements to the management of these patients.

Purpose: The purpose of this research is to develop a patient-specific computational pipeline that allows the modelling of blood flow in diseased arteries of patients suffering from ToF and CoA. The project aims to prove the feasible use of broadly available imaging techniques - CT angiograms (CTA) and echocardiographs (echo) - for achieving this in low-to-middle income countries. The capability of the pipeline will be demonstrated through a qualitative study of the effects of different systemic to pulmonary shunt configurations used in the palliative treatment of ToF. In addition, the effects of idealised stent configurations on the blood flow through the aorta of a patient with CoA will be studied.

Methods: A retrospective search through the hospital database was conducted to select suitable CTA data for a CoA and ToF case. Data for patient A, a five-month-old child with typical CoA, and patient B, a twelve-month-old child with typical ToF who had a central shunt in place, was found. Echo data was obtained for patient A through an investigation protocol which focused on CFD application whereas there was no echo data available for patient B. As a result, idealised volume flow rate data was implemented for patient B. Geometries for patient A and patient B were extracted and volume discretisation was implemented for grid independence testing. The Navier-Stokes governing equations for fluid flow were solved using the open source software, OpenFOAM, for the transient case where inlet volume flow rate was defined for four cardiac cycles. Figure 1 shows key features of the flow in the shunt and pulmonary branches (A), the aortic arch (B), the inlet at the ascending aorta (C) and the descending aorta (D) for the geometry extracted from the data set of patient B.

Results and discussion: We have implemented CFD models which are able to qualitatively assess the favourable or unfavourable impact of different approaches to ToF and CoA repairs on the characteristics of blood flow in the aorta and pulmonary arteries. An echo investigation protocol has been developed and successfully applied. CTA studies have been shown as feasible sources of geometry data in spite of the restriction on quality by the important requirement for low doses of radiation in paediatric patients. This project represents progress towards an advanced tool that may be broadly implemented in both well-resourced and minimally-resourced hospitals.

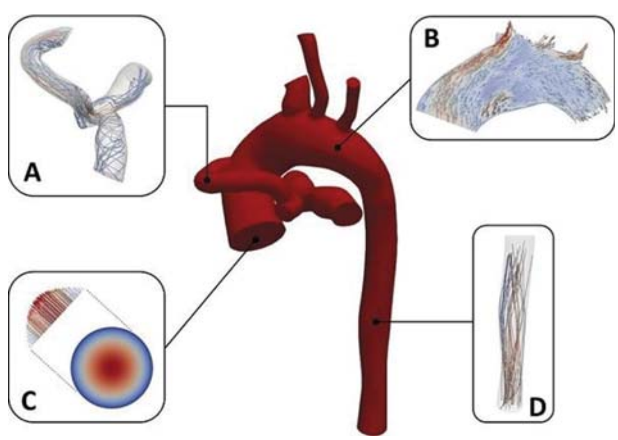

Figure 1. Key flow features of patient B