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A methodology to investigate the blood flow in patient-specific models of tetralogy of Fallot

Maria Boumpouli[1], Emilie Sauvage[2], Claudio Capelli[2], Silvia Schievano[2], Terence Gourlay[1], Asimina Kazakidi[1]

1. Department of Biomedical Engineering, University of Strathclyde, Glasgow, UK;
2. University College London, Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London UK

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Abstract

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease with a prevalence of 1 in 3000 live births [1]. Adults with repaired TOF are at risk of chronic complications including branch pulmonary stenosis and regurgitation, which may lead to dysfunction of the right ventricle and the pulmonary valve [2]. It is therefore important to improve our understanding of the haemodynamic environment in the pulmonary bifurcation of these patients for better evaluation of the disease and treatment. The focus of this study was to computationally investigate the blood flow in patient-specific geometries of the TOF pulmonary bifurcation. Three-dimensional models of the pulmonary junction were reconstructed from MRI images of patients with TOF. Flow data of the same patients were also retrospectively acquired with phase-contrast MRI (PC-MRI) and used at the boundaries of the models. Wall shear stress (WSS) values around the pulmonary junction were evaluated. An investigation of the effect of smoothing the geometries without losing the details of the curvature and angle of the branches was also conducted. All simulations were performed using a validated finite volume scheme in OpenFOAM®. There was a great variation in the morphology of the pulmonary bifurcation among the patients, and blood flow development was dependent on such characteristics. Time averaged WSS (TAWSS) values calculated with the through-plane 3D inlet velocity profile, obtained from PC-MRI data shared qualitatively similar characteristics with the TAWSS pattern obtained with a uniform time-dependent inlet velocity profile, based on the patient's pulsatile waveform. Patient-specificity is deemed necessary to better diagnose and treat patients with tetralogy of Fallot. Nevertheless, in the absence of flow data, a uniform velocity at the inlet can still capture the TAWSS at the pulmonary junction of the models. Future work will include a larger cohort of patients and possibly the correlation of the flow results with clinical outcomes.

References

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