Understanding the blood flow in realistic and idealised models of the pulmonary bifurcation

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Adults patients with congenital heart disease are at risk of chronic complications including dysfunction of the pulmonary valve and narrowing of the branch pulmonary arteries [1]. Understanding the hemodynamic environment of the pulmonary bifurcation in these patients, is of immense importance, to prevent the clinical consequences of abnormal lung development and elevated pulmonary vascular resistance [2]. The aim of this study is to numerically investigate the blood flow characteristics in the pulmonary trunk of adults with congenital heart defects. In this work, we present results from a parametric analysis conducted, to study the effect of variations in morphology and boundary conditions.

Blood flow simulations were performed in idealised and realistic geometries of the pulmonary arteries. The fluid was considered incompressible and governed by the Navier-Stokes equation. Local velocities, wall shear stress values and pressure ratios were evaluated in all cases. The flow was also examined in the case of a model with a static idealised pulmonary valve and by accounting the elasticity of arterial walls.

The computational results indicate that the hemodynamic environment and the wall shear stress distribution are affected by variations in morphology and boundary conditions. The pressure in the left pulmonary artery was found higher than the right and main arteries, but reduced in the presence of stenosis. Downstream pressure conditions altered the flow in the pulmonary arteries and explained realistic flow splits between the branches. Different flow patterns were also noticed when pulmonary valve and elasticity of arterial walls are included in the pulmonary arterial models.

Computational fluid dynamics is a powerful tool that has been utilised in this study to investigate blood flow in the pulmonary arteries under a range of geometrical characteristic and boundary conditions. Notable differences are noticed in the flow of the stenotic models or when pressure difference is assigned in the branch outlets. Modelling the pulmonary valve and the elasticity of the arterial wall are important parameters to consider in the computational models.

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References

1. McElhinney D.B. et al. The Annals of Thoracic Surgery 1998; 65:1120-1126.
2. Harris M.A. et al. Cardiovascular Imaging 2011; 4:506-513.