Blood flow in the pulmonary bifurcation under healthy and diseased conditions

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Adult patients with congenital heart disease are at risks of chronic complications including pulmonary regurgitation [1] and stenosis in the left pulmonary branch [2]. Long-term pulmonary stenosis is also associated with abnormal lung development and elevated pulmonary vascular resistance [3]. In this study, the haemodynamic environment of the pulmonary bifurcation is investigated, assuming different physiological and pathological cases based on various geometries and boundary conditions. Within the finite volume method framework of OpenFOAM®, blood flow simulations were performed in simplified two- and three-dimensional models of the pulmonary bifurcation. Newtonian and non-Newtonian blood rheology was considered for incompressible fluid flow governed by the Navier-Stokes equations. The simulation results demonstrated that the pulmonary arterial flow can be significantly affected by different geometrical characteristics and boundary conditions. Flow separation varied in models with different branch angle, origin, and obstruction. Local stenosis in the left pulmonary artery had a notable effect in the axial velocities and shear stresses developed on the vessel wall. Peripheral stenosis and pressure difference in the branch outlets resulted in variations in the branch flow splits, representative of pulmonary hypertension conditions. The branch pressure ratio was further analysed, based on disease severity, as an indicator of flow discrepancies between the different cases. The obtained results were comparable to flow simulations in a three-dimensional model, for both steady and unsteady flow. Future work will involve simulations in more complex patient-specific geometries from patients with congenital heart diseases. Peripheral resistances and patient-specific blood flow inlet waveform will be also considered.

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