Blood flow simulations in the pulmonary bifurcation for the assessment of valve replacement in adult patients with congenital heart disease

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Introduction

Adult patients with congenital heart disease comprise a growing population with complex cardiac conditions, among other ageing-associated diseases. This particular group of patients may undergo multiple surgical procedures in their lifetime, a significant number of which involves pulmonary valve replacement (PVR). The clinical decision for such surgical intervention is currently relying on symptoms, including arrhythmias, and measures of right ventricular dilatation, at e.g. 80-90 mL/m^2 end-systolic and 150-160 mL/m^2 end-diastolic volumes [1,2]. However, there is no common consensus on the reliability of these criteria, and more accurate and timely assessment for PVR treatment is necessary. The overall objective of this work is to investigate the altered haemodynamic environment in the adult with congenital heart defect, including pre- and post-operative conditions. Here, we show computational results in the pulmonary bifurcation with the scope to establish a novel and reliable metric for pulmonary valve replacement.

Methods

Within the finite volume method framework of the open-source library OpenFOAM [3], we implemented simplified models of the pulmonary trunk. This approach allows for direct interpretations of geometry and flow-dependent effects on local velocity and wall shear stress values. Blood flow results were obtained numerically solving the incompressible Newtonian Navier-Stokes equations, based on physiological boundary conditions and vessel dimensions.

Results and Discussion

The computational results reveal a strong dependence of blood flow development within the pulmonary bifurcation on specific geometrical characteristics and haemodynamic conditions. Increasing the angle of the bifurcation, increases flow separation and has an important effect on velocity and shear stresses developed on the vessel wall. The numerical study evaluates these parameters qualitatively and can provide an insight into the underlying flow mechanisms of more complex 3D patient-specific geometries. Future work will involve anatomically-correct reconstructions from CT and MRI image data of adult congenital heart patients that have or are about to undergo pulmonary valve replacement.

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References

[1] Lee C., et al. (2012). *Journal of the American College of Cardiology.* **60** p1005
[2] Buechel, E.R.V., et al. (2005). *European Heart Journal*. **26** p2721
[3] www.openfoam.com