6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

OPENING AND CLOSING BEHAVIOUR OF DIFFERENT PULMONARY VALVE DESIGNS

Harkamaljot S. Kandail[1]*, Marcelle Uiterwijk[2], Jolanda Kluin[2], Frans van de Vosse[1], Carlijn Bouten[1], Anthal Smits[1] and Sandra Loerakker[1]

[1] Department of Biomedical Engineering, Eindhoven University of Technology, 5600 MB, Eindhoven, Netherlands
[2] Department of Cardio-Thoracic Surgery, Academic Medical Centre, 1105 AZ, Amsterdam, Netherlands

Key Words: *Right ventricular outflow tract, Transannular patch, Pulmonary valve, Finite element methods.*

Purpose: The right ventricular outflow tract in children with congenital heart diseases, such as Tetralogy of Fallot, is often reconstructed with a transannular patch and a monocusp valve. However, there are no set standards for the monocusp valve design and as such, these designs vary from clinic to clinic. The aim of this investigation is to propose an optimal pulmonary monocusp valve design with physiologic opening and closing behaviour, good coaptation and minimal aortic regurgitation.

Methods: The opening and closing behaviour of a pulmonary monocusp valve which is currently under pre-clinical evaluation within the 1Valve program, hereinafter referred to as PMV-1 valve, were simulated using finite element (FE) methods. A second hypothetical valve design was then proposed to overcome the limitations of the PMV-1 valve and its dynamic behaviour was also simulated using FE methods. The native pulmonary artery was modelled as an anisotropic material using a Holzapfel-Gasser-Ogden model while the monocusp valves and transannular patches were modelled as isotropic Neo-Hookean hyperelastic materials. Valve dynamics were simulated by imposing the pressure difference between the right ventricle and the pulmonary artery on the ventricular side of the respective monocusp valve designs and all simulations were performed for three cardiac cycles.

Results: Dynamic behaviour of the PMV-1 valve from the FE model were compared with dynamics from an ex-vivo heart model and a good agreement between the numerical and experimental results was observed. The PMV-1 valve was implanted in the pulmonary artery in the closed position and its free-edge was prone to folding when the monocusp valve opened during systole. During diastole, the coaptation length between the free-edge of PMV-1 valve and pulmonary artery was approximately 1 mm. Unlike the initial design, the proposed design of the second monocusp valve is meant to be implanted in the open position. FE results for the second monocusp valve predicted that the free-edge of this valve design does not fold during the entire cardiac cycle. Also, better coaptation was seen for this valve design as the coaptation length between the free-edge and pulmonary artery was approximately 2.1 mm. Based on these findings, another FE simulation was performed for a PMV-1 valve which was now implanted in the open position. It was observed that along with valve design, the implanting position, i.e. open or closed also has a considerable impact on the dynamic behaviour of the pulmonary valve as similar opening and closing behaviour was observed for both PMV-1 valve (implanted in the

open position) and the proposed valve design.

Conclusion and future work: FE results from this investigation suggest that it is desirable to implant the pulmonary monocusp valve in the open instead of the closed position to achieve physiologic valve dynamics. This is an ongoing research project and fluid-structure interaction simulations are currently being performed to quantify aortic regurgitation and the risk of thrombosis associated with each valve design.

Acknowledgements: This research is supported by the Netherlands CardioVascular Research Initiative (CVON2012-01).