

PATIENT-SPECIFIC SIMULATION OF PERCUTANEOUS PULMONARY VALVES: A FLUID-STRUCTURE INTERACTION FRAMEWORK

Mariachiara Arminio (1), Dario Carbonaro (1), Diego Gallo (1), Umberto Morbiducci (1),
Silvia Schievano (2,3), Claudio Chiastra (1), Claudio Capelli (2,3)

1. Politecnico di Torino, Turin, Italy; 2. University College London, London, UK; 3. Great Ormond
Street Hospital for Children, London, UK

1. Introduction

Tetralogy of Fallot and pulmonary stenosis account for approximately 10% of congenital heart diseases [1]. Both conditions may require the implantation of percutaneous pulmonary valves (PPVs) to restore pulmonary valve functionality [2]. In these circumstances, fluid-structure interaction (FSI) simulations enable the assessment of both restored blood flow patterns and device performance under realistic conditions. This study presents an FSI framework for analysing the post-implant performance of PPVs in patient-specific scenarios, aiding in PPVs procedural planning and future devices' testing.

2. Materials and Methods

Data from four patients who underwent PPV implantation were retrospectively retrieved from our Centre. Patient-specific models of right ventricular outflow tract, pulmonary artery and bifurcation were generated from computed tomography images. The geometrical model of the Melody (Medtronic) PPV was created with SolidWorks (Dassault Systèmes) (Fig. 1A). The device was assembled to each patient-specific model to match the post-procedural configuration, and the resulting models were meshed in HyperMesh (Altair). For each patient, FSI simulations were conducted using LS-DYNA (Ansys Inc.), coupling the incompressible flow solver and the implicit structural solver. A flow-rate waveform and resistance boundary conditions were imposed at the inflow and outflow boundaries, respectively (Fig. 1B). For each patient, the flow-rate waveform (Q) and the resistances (R) were tuned to match patient-specific data on forward flow, backward flow and flow split between the pulmonary arteries. The arterial wall and the valve leaflets were assumed rigid and linearly elastic, respectively.

3. Results

The FSI framework captured key features of the PPV biomechanics including: i) the central systolic flow jet, ii) the vortex structures in the pulmonary bifurcation, and iii) the valve kinematics (Fig. 1C). Figure 1C shows velocity streamlines for one patient, whose transvalvular pressure drop at peak systole was 5.2 mmHg, in agreement with in vivo measurements.

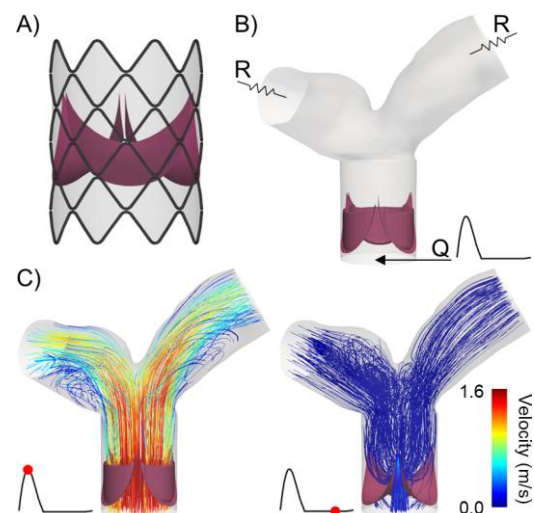


Figure 1: A) Melody valve model. B) Set up for the FSI framework. C) Velocity streamlines at peak systole and during diastole for one of the patients.

4. Discussion and Conclusions

The proposed FSI framework enables the study of patient-specific PPV post-implant biomechanics capturing the complex fluid dynamics determined by the interplay between the PPV and patient-specific anatomy. The framework allows for preprocedural planning evaluations and device testing in scenarios with different anatomies and boundary conditions.

5. References

1. Liu Y et al., *Int J Epidemiol*; 48:455-463 (2019).
2. Chau AK, *Pediatr Investig*; 6(4):280-290 (2022).