EXPERIMENTAL VALIDATION FOR AORTIC VALVE FLUID-STRUCTURE INTERACTION NUMERICAL SIMULATION

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1. Introduction

Increased and repetitive leaflet mechanical stress appears to be a key determinant of structural valve deterioration and bioprosthetic heart valve (BHV). *In vitro* and *in silico* studies provide a unique opportunity to assess and compare the stresses of different models and sizes of BHVs. The aim of this study is to develop a new *in vitro* validation method for numerical simulations using a simplified BHV model.

2. Materials and Methods

Custom coded python program based on the parametric geometry of Xu et al. [1] was used to create the geometry and mesh for the simulation and the mold for *in vitro* experiments. A valve geometry was created with two leaflets at 0.5 mm and one at 1 mm to mimic a fibrosed BHV leaflet. The silicone valve was molded (DragonSkin10, Smooth-On, Inc., PA, USA) using a 3D printed (Lulzbot Inc., ND, USA) mold and stent. A double activation simulator [2] was used for *in vitro* testing of modified BHV and custom-made silicone AV. The heart rate was set to 70 bpm, mean aortic pressure to 100 mmHg, stroke volume to 70 ml and fluid viscosity to 3.9 cP. Mean transprosthetic pressure gradient (TPG) and effective orifice area (EOA) were measured *in vitro* by continuous-wave Doppler (GE Vivid 7, GE Health Medical, Norway). The geometric orifice area (GOA) was obtained using high speed, en-face, imaging (FASTCAM Mini AX50, Photron Inc., CA, USA) and calculated to compare *in vitro* and *in silico* tests. A numerical simulation of systole was performed with a finite element (FE) method using CalculiX software and the fluid-structure solver developed at M2P2 [3] using the lattice Boltzmann method and immersed boundary method. Operating conditions were set identical to those in the *in vitro*.

3. Results

There was no significant difference ($p>0.05$) between the BHV vs. silicone AV hemodynamic parameters (TPG: 9.13±0.35 vs. 9.58±0.27 mmHg, EOA: 1.90±0.12 vs. 1.80±0.10 cm²). Valve kinematics and GOA were evaluated to compare the *in vitro* and the *in silico* tests. The difference between *in vitro* and *in silico* GOA at maximum opening time was 4.21% (2.23 vs. 2.14 cm²).

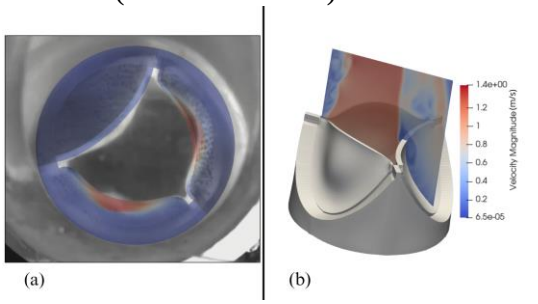

Figure 1: (a) Comparison of GOA in vitro and in silico ; (b) Flow velocity visualization

4. Discussion and Conclusions

This study demonstrates how to validate simulations with *in vitro* studies using simplified test models with well-defined materials and geometries. The custom made silicone valve mimics accurately the BHV's anatomy and hemodynamics. To better understand and determine the durability, further FSI simulations with different degrees of calcification and stress computation will be carried out.

5. References

1. Xu et al. *Int J Numer Method Biomed Eng*. 2018;34(4):e2938. doi:10.1002/cnm.2938

2. Tanné, D., et al., Exp Fluids, 2010. 48: p. 837-850

3. Fringand et al. Comput. Methods Appl. Mech. Eng. 421 (2024) 116777.