FSI MODEL OF A POLYMERIC AORTIC VALVE: COMPARISON WITH EXPERIMENTAL RESULTS AND SIMULATION IN A PATIENT-SPECIFIC AORTIC ROOT

POLITECNICO DI MILANO

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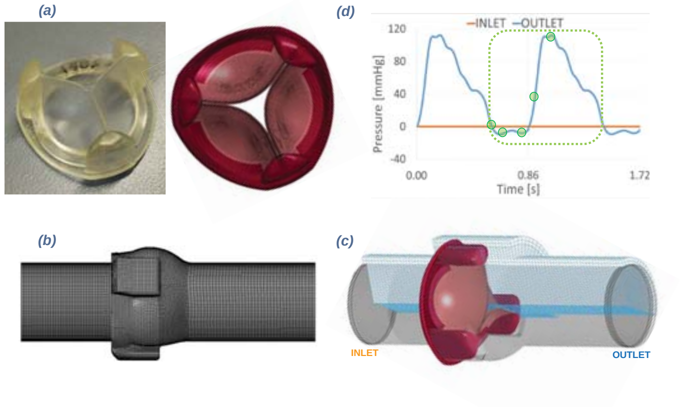
Introduction & Aim of the work

The function of diseased native heart valves can be replicated by heart valve prostheses. Excellent candidates to mimic the structural and fluid dynamic behavior of the native valves are bio-inspired polymeric heart valves (PHVs). In this study a **fluid-structure interaction (FSI) model** of a new PHV [1] is proposed. In vitro hydrodynamic pulsatile experiment was carried out to test the valves and to record their kinematics. Application of the FSI methodology to a **patient-specific case** is also outlined.

In vitro test and FSI model

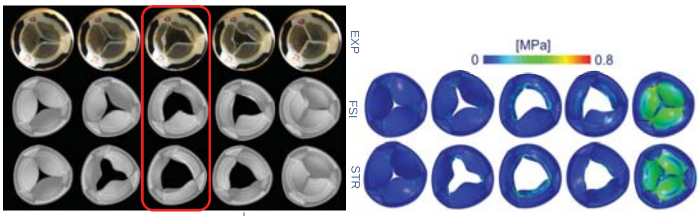
The in-vitro hydrodynamic test of PHV: trans-valvular pressure drop was measured at a constant frequency (70 bpm) at the flow rate of 4.5 l/min. The model was created according to the measurement of the dimensions and material properties.



a) Sample and corresponding model of the PHV.
b) Model of the aortic valve housing.
c) FSI model including the valve, the compartment and the fluid domain.
d) Difference between downstream and upstream pressure during the in vitro test imposed as boundary condition. Green points on the curve shows the time points where the results will be shown.

RESULTS

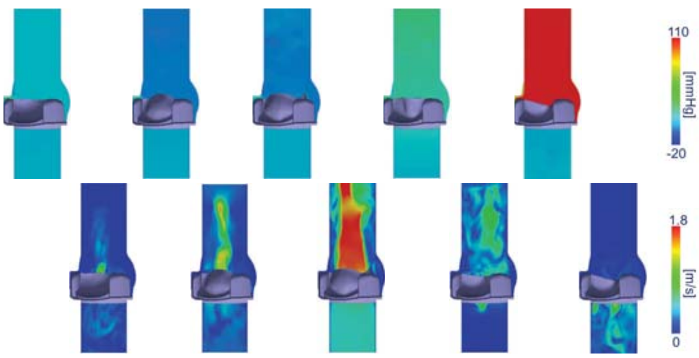
The FSI simulation reflected leaflet kinematics to the experiment more similar then structural simulation in which delta pressure was applied directly on the leaflets.



	Geometric Orifice Area $[mm^2]$	Error
EXP	160	
FSI	167	4.3%
STR	234	45.8%

Valve kinematic from experimental test, FSI and structural (STR) simulations and Von Mises stresses. Geometric Orifice Area and the relative errors in vitro/in silico at the maximum opening area (in red area) are also calculated.

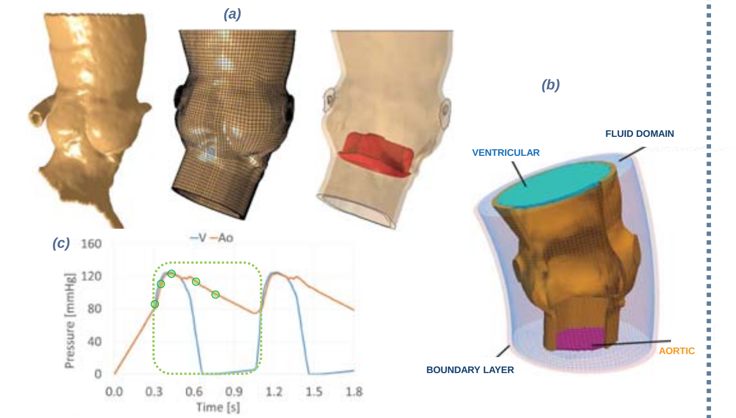
From the FSI simulation, fluid pressure distribution and velocity magnitude, can also be evaluated. These results provide a clear indication how the fluid part was interacting with the structural part.



Pressure and velocity contour maps of the in vitro FSI simulation.

FSI model for patient-specific case

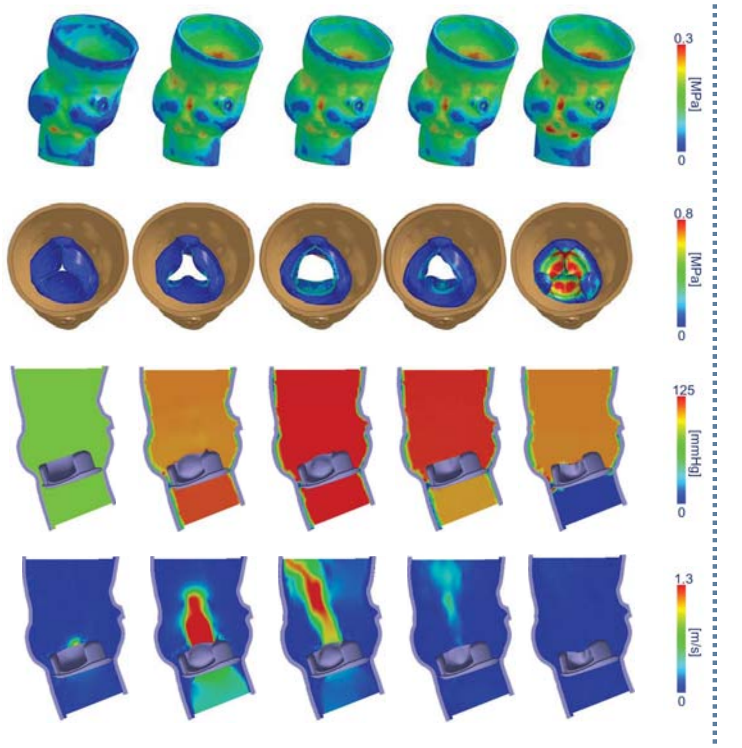
The aortic root model was created from CT images. After structural simulation of the PHV implantation, the pressure tracings were applied in the FSI model. Fluid-structure coupling was set up between the fluid and the valve plus aortic root [2].



(a) Anatomy of the aortic root of the patient-specific case, meshed portion of the model used for the FSI simulation and positioning of the PHV inside the aortic annulus.
(b) FSI model with fluid domain, aortic and ventricular surface and boundary layer.
(c) Aortic (ao) and ventricular (v) pressure tracings. Green points on the curve shows the time points where the results will be shown.

RESULTS

FSI simulation predicted the leaflet kinetics, blood pressure, velocity magnitude after the valve was implanted into the aorta root.



FSI patient-specific case: Von Mises stresses on the aortic root and on the valve, pressure and velocity contour maps on fluid domain.

Conclusion

This work proves **advantages of FSI simulation**, compared to structural analysis; the developed method represents a useful tool to check out design errors, to study the fatigue behavior or to provide clues for the design optimization before the fabrication of prototypes and the performance of tests. Furthermore numerical FSI method carried out on patient-specific cases can be used to predict the behavior of the valve and to support clinical decisions.

References

[1] De Gaetano, F., M. Serrani, P. Bagnoli, J., J. Brubert, J. Stasiak, G. D. Moggridge, and M. L. Costantino. Fluid dynamic characterization of a polymeric heart valve prototype (Poli-Valve) tested under continuous and pulsatile flow conditions. *IJAO* 38(11): 600-606, 2015.

[2] Wu, W., D. Pott, B. Mazza, T. Sironi, E. Dordoni, C. Chiastra, L. Petrini, G. Pennati, G. Dubini, U. Steinseifer, S. Sonntag, M. Kuetting, and F. Migliavacca. Fluid-Structure Interaction Model of a Percutaneous Aortic Valve: Comparison with an In vitro Test and Feasibility Study in a Patient-Specific Case. *Ann. Biomed. Eng.* 44 (2): 590-603, 2016.