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.

The FSI simulation reflected leaflet kinematics to the experiment more similar than structural part.

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.

<table>
<thead>
<tr>
<th>Valve</th>
<th>Geometric Orifice Area [mm²]</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>STR</td>
<td>160</td>
<td>4.3%</td>
</tr>
<tr>
<td>FSI</td>
<td>160</td>
<td>4.3%</td>
</tr>
</tbody>
</table>

Valve kinematics 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 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