POTENTIAL OF USING SHELL ELEMENTS METHODS IN FSI SIMULATIONS OF PULMONARY ARTERIES

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Introduction

Using an *in-silico* model for cardiovascular hemodynamics simulations has grown significantly in recent years. The increased use of *in silico* models can be attributed to several useful properties like their accuracy in calculating vessel wall deformations, wall shear stress, velocity, and pressure fields. Moreover, their capability to evaluate multiple physiological scenarios within a wide range of patients can either improve the design of *in vivo* experiments, or even completely replace them. However, selecting the best model configuration for a specific cardiovascular application is a significant challenge, emanating from the required model accuracy, computational costs, the available data, and the type of analysis and study.

Three-dimensional (3D) fluid-structure interaction models provide the most detailed information regarding vessel wall deformation and hemodynamics, but these models are also hampered by large run-times and memory requirements. Using shell elements instead of solid elements is a promising way to reduce the computational cost while still considering wall movement, which is lost when using rigid tube computational fluid mechanics (CFD) approaches.

In this study, we investigate the potential of using shell elements in an FSI simulation of pulmonary arteries.

Methods

A patient-specific geometry of the proximal pulmonary artery was generated, which includes the main pulmonary artery that bifurcates into the left and right pulmonary arteries. Blood was modeled as a Newtonian and incompressible fluid to simulate the hemodynamics. To impose the inlet condition, a physiologic time-averaged flow was used as the outflow of the right heart. A three-element Windkessel was applied at the outlets to mimic the physiological condition of the distal vasculature. To investigate the effect of the shell method on the local hemodynamics, FSI simulations with both solid and shell elements, and a rigid CFD simulation was done. For the FSI simulations, a hyperplastic model for the blood vessel wall was used.

To investigate the performance of each simulation and compare the difference in outcome, the wall shear stress (WSS) was analyzed using the COMSOL computing platform (https://www.comsol.com/). Being influenced both by wall motion and fluid flow, the WSS was considered an important hemodynamic parameter for this comparison.

Results

After a mesh convergence study, all simulations were run successfully. The globally distribution of WSS in all three case was similar, but locally have some different. In CFD case, the local WSS was different from FSI cases, while in FSI-Shell the pattern was close to FSI-Solid. The FSI-Shell simulations were two times faster than the FSI-Solid simulations.

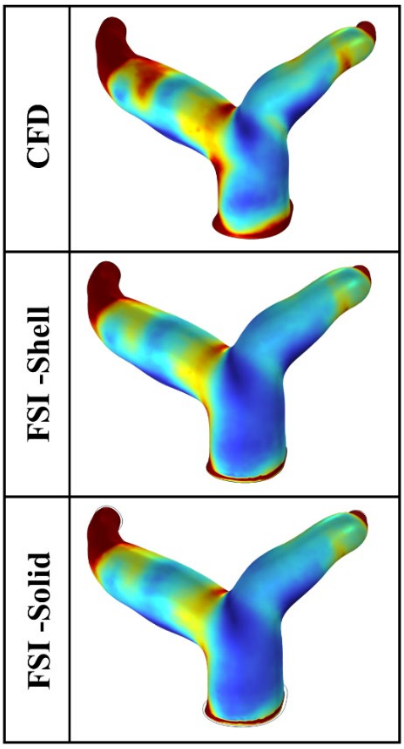

Figure 1: Comparison of wall shear stress in CFD, FSI-shell, and FSI-solid simulation of the flow in a pulmonary artery bifurcation.

Discussion

The result shows positive potential of using of shell elements method in FSI simulation when considering hemodynamics. This methos have the accuracy and computational cost between CFD and FSI-solid methods. In future work, the analysis will be repeated for transient inflow conditions.

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