CFD STUDY OF TYPE-B AORTIC DISSECTIONS WITH FLAP MOTION: PROOF OF CONCEPT OF OVERSET MESHING

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Keyword(s): biomechanics, modeling of physiological systems

1. INTRODUCTION

Type-B Aortic dissection is characterized by a separation of the wall of the thoracic aorta resulting in the formation of secondary channel (false lumen) separated from the true lumen by a thin membrane (intimal flap) and connected via one or more tears. Movement of the intimal flap over the cardiac cycle and resultant pressure differences between the true and false lumen have been well studied in an Arbitrary Lagrangian-Eulerian (ALE) framework [1,2]. In this proof-of-concept study, we utilize an overset technique (Chimera) to move the intimal flap where a component grid overlaps with a uniform cartesian grid. This method takes into account the body conforming advantages of ALE and the large displacement of the Immersed Boundary Method to ensure the intimal flap can deform to a large extent with minimal loss in grid quality. As a secondary objective, we assessed the impact of the presence of a side branch emanating from the false lumen, which is not only expected to have a large impact on the false lumen hemodynamics, but also on parameters such as wall-shear stresses and true-to-false lumen pressure differences which are indicative of disease progression.

2. MATERIALS AND METHODS

A patient-inspired model was generated using the in-house open source tool pyFormex. Boundary layer meshes were created based on this model in ICEM(Ansys Inc, USA). With a few geometric manipulations, a single component mesh and a uniform cartesian background mesh were created. A side branch was added towards the distal exit of the false lumen as shown in Figure 1 and the overset feature in FLUENT 2019R3(Ansys Inc, USA) was used to generate the final geometry and solve the governing flow equations. A net displacement of 4mm was prescribed on the flap throughout the cardiac cycle with a 2mm amplitude during peak systole and early diastole respectively. The outlet pressure waveform was calculated using a 3-element windkessel model [1]. The windkessel parameters were manually tuned to ensure 5%, 2.5% and ~ 0% of total flow through the side-branches and a mean pressure of 94.33 mm-Hg throughout the domain. A user-defined function in FLUENT was used to prescribe the pressure explicitly in each time-step at the outlets. An inlet velocity profile was prescribed such that the flow was assumed to be laminar. Blood viscosity was assumed to be Newtonian in nature.

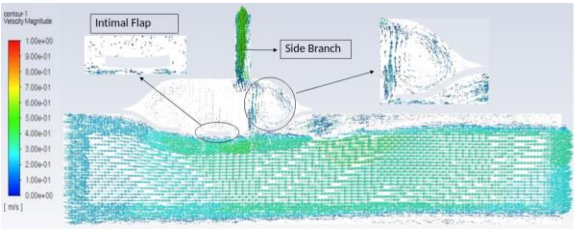

Figure1. Velocity vectors at t = 0. 24375 s during the deceleration phase of the cardiac cycle.

3. RESULTS AND DISCUSSION

The side branch flow has a large impact on the flow field within the false lumen as observed in Figure 1, but minimally affects true-to-false lumen pressure difference, which increases marginally with increase in side branch flow rate in systole. Keeping the flap in a fixed position, a marginal increase in true-to-false lumen pressure difference was observed in systole compared to a moving flap. These preliminary results are a precursor to a fully coupled FSI simulation which would give a more accurate representation of flap motion, hemodynamics and true-to-false lumen pressure variation.

References

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