FROM CASE STUDIES TO COHORTS: AUTOMATING FSI SIMULATIONS TO UNCOVER THE DOWNSTREAM EFFECTS OF ASCENDING AORTIC GRAFTS

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Background: The replacement of the ascending aorta with a synthetic graft is a well-established surgical intervention for aortic aneurysms. However, it can be associated with life-threatening long-term post-surgical degeneration of the descending aorta. Compliance mismatch between the graft and the native aorta is regarded as one of the main risk factors for late adverse events [1], as it alters the hemodynamic in the distal regions, potentially contributing to descending aorta disease progression [2]. Fluid-Structure Interaction (FSI) simulations provide valuable insights into the complex interplay between flow and aortic wall. Nevertheless, existing approaches are largely manual, time-consuming and limited to single-patient case studies [3]. Here we propose a novel fully automated FSI-based approach that incorporates comprehensive patient-specific data to evaluate the biomechanical impact of ascending aortic graft implantation. **Methods**: For each patient, MRA, 4D flow MRI, and cine-MRI scans are collected both before and after surgery and used to set two different simulations: i) real pre-operative scenario, ii) Dacron graft implantation. The vessel geometry is reconstructed from MRA images and meshed using an in-house Python code. Patient-specific inlet velocity profile is derived from 4D flow MRI, while outlet boundary conditions are modelled with a three-element Windkessel tuned to match in vivo measured systolic and diastolic pressures. The aortic wall is modelled as an incompressible, hyperelastic, anisotropic material with different properties assigned to three key regions: the ascending aorta, the aortic arch, and the descending aorta. Regional compliance values are extracted from cine-MRI data, while the material parameters are determined by fitting constitutive models from literature to the measured compliance (Fig 1). Two preliminary simulations are run: a fluid dynamic simulation to compute inner wall pressure, followed by a structural simulation to determine the prestress distribution at the time of imaging. These results are then used as inputs for the final FSI simulation, ensuring an accurate representation of in vivo biomechanics. **Results:** The workflow has been tested on 5 patients, resulting in 10 FSI simulations that were implemented and run automatically. Each simulation, including the pre-processing phase, required approximately 4 days. Significant differences in Wall Shear Stress (WSS) distributions were observed between pre- and post-operative models, with higher WSS values (~10 Pa) consistently appearing in the post-graft simulations. Furthermore, all patients exhibited an increase in pulse wave velocity (PWV) post-implantation, particularly in the proximal descending aorta. **Conclusion:** The novel workflow herein proposed successfully allows

us to automatically perform multiple simulations for a cohort of patients. Simulations outcomes suggest that ascending aortic graft implantation alters downstream hemodynamics, resulting in elevated PWV that may contribute to adverse remodeling or disease progression in the descending aorta.

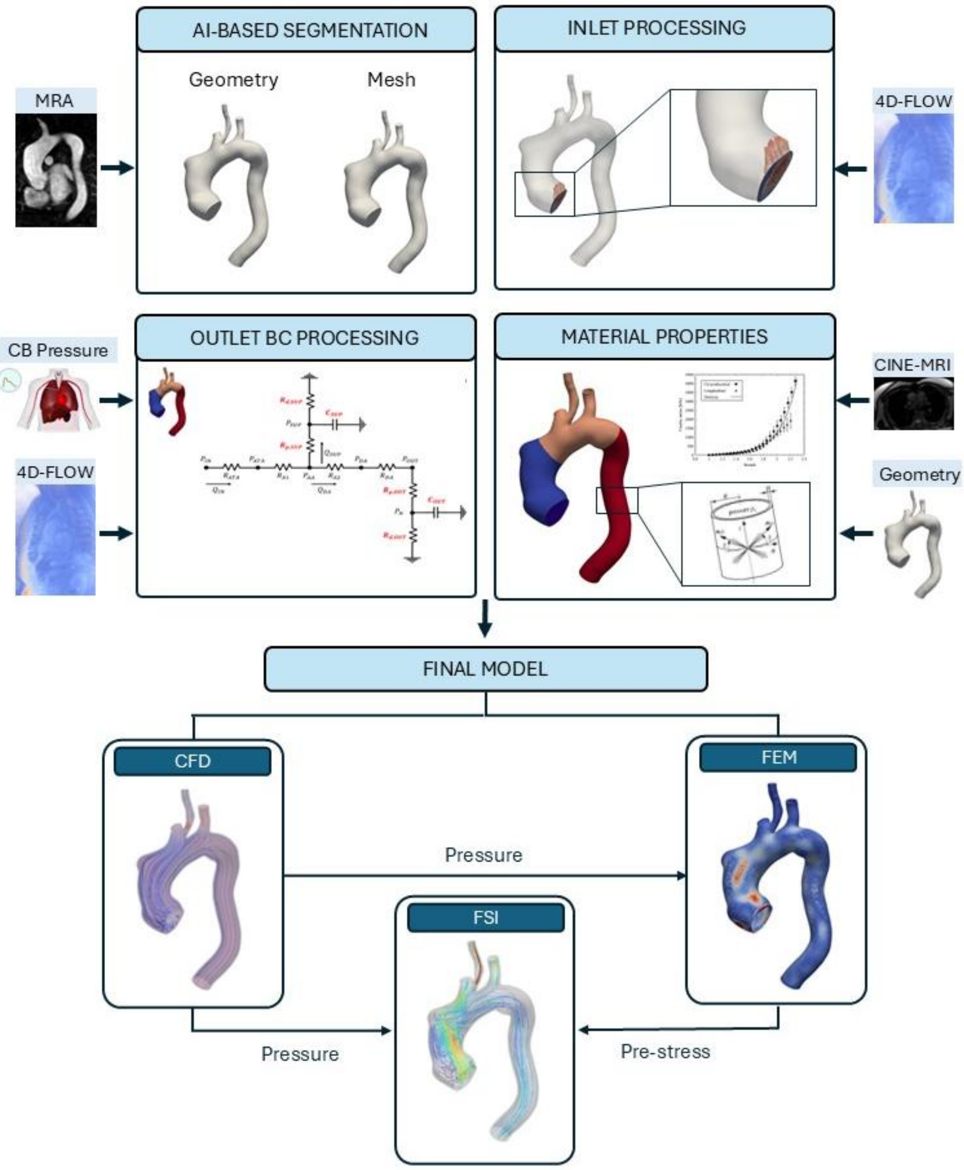

Figure 1: Schematic representation of the workflow developed to build a patient-specific model.

Bibliography

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Acknowledgements

This paper is funded by NIH project #1R01HL170570-01 “Towards Personalized Prosthetic Graft Replacement for Genetically Triggered Thoracic Aortic Aneurysms”.