Numerical Study of Organs Perfusion in Aortic Dissection Patients with Multilayer Flow Modulators

Farhad Rikhtegar Nezami\textsuperscript{1}, Lambros S. Athanasiou\textsuperscript{1,2}, and Elazer R. Edelman\textsuperscript{1,2}

\textsuperscript{1}Institute for Medical Engineering and Science, Massachusetts Institute of Technology, Cambridge, United States
\textsuperscript{2}Cardiovascular Division, Brigham and Women’s Hospital, Harvard Medical School, Boston, United States

Introduction: Management of aortic dissections (AD) is still challenging. No universally-approved guideline is available to choose among several surgical, endovascular or medical therapies. \textasciitilde 25\% of AD patients suffer post-intervention malperfusion syndrome or hemodynamic instability, with the risk of sudden death if left untreated. Malperfusion syndrome significantly compromises vital-organ function and limits the success rate of treatment strategy for type-B AD. Transcatheter implantation of a multilayer flow modulator (MFM), a multilayer mesh construct of cobalt alloy wires, is becoming the method of choice for minimally-invasive treatment of AD patients. However, MFM performance in recovering physiologic perfusion has not been fully assessed.

Materials and Methods: We used patient specific geometry of Type-B AD obtained pre-surgically (PS) and after MFM implantation. In-house semi-automatic segmentation routines are applied to computed-tomography (CT) images to reconstruct the lumen. The device was numerically reconstructed and adapted to the post-surgical geometry concentrically fitting to the true lumen centerline (Figure 1). Computational Fluid Dynamics (CFD) methods were used to numerically study the time-dependent flow patterns, shear stress metrics and perfusion to vital organs. To enhance the simulation accuracy, a lumped parameter module of the three-element windkessel model was coupled to the finite volume solver to assign appropriate outlet boundary conditions.

Results and Discussion: Results showed increased blood flow and decreased wall shear stress (WSS) in the true lumen of post-surgical case (Figure 1). We observed that MFM device not only significantly reduces the blood flow to the false lumen, eliminates local flow disturbances, and globally regulates WSS distribution; but also maintains physiologic perfusion to peripheral vital organs. We propose further investigation in this field recruiting several cases and more extensive numerical study to focus the management of AD on both modulation of blood flow and restoration of physiologic end-organ perfusion rather than mere restoration of vascular lamina morphology.

![Figure 1](image)

Translational Impact: Numerical simulations, if employed with physiological inputs could serve as the method of choice for regulatory officers to assess the performance of medical devices. The majority of aortic dissection modeling efforts, thus far, have focused on maintaining physiological flow through implanting endovascular devices. This numerical approach studies, in addition to hemodynamics, the capability of novel endovascular implants in restoring perfusion to vital organs using a dynamic framework of time-varying arterial waveforms.

Disclosure Statement: Cardiatis provided access to data and partial funding for LA.

Acknowledgements: ERE and FRN were funded in part by a grant from the NIH (R01 GM49039).