Proceedings of the Canadian Society for Mechanical Engineering International Congress 2022
CSME Congress 2022
June 5-8, 2022, Edmonton, AB, Canada

Use of flow manipulators to correct blood flow in the aorta

Christopher E.H. Aitken[1], Kumaradevan Punithakumar[2], Michelle Noga[2], Arman Hemmati[1*]
[1]Department of Mechanical Engineering, University of Alberta, Edmonton, Canada
[2]Department of Radiology & Diagnostic Imaging, University of Alberta, Edmonton, Canada
*arman.hemmati@ualberta.ca

ABSTRACT

Cardiovascular diseases are the leading cause of death globally. Aorta coarctation, which accounts for 5%-7% of congenital heart diseases, is commonly treated with either surgery, balloon angioplasty, or stenting. Complications involve recoarctation of the aorta, hypertension, aortic aneurism, and altered hemodynamics leading to the coronary artery and cerebrovascular disease. Flow manipulators are objects placed in a fluid flow to change pressure or flow characteristics and have been successfully used in aerodynamics and pipe flow. The use of flow manipulators in human vasculature may lead to a novel treatment technique for aorta coarctation. Such a technique would have more direct control of hemodynamics and may mitigate some of the complications associated with current techniques. This study will explore the effect of flow manipulator shape and location with respect to the aortic anomaly. The outcome involves the design of a flow manipulator useful for the treatment of aorta coarctation.

Recently, computational fluid dynamics (CFD) has been used to estimate hemodynamics in the aorta and provides an environment to evaluate the effectiveness of flow manipulators. Deformation of blood vessel walls plays a significant role in hemodynamics due to the pulsatile nature of the cardiac cycle; as such, fluid-structure-interaction (FSI) will be considered. Whole blood will be modelled as an incompressible Newtonian fluid and Direct Numerical Simulations will be performed in OpenFOAM (an open-source CFD platform) to resolve hemodynamics.

Flow manipulator design will be based on an NREL S809 airfoil, whose flow corrections are similar to those expected to be needed in an aorta with coarctation. First, the effect of flow manipulator shape will be examined in a simplified vessel under cardiovascular conditions: the deformable vessel will be exposed to pulsatile flow similar to that experienced in the aorta. The effect of varying thickness, curvature, and length will be examined. Furthermore, the effect of orientation on performance will be classified since perfect orientation is difficult in a surgical setting. After shape determination, the effect of flow manipulator location with respect to the aortic anomaly will be explored in aortas of real patients. Patient-specific geometry and boundary conditions will be obtained from in vivo measurements (magnetic resonance imaging) and used in CFD simulations. Results will allow for the selection of an effective flow manipulator shape and location. Simulation in a larger population with aortic anomalies will allow for the generalizability of results and the development of flow manipulators as a potential treatment option.

Word count: 398