TRIDIMENSIONAL QUANTIFICATION OF CARDIOVASCULAR HEMODYNAMICS PARAMETER USING FINITE ELEMENT METHODS FROM 4D FLOW MRI DATA

JULIO SOTELO, SERGIO URIBE, AND DANIEL HURTADO

Abstract. 3D PC-MR imaging can provide measurements of blood flow velocities in three dimensions, providing data that can potentially allow us to obtain new insight of the cardiovascular system. Hemodynamics parameter as wall shear stress (WSS), oscillatory shear index (OSI), vorticity, helicity and energy, are important parameters for the assessment of the loss of vascular function, the integrity of the vessel tissue and the hemodynamic behavior[1]. Several methods have been proposed to estimate these parameters from 3D PC-MRI, where the in-plane gradients of velocity on 2D planes are approximated through finite differences or differentiation of other interpolation schemes. However, such methods neglect the longitudinal velocity gradients that typically arise in cardiovascular flow, particularly on vessel geometries whose cross section and centerline orientation strongly vary in the axial direction. In this work we propose a 3D finite-element method for the quantification of different hemodynamics parameter from 3D PC-MRI that accounts for both in-plane and longitudinal velocity gradients in real geometries. We demonstrate the convergence and robustness of the method on cylindrical geometries using a synthetic phantom and CFD simulation. To show the medical applicability of the method, we compute 3D maps of different hemodynamics parameters for 3D CINE PC-MRI data sets from an aortic phantom and eighteen healthy volunteers and different patients. Our method improves the estimation of these hemodynamics parameters allowing for more accurate estimates in vessel with pathologies in that the out of plane information was important, such as coarctation and aneurysms. Also we avoid the used of reformatting 2D planes from 3D CINE PC-MRI and the use of pathlines that not cover the entire vessel, as the actual methods.

Keywords: Finite Element, 3D PC-MRI, Wall Shear Stress, OSI, Vorticity, Helicity, Energy

Mathematics Subject Classifications (2010): 37C10, 65L60, 68U10, 65D18

References

[1] Z. Stankovic, B.D. Allen, J. Garcia, K.B. Jarvis, and M. Markl. 4D flow imaging with MRI. *Cardiovascular Diagnosis and Therapy*, 4(2):173-192, 2014.

Biomedical Imaging Center, Electrical Engineering Department, Structural and Geotechnical Engineering Department, Pontificia Universidad Catlica de Chile, Santiago, Chile
E-mail address: jasotelo@uc.cl

Biomedical Imaging Center, Radiology Department and Biological and Medical Engineering Institute, Schools of Engineering, Medicine and Biological Sciences, Pontificia Universidad Catlica de Chile, Santiago, Chile
E-mail address: suribe@med.puc.cl

Structural and Geotechnical Engineering Department and Biological and Medical Engineering Institute, Schools of Engineering, Medicine and Biological Sciences, Pontificia Universidad Catlica de Chile, Santiago, Chile
E-mail address: dhurtado@ing.puc.cl