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# Modelling Blood Flow in an Aorta with Realistic Boundary Conditions

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## Extended Abstract

Computational Fluid Dynamics (CFD) methods together with realistic geometries of arteries, obtained from an MRI data, are commonly used for modelling blood flow in an aorta in scientific research, but also more and more often in clinical applications [1-6]. They enable to assess significant haemodynamic parameters such as velocity profiles, pressure distributions, wall shear stress and oscillatory shear index in physiological and pathological cases. The accuracy of applied boundary conditions and validation of obtained results remain an open question. A typical approach for defining inlet boundary condition is to take the data from available measurements like a phase-contrast magnetic resonance or Doppler ultrasound as a time profile of flow rate [1, 2, 3, 4, 5]. To reconstruct a spatial velocity distribution usually a Womersley solution of Navier-Stokes equations is being used [5, 6], which is valid inherently with an axisymmetric tube assumption. Especially when modelling blood flow in an ascending part of an aorta, there is a complicated 4-dimensional velocity profile induced by the movements of the aortic valve. In the presented work, we proposed a methodology of obtaining an accurate inlet velocity condition for an aorta blood flow modelling using local flow measurements done with time-resolved three-dimensional flow-sensitive cardiovascular magnetic resonance (4D-flow) [7, 8].

A robust workflow was created by combining the PMOD software (PMOD Technologies Ltd., Zurich, Switzerland) and ANSYS software. A realistic geometry of aorta is obtained from an MRI data using a semi-automatic iso-contouring (region growing) method in the PMOD software and exported in an stl format to the ANSYS Fluent Meshing software. Then a high-quality CFD mesh with boundary layer is generated using automated scripts. A 4D velocity profiles are extracted from a 4D-flow data using the PMOD software and interpolated to the CFD model in ANSYS Fluent using User Defined Functions written in C. Afterwards a blood flow simulation could be performed using a realistic 4-dimensional inlet velocity profile.

To test the proposed methodology a comparative study was performed. We have compared the results of the proposed workflow with traditional time-dependent flat velocity inlet profile. We have observed large differences in the velocity and shear stress distribution in an ascending part of the artery. In the latter part of the artery the differences vanish and in its descending part, there was no significant difference in the flow distribution. Also, a maximum shear stress values and its location (three major branches of the aortic arch) was not influenced by the inlet specification. It was shown that in the ascending part of the aorta a realistic inlet boundary conditions are necessary to properly recreate all flow features.

## References

[1] Olufsen, Mette S., et al., "Numerical simulation and experimental validation of blood flow in arteries with structured-tree outflow conditions," *Annals of biomedical engineering*, vol. 28. , no. 11, pp. 1281-1299, 2000.
[2] Tse, Kwong Ming, et al., "Investigation of hemodynamics in the development of dissecting aneurysm within patient-specific dissecting aneurismal aortas using computational fluid dynamics (CFD) simulations," *Journal of biomechanics*, vol. 44, no. 5, pp. 827-836, 2011.
[3] Karimi, Safoora, et al., "Effect of rheological models on the hemodynamics within human aorta: CFD study on CT image-based geometry," *Journal of Non-Newtonian Fluid Mechanics*, vol. 207, pp. 42-52, 2014.

[4] Morris, Paul D., et al. "Computational fluid dynamics modelling in cardiovascular medicine," *Heart*, vol. 102, no. 1, pp. 18-28, 2016.
[5] Daidzic, Nihad E., "Application of Womersley model to reconstruct pulsatile flow from Doppler ultrasound measurements," *Journal of Fluids Engineering*, vol. 136, no. 4, pp. 041102, 2014.
[6] Aboelkassem, Yasser, and Zdravko Virag, "A hybrid Windkessel-Womersley model for blood flow in arteries," *Journal of theoretical biology*, vol. 462, pp. 499-513, 2019.
[7] Thakrar, Darshit, et al., "Complex 3D blood flow pathways in two cases of aorta to right heart fistulae: A 4D flow MRI study," *Magnetic resonance imaging*, vol. 31, no. 8, pp. 1453-1455, 2013.
[8] von Knobelsdorff-Brenkenhoff, Florian, et al., "Blood flow characteristics in the ascending aorta after aortic valve replacement—a pilot study using 4D-flow MRI," *International journal of cardiology*, vol. 170, no. 3, pp. 426-433, 2014.