Flow patterns in turbulent cardiac flows using computational fluid dynamics and classical analysis tools

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Cardiovascular diseases are a leading cause of death worldwide, with over 17 million deaths each year. A better understanding of the hemodynamics of the heart is essential for the diagnosis, treatment, and prevention of these diseases. Computational fluid dynamics (CFD) has been widely used to simulate and analyze blood flow in the cardiovascular system. However, simulating the complex dynamics of cardiac flow requires high computational costs, which limits its clinical applicability.

In this work, we analyze the complex dynamics of cardiac flow using data-driven techniques, including proper orthogonal decomposition (POD)[1], higher-order dynamic mode decomposition (HODMD)[2], and data-driven resolvent analysis[3]. These techniques allow us to identify the dominant patterns and mechanisms of the flow using a reduced number of variables.

We focus on numerical simulations of the left side of the heart, including the pulmonary veins (inlet), the left atrium, the left ventricle, and the aorta (outlet), using Ansys Fluent with both rigid and moving walls. We examine different cases of the heart, such as healthy, hypertrophy, and diabetes among others, by analyzing both simulation and experimental data.

These findings provide insights into the underlying mechanisms of cardiac flow dynamics and can contribute to the development of more efficient simulations for clinical applications.

Overall, this work presents a promising approach for studying the complex dynamics of cardiac flow and improving the efficiency of associated simulations. The results can have significant implications for the diagnosis, treatment, and prevention of cardiovascular diseases, ultimately contributing to the improvement of patient care.

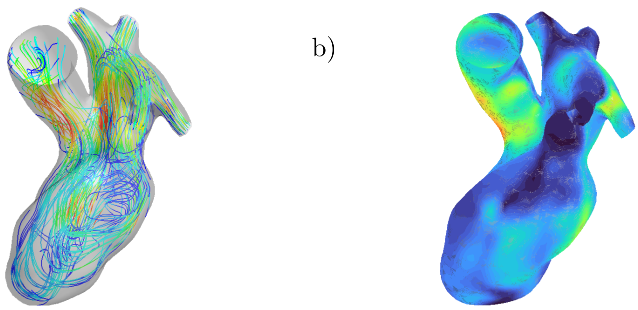
a)

b)

Figure 1: (a) Velocity streamlines for rigid walls. (b) Wall shear stress for rigid walls.

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[1] J.L. Lumley, *Atmospheric Turbulence and Radio Wave Propagation*, 166-177 (1967).
[2] J.M. Vega and S. Le Clainche, *Academic Press*, (2020).
[3] B. Herrmann et al., *Cambridge University Press* **918**, A10 (2021).