A Coupled Bi-Ventricle Flow Model With Explicit Arterial Circulation

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The development of a comprehensive model of myocardial perfusion is challenging due to the need to incorporate many complex interactions across spatial and temporal scales, and physical domains. Previously, we have presented poro-elastic flow models for the beating left ventricle coupled together with a 1D model for blood flow in the coronary arterial and venous tree that perfuse the myocardium [1].

Here, we present an important extension of this coupled left ventricle model to a poro-elastic bi-ventricle model. In this model, the left ventricle is coupled with the systemic arterial tree including the coronary arterial network and the right ventricle is coupled with the pulmonary circulatory system. We model the large vessels of vascular networks explicitly using imaged data and data from the literature. Feedback between the ventricular models and the arterial flow models on a per time-step basis allow the model to respond to the mechanical stimulus of pressure in a physiologically realistic manner.

We will discuss the separate components of the model, the challenges encountered in coupling the separate parts, and methods used to ascertain that the observed behaviours are reasonable. This coupled myocardial perfusion, and systemic and pulmonary flow model is benchmarked in a healthy heart, and we will present some results for cases of arterial disease.

The development of this model represents a significant step towards the longer-term goal of developing a four-chamber heart model with true feedback loop between the circulatory system and beating heart.

[1]: Richardson, S. H., Mackenzie, J., Thekkethil, N., Feng, L., Lee, J., Berry, C., ... & Gao, H. (2024). Cardiac perfusion coupled with a structured coronary network tree. *Computer Methods in Applied Mechanics and Engineering*, *428*, 117083.