DATA-DRIVEN COMPUTATIONAL MODELS OF HEART ANATOMY, MECHANICS AND HEMODYNAMICS: AN INTEGRATED FRAMEWORK

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Cardiac therapies aim to correct pathological blood flow. Patient-specific therapy planning is challenging due to the large variability in disease cause, location and severity. A predictive framework is therefore needed to assess the optimal treatment for a patient in terms of maximizing effectiveness (blood flow velocity, vorticity, cardiac output, etc.) and minimizing the risk of complications. Multi-physics fluid-structure interaction models have been proposed to investigate the function of the bi-ventricular myocardium (see [1] and references therein). Yet, no or only partial patient-specific data have been used due to the lack of efficient methods for accurate modeling of patient's cardiac anatomy from images.

Current imaging technologies enabling assessment of cardiac anatomy, dynamics and tissue structure, we propose an integrated framework for multi-physics heart modeling based on imaging data. Our approach relies on efficient machine-learning methods to estimate an accurate and comprehensive model of patient's anatomy from MRI [2]. A computational model of cardiac electrophysiology [3] and biomechanics [4] is then solved on patient's anatomy. The main free parameters of the model are personalized from time sequence images as in [5]. Endocardial pressures are modeled as lumped variables. Boundary conditions are prescribed based on a 3-element Windkessel model of arteries personalized from pressure catheterization measurements and arterial flow. Finally, the simulated cardiac motion is provided as input to a computational fluid dynamics (CFD)-based model [6] to compute intra-cardiac blood flow throughout the cardiac cycle.

Preliminary experiments on a patient with dilated cardiomyopathy yielded promising simulations both in terms of myocardium electromechanics and intra-cardiac blood flow patterns (Fig. 1). The model being generative, postoperative blood flow and muscle efficiency could be assessed *in-silico* from preoperative data. By coupling patient data, electromechanics and fluid dynamics, our framework paves the way to more systematic evaluations of multi-physics models in clinical setups and may constitute a surrogate tool for therapy planning.

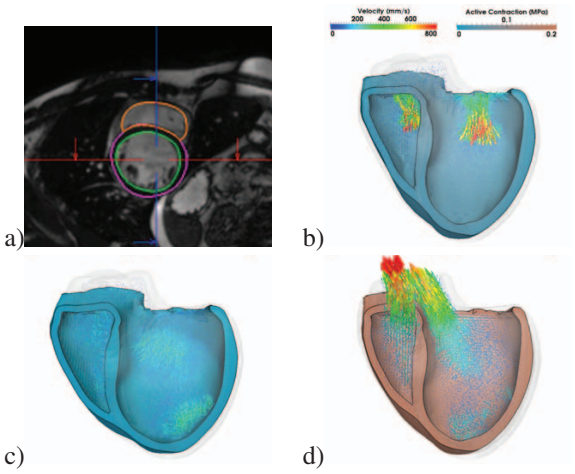


Fig. 1. *a)* Patient-specific anatomical model estimated from cine MRI. *b-c-d)* CFD model of cardiac blood flow (arrows) computed from an electro-mechanical simulation.

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