Personalized Modeling for Cardiovascular System Dynamics and Hemodynamics: A CircAdapt Approach

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Abstract: Cardiac Resynchronization Therapy (CRT) is a widely accepted and successful treatment for heart failure occurring in combination with electrical conduction delay, e.g. left bundle branch block. Large clinical studies have shown that CRT improves left ventricular function and affects long-term survival. However, the response of any given individual to CRT response is difficult to predict for reasons that are not completely understood. In this study, we focus on personalizing a phenomenological model in an effort to shed light on this problem.

Magdeburger cardiologists included 111 patients with standard CRT indications in a clinical study. Data collection was performed via echocardiography, as well as left- and right-heart catheterization including conductance catheterization (pressure-volume loop measurement). We carefully selected a subgroup for an in silico analysis.

Researchers have elaborated highly complex and detailed cardiac simulators on the cell and tissue level. However, for the sake of low computational effort and whole-heart modeling we have chosen to work with CircAdapt. The CircAdapt model describes the heart and circulation in a phenomenological way, calculating beat-to-beat hemodynamics and cardiac mechanics with ordinary differential equations. It enables close to real-time simulation.

First, clinical data was used to specify a subroup of model parameters. Second, we performed a global sensitivity analysis to identify sensitive ventricular volume parameters. On the basis of the obtained insights and measured pressure-volume data, we were able to work out a parameter estimation algorithm. Finally, the acute CRT response of the patient-specific model was observed by changing the ventricular electrical activation pattern and running 30 heart cycles without homoestatic pressure-flow regulation.

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