Multi-Resolution Cardiovascular Model Coupling in Hypertrophic Cardiomyopathy

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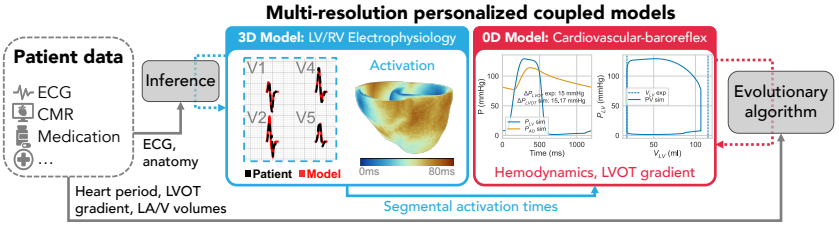
Aim: Hypertrophic cardiomyopathy (HCM) is a common heritable cardiovascular disease with heterogeneous phenotypic expression, involving cardiac, hemodynamic and autonomic processes. Multiscale and multiresolution modelling approaches could be used to investigate these complex physiological mechanisms. This study aimed to provide a proof-of-concept of multi-resolution cardiovascular model coupling in the context of HCM.

Methods: A framework for coupling 0D cardiovascular-baroreflex and 3D electrophysiology models was proposed and personalized to an HCM patient's clinical data. The 3D model comprises multiscale cardiac electrophysiological function. The 0D model includes the atria and multi-segment ventricles, the circulation, left ventricular outflow tract (LVOT), and baroreflex regulation. First, the 3D electrical activation sequence was inferred by fitting to the patient QRS complexes. These activation times were used as parameters for the 0D model multi-segment ventricles. Finally, a self-adaptive differential evolution algorithm was used to fit the patient's clinical data: left atrial/ventricular (LA/V) end-diastolic/systolic volumes, heart rate, and LVOT pressure gradient.



Results: A good fit was obtained between the simulated and clinical data, with a 12-lead ECG correlation coefficient of 0.89 (3D model), and an error of 7 ms for the heart period, 0.04 mmHg for the LVOT gradient, and on average 2.21 ml for the LA and LV volumes (parameterized 0D model). This work demonstrates the successful coupling and personalization of multi-scale cardiovascular models, paving the way towards integrated HCM digital twins.