The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

3D-0D closed-loop model for the simulation of cardiac electromechanics

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Keywords: *Cardiac electromechanics, Cardiac fiber architecture, Multiphysics modeling, Finite Elements, 3D-0D coupling.*

Over the years, cardiac computational models have been developed with increasingly biophysical details, by taking into account the interacting physical phenomena contributing to the heart function - electrophysiology, active contraction, mechanics and fluid dynamics. Even though some area of heart modeling reached a certain level of maturity, whole heart models are a far-reaching endeavour and are still in their infancy. In this work, we provide a detailed fully-coupled multiscale mathematical and numerical model of cardiac electromechanics (EM) of the whole human heart. Two crucial factors for accurate numerical simulations of cardiac EM are: i) reconstructing the muscular fiber architecture that drives the electrophysiology signal and the myocardium contraction; ii) accounting for the interaction between the heart and the circulatory system, that determines pressures and volumes loads in the heart chambers. In this work, we present a 3D whole heart EM model coupled with a 0D closed-loop model of the whole cardiovascular system, that addresses the two former crucial factors. Our whole heart 3D-0D model includes a detailed myocardial fibers architecture, simulates the electrophysiology, the mechanical activation and the mechanics of ventricles and atria, and is strongly coupled with a 0D-closed loop model of the whole cardiovascular system. We present a unified mathematical framework, based on Laplace-Dirichlet-Rule-Based-Methods, to prescribe myocardial fibers orientation in computational full heart geometries.Moreover, we provide a biophysically detailed 3D EM model coupled with a 0D closed-loop lumped parameters model for the haemodynamics of the whole circulatory system.Finally, we show physiological EM simulations, on a realistic whole heart geometry, using the 3D-0D model.

Acknowledgements: This project has received funding from the European Research Council (ERC) under the European Unions Horizon 2020 research and innovation programme (grant No 740132).