Automating Workflows for Creating Digital Twins of Cardiac Electrophysiology from non-invasive Data

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1. Abstract

Computational models of cardiac electrophysiology (EP) are an important tool supporting the quantitative analysis of experimental data, but are increasingly considered in clinical applications. These rely on the ability of models to replicate seen clinical observations and, for making predictions on the acute therapeutic responses, to account for relevant EP mechanisms. Models offering these capabilities are referred to as cardiac digital twins (CDTs) – digital replicas of patient hearts derived from clinical data that match like-for-like all available observations. Their development and clinical validation poses numerous challenges.

Currently used CDT workflows are laborious and computationally expensive. These must be advanced to fully automate the generation of cardiac anatomy models and the personalization of their EP function, using, ideally, non-invasive data only. Novel techniques for the functionalization of high dimensional models are needed that facilitate the unattended alteration of complex parameter fields influencing cardiac EP simulation outcomes, such as the ventricular conduction system, orthotropic conduction in the ventricles and heterogeneity in action potential shape and duration in a given individual.

We report on the development of an automated workflow for building CDTs using tomographic imaging and non-invasive ECG recordings. The workflow consists of three major stages; generation of a finite-element mesh from clinically-attained 3D whole heart and torso MRIs, physiologically-constrained funtionalization of the models according to a feature vector consisting of both global and spatially-dependent parameters, and a fast-forward model of cardiac EP for simulation of ECGs to guide parameter identification. We demonstrate feasibility of our workflow to automatically generate CDTs compatible for clinical use by generating a virtual cohort of 13 CDTs from volunteer subjects [1]. An initial proof of concept of the unattended generation of an EP CDT is given for one subject using both a stochastic sampling approach [1,2] and a gradient-based optimization method [3,4].

2. References

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