Computational Approaches to Integrated Modeling of Electrophysiology of the Heart

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ABSTRACT

An accurate understanding of cardiac function necessitates the knowledge of regulation of electromechanical events during a cardiac cycle both on the cellular and organ level. Electrocardiogram (ECG), a recording of the electrical impulses throughout the heart by placing electrodes on specific locations of the body surface, is the most commonly used diagnostic tool measuring the electrical activity of the ventricles and atria through series of waveforms and intervals [1]. ECG is approved to be a key diagnostic tool to detect cardiovascular disease e.g. myocardial infarction (MI) [1]. The evolution of MI in the heart results in significant changes in the ECG patterns [2]. Moreover, ECG does not only reveal the existence of an injury on the myocardial wall, but it also provides information about the infarct size and location.

In this study, we propose an efficient computational approach to integrated modeling of electrophysiology of the heart embedded in the torso. The electrical activity in cardiac tissue is modeled through nonlinear reaction-diffusion equations where the current source is constituted by the ten Tusscher-Panfilov model [3] within the mono- and bi-domain settings [5,6]. The torso is considered as a linear conductor with constant coefficients of conductivity. The governing non-linear excitation equations of the heart and the linear conduction equation of the torso are discretized by using an implicit finite element model [4-6]. Owing to the linear form of the governing equations of the torso, the system of linearized equations is condensed out by decomposing the coefficient matrix at the very first time step. The electrical potentials in the torso are then recovered once the electrical potentials in the heart are obtained iteratively. The performance of the model is demonstrated by several comparative numerical examples involving physiological and pathological cases.

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