The electrodynamic model of the cardiac electric signal propagation expressed in Maxwell's equations with a B. van der Pol oscillator

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ABSTRACT

On the analysis of the propagational behaviour in multidimensional anisotropic structure of the heart, difficulty arises because the widely-used FitzHugh-Nagumo (FHN) equations only describe the dynamics of the wavefront displaying the time-dependent contours of the membrane potential. These contours are fundamentally phenomenological, thus they are convenient to indicate each phase of excitation at each time, but do not provide deterministic predictions on the irregular behaviour of the propagation, especially on breaking-ups in curved anisotropic structure that are crucial in predicting the electrophysiological disorders such as arrhythmia and fibrillation [1].

In order to compensate these drawbacks of the FHN equations, we propose (i) the trajectory-based point of views on the cardiac electric signal propagation and (ii) vector quantities representing the flow of charged ions. To achieve this, a set of Maxwell's equations is constructed such that the dynamics of the scalar potential represents the the Bonhoeffer van der Pol (BvP) mechanism of the cardiac electric signal propagation same as the FitzHugh-Nagumo model in the macroscopic bidomain. The BvP oscillator is reflected in the electric polarization of the displacement field that is caused by the membrane current responding to the magnitude of the electric field.

Being phenomenologically described in terms of the scalar membrane potential, the dynamics of the propagation is now interpreted and analysed in the perspective of vector fields. This new approach not only provides new insights on the unique properties of the cardiac electric signal propagation that were not explained in classical dynamics, but also paves the most efficient mathematical and computational analysis on the behaviour of the propagation on complex anisotropic structure of the heart, especially on fibrillation and defibrillation [2].

REFERENCES

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2. Sehun Chun, "An electrodynamic model of the cardiac electric signal propagation in the macroscopic bidomain", submitted, 2014.