3D Model of the Heart Electrical Activity with Heterogeneous Ventricular Action Potentials

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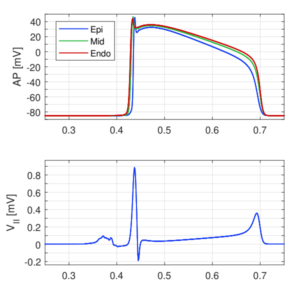
Aims: Development of a three-dimensional finite element model of the electrical activity of the heart embedded in the torso. The model is proposed as a useful tool to simulate ECG signals both in healthy and pathological conditions.

Methods: The electrical activity of the cardiac tissue is reproduced with the bidomain model. The ionic current dynamic is represented with a modified version of the FitzHugh-Nagumo model. In particular, we added the description of transient outward current, which allows reproducing the typical notch of the action potential. We improved the quality of the simulated action potential through the introduction of a shape parameter. The geometry of our model is composed by different regions defining torso, lungs, myocardium and cardiac chambers. The torso the lungs and the cardiac chambers are considered passive conductors. The myocardium is divided in different sub-domains with heterogeneous action potentials describing the sinoatrial node, atria, atrioventricular node, His bundle, bundle branches, the endocardium, the midcardium and the epicardium. As example of pathological condition, we simulated anterior subepicardial ischemia. To reproduce ischemic action potential we simply adjusted some model parameters.

Results: The model generates a controlled spontaneous activation in the sinoatrial node and it is also able to generate realistic electrocardiographic signals. Moreover, the heterogeneity of the ventricular action potentials and the introduced characteristic of the cell model result in a smoother and more realistic T-wave with respect to our previous results. Our model reproduces well both healthy ECG and the main changes induced by ischemia.

Conclusion: We believe the developed model could be useful for educational and research purposes regarding the study of cardiac bioelectrical phenomena and their modifications induced by pathological conditions. A possible improvement of our model could be the use of anatomically realistic and patient-specific geometry, including also anisotropic fiber conductivity.



Healthy simulation. Top: Ventricular action potentials. Bottom: II Einthoven lead