Noise-induced early afterdepoarizations in a cardiac action potential model

Evdokiia Slepukhina
University of Hohenheim (Stuttgart, Germany)

Early afterdepolarizations (EADs) are among the possible pathologies in the formation of the action potential of a cardiomyocyte. These are additional oscillations in the membrane potential that occur after the normal action potential until the membrane is completely recovered to the resting state. EADs can lead to various types of arrhythmias and sudden cardiac arrest.

Currently EADs are studied by means of mathematical models and bifurcation analysis, and the intrinsic mechanisms of EADs generation are associated with various bifurcations and dynamical regimes.

Besides that, it is commonly accepted that real systems are susceptible to random disturbances. Noise in nonlinear systems can considerably affect their behavior and induce a variety of unexpected stochastic phenomena.

In this work, we study a stochastic variant of the three-dimensional model of cardiac action potential [1,2]. The original deterministic system undergoes a cascade of period adding saddle-node bifurcations resulting in the appearance of small amplitude oscillations that correspond to EADs [3]. We consider a parameter region where the deterministic system exhibits normal action potential behavior and show that a small additive noise can induce EADs in this region. This stochastic phenomenon is confirmed by changes in the probability density distributions for phase trajectories and inter-event intervals. These qualitative changes in the system dynamics can be associated with a stochastic P-bifurcation. The probabilistic mechanism of noise-induced EADs is studied with an approach based on the stochastic sensitivity function technique, the method of confidence domains and Mahalanobis metrics [4,5].

1. C. H. Luo, Y. Rudy, Circ. Res., 68, 1501-1526 (1991).
2. D. X. Tran et al. Phys. Rev. Lett., 102, Iss. 25, 258103 (2009).
3. P. Kügler P, A.H. Erhardt, M.A.K. Bulelzai, PLoS ONE 13 (12), e0209498 (2018).
4. I. A. Bashkirtseva, L. B. Ryashko, Math. and Comp. in Simulat., 66 (1), 55-67 (2004).
5. E. Slepukhina, L. Ryashko, P. Kügler, Chaos, Solitons and Fractals, 131, 109515 (2020).