Suppressing Fibrillative Cardiac Activity By Weak Point Periodic Excitations

E.A. Zhuchkova*, B.D. Radnayev, A. Loskutov

Physics Faculty, Moscow State University, Leninskie gory, Moscow 119992, Russia
* Electronic Address: zhkatya@polly.phys.msu.ru

Cardiovascular diseases (CVDs) are responsible for 4 million deaths each year in Europe. A major group of CVDs involve disturbances of the normal cardiac rhythm (cardiac arrhythmias). The extreme form of cardiac arrhythmias is ventricular fibrillation (VF), which is related to persistent re-entrant waves in the larger chambers of the heart, and is believed to be the prevalent mode of sudden death among patients with CVDs.

Since VF, sustained for only a few minutes, leads to death, an immediate intervention is required. In emergency care medicine the application of high-energy electrical stimulation through the patient's chest is commonly used to restore the normal rhythmicity of the heartbeat. However, high-energy shock can cause the necrosis of myocardium or give rise to functional damage manifested as disturbances in atrioventricular conduction. Thus there is high demand in clinics on alternative methods of defibrillation which would work with lower voltages.

Following the contemporary conjecture, VF is produced by multiple wavelet reentry (spiral waves in 2D and scroll waves in 3D) [1] (i.e. by spatio–temporal chaos or spiral–wave turbulence). The recent investigations in the active media theory offer new opportunities: The amplitude of the external stimulation can be *essentially* decreased and the turbulent regime in excitable systems may be stabilized by a sufficiently weak parametric excitation or external forcing applied to a point of a medium [2, 3]. By this manner, it is possible not only to suppress spatio–temporal chaos and stabilize the media dynamics, but also in some cases to reestablish the initial cardiac rhythm, because after stabilization the media goes to the spatially homogeneous steady state.

In the present investigation we consider the problem of suppressing spiral waves using a realistic computational model of re-entrant fibrillation. We have tested low-voltage force suppressing (non-feedback point periodic stimulation of monophasic and biphasic shapes) on the simplified ionic model of the cardiac action potential, so-called the three variable Fenton-Karma model. We have found that under some conditions re-entrant waves can be eliminated by mild stimulation. For both monophasic and biphasic signals suppression efficiency strongly depends on stimulation frequency and suppression onset. In contrast to the suppression onset chosen randomly, the frequency of the signals was selected to ensure the maximal possible frequency of target waves for a given set of model parameters. We have observed re-entry elimination for two stimulation frequencies for both shapes of stimuli. In addition, we have found nonlinear dependence of suppression efficiency on the amplitude of the biphasic signal.

Generalizations of these investigations would influence the current medical practice of clinical cardiologists, and physicians would be able to use new methods of treatment.

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[2] S.A. Vysotsky, R.V. Cheremin and A. Loskutov, *J. Phys.: Conf. Series* **23**, 202 (2005).

[3] H. Zhang et. al., *Phys. Rev. Lett.*, **94**, 188301 (2005).