Areas of Effectiveness of Defibrillating Pulse in the Energy/Phase Diagram for the Fibrillation Cycle on the Cardiomyocyte Model

B.B. Gorbunov¹, V.A. Vostrikov², I.V. Nesterenko¹, D.V. Telyshev¹

¹National Research University of Electronic Technology, Bld. 1, Shokin Square, Zelenograd, Moscow, Russian Federation
²V.A. Negovsky Scientific Research Institute of General Reanimatology, Petrovka str. 25, b. 2, Moscow, Russian Federation
Contact: boris.b.gorbunov@org.miet.ru

Introduction

The use of implantable, remote monitoring devices might help to avert hospitalization by detecting early evidence of HF decompensation, thus allowing implementation of outpatient interventions. Implantable remote monitoring devices include implantable cardioverter-defibrillators (ICDs) or cardiac resynchronization therapy defibrillators (CRT-D), which can be used to monitor intrathoracic or intracardiac electrical impedance, respiratory rate, physical activity, rhythm abnormalities, and heart rate variability [1]. The main function of the ICD and CRT-D is passing the electrical pulse (defibrillation pulse) through the myocardium in case of the ventricular fibrillation. The optimal form of the defibrillation pulse and the level of the defibrillation energy is still an open question for the researchers. The aim of this work is to study the areas of effectiveness of defibrillating pulse in the energy/phase diagram for the fibrillation cycle on the cardiomyocyte model.

The hypothesis about the role of refractory period extension of cardiomyocytes during cardiac defibrillation was put forward on the basis of experiments in the early 1990s [2–4]. In 1997, the results of experiments on isolated rabbit hearts confirming this hypothesis were published [5]. It was also confirmed on a two-dimensional model of the myocardium [6]. In the study [7] performed on the human ventricular cardiomyocyte model, energy/phase diagrams of the lower energy threshold of a rectangular depolarizing pulse extending its refractory period were constructed. The diagrams were constructed based on the assumption of the lower threshold only, i.e. the value of energy below which the refractory period does not lengthen. However, when modeling was performed, the existence of upper thresholds was also noted at high values of the pulse energy, i.e. values of energy above which the refractory period does not extend. This led to a more detailed study of the response to the impact of the depolarizing pulse on the cardiomyocyte, which is under the influence of fibrillation waves.

Results

The results are presented on the diagrams for the depolarizing pulse durations of 15, 30 and 45ms respectively.
provide a long-term extension of refractoriness of all cardiomyocytes at lower energy levels of the depolarizing pulse. Presumably, this is also the mechanism of suppression of the fibrillation wave. At high energy levels, the action of the depolarizing pulse leads to a one-time extension of refractoriness of all cardiomyocytes at high energy of depolarising pulse are the mechanisms of defibrillation.

**References**


Figure 3: Energy Threshold Values of Refractoriness Extension Areas at a Depolarizing Pulse Duration of 15ms

Figure 4: Energy Threshold Values of Refractoriness Extension Areas at a Depolarizing Pulse Duration of 30ms

Acknowledgments
This work was funded by Ministry of Education and Science of the Russian Federation (Agreement 14.575.21.0145, RFMEFI57517X0145 from September 26, 2017).
Figure 5: Energy Threshold Values of Refractoriness Extension Areas at a Depolarizing Pulse Duration of 45ms

Figure 6: Time Chart of the Transmembrane Potential under the Action of a Rectangular Depolarizing Pulse Duration of 15ms in the Area of Effectiveness No 5