Defibrillation mechanisms on a one-dimensional ring of cardiac tissue

J. Bragard, A. Šimić*, E. M. Cherry†, F. Fenton‡, N. Otani‡

Dept. of Physics and Applied Mathematics, Faculty of Sciences, University of Navarra, Pamplona, Spain

Defibrillation is a medical treatment used to terminate ventricular fibrillation or pulseless ventricular tachycardia. An electrical device via a pair of electrodes delivers controlled amount of electrical energy to the heart in order to reestablish the normal heart rhythm. First generation of defibrillators applied monophasic shock, in which electrodes did not change polarity during the application of the shock. Later it was found that changing the polarity of the electrodes during the shock leads to better result with less energy applied. Optimal monophasic and biphasic shock release approximately 200 J and 150 J, respectively. It is desirable to use as less energetic shock as possible in order to reduce the damage done to the tissue by the strong electric current. However, to this day, there is no full understanding why biphasic shocks are better than monophasic shocks. To assess this question, we have used a bidomain model for cardiac tissue with modified Beeler-Reuter model[1] for transmembrane currents. Modifications account for anode break phenomena and electroporation effect known to happen during defibrillation. We have studied three different types of protocols for shock application (i.e. monophasic; symmetric biphasic; and asymmetric biphasic shock) in a one dimensional ring of cardiac tissue. The size of the ring was chosen to exhibit a discordant-alternans dynamics. Results of the numerical simulations reveal that monophasic shocks defibrillate with higher rate of success than the two biphasic shock protocols at lower energies. On the contrary for higher shock energies, the biphasic shock are significantly more effecient than monophasic shocks. This latter result confirms the medical common wisdom about defibrillators. Moreover, in this study, we were able to identify and classify the different defibrillation mechanisms that happen in this system. One identifies four different types: direct block, delayed block, annihilation and direct activation. Which defibrillation mechanism prevails depends on the energy level, the current dynamic state of the system and the shock protocol. This study has permitted to uncover and confirm the experimental fact stating that biphasic shocks are more efficient (at high energy) than monophasic shock to defibrillate cardiac tissue.

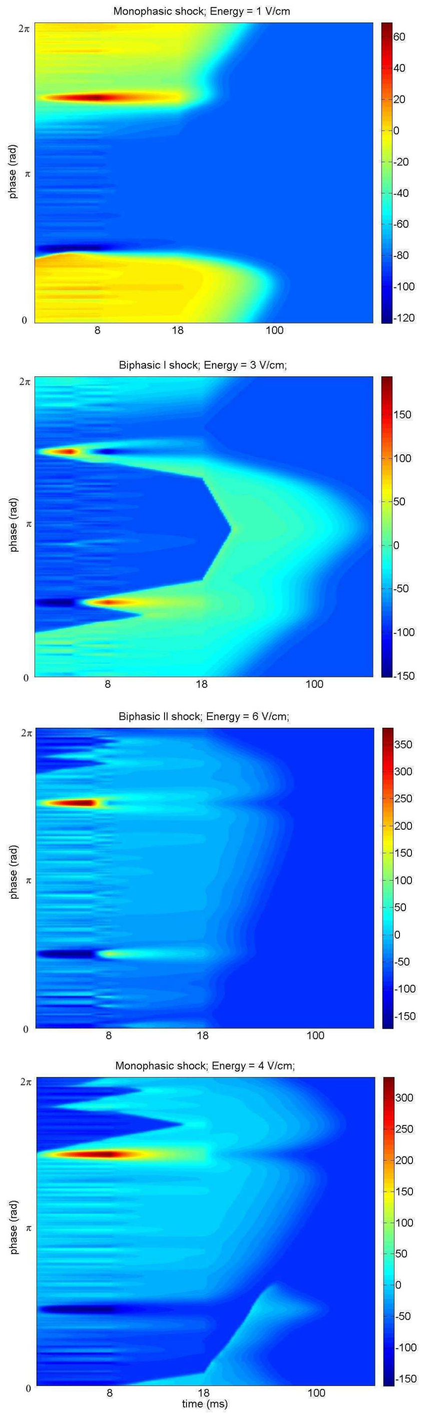

FIG. 1. Defibrillation mechanisms. Defibrillation by : direct block, annihilation of the fronts, direct activation and delayed block (from top to bottom).

---

* asimic@alumni.unav.es

† School of Mathematical Sciences, Rochester Insititute of Technology, Rochester, USA

‡ Dept.of Biomedical Sciences, Cornell University, Ithaca, USA

[1] G. W. Beeler, H. Reuter, J. Physiol. **268**, 177-210 (1992).