Comparison of the Influence of the First Phase of Some Biphasic Defibrillation Pulses on the Cardiomyocyte Model

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We investigated the first phase of bipolar pulses of the following forms: quasi-sinusoidal, rectilinear, truncated exponential, truncated exponential modulated, equivalent of truncated exponential modulated, trapezoidal with sloped rising and falling, stepwise quasi-sinusoidal. Freely-available Cell Electrophysiology Simulation Environment (CESE) OSS 1.4.7 and Luo-Rudy Mammalian Ventricular Model II has been used for modeling [1]. The pulses are compared with respect to the value of the threshold excitation energy for this calculated their energy ratio. The methodology of the study is described in [2]. Rectangular pulse duration with a minimum excitation threshold energy on Luo-Rudy Model is 11 ms [3], while for the human heart, it is about 4 ms [4]. Based on this was selected pulse duration of 2.75 times larger than the actual ones. The waveform of investigated pulses with amplitude value of the excitation threshold shown in Fig. 1.

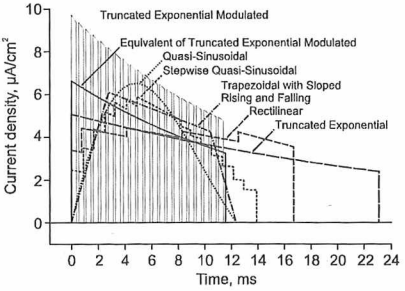

Fig. 1 The waveform of investigated pulses with amplitude value of the excitation threshold.

The lowest threshold energy ratio was obtained in the stepwise quasi-sinusoidal pulse (230 $\mu A^2 \cdot ms/cm^4$). Perhaps this is due to the presence of his "pedestal" — the initial sharp rise in current followed by a gradual increase. Quasi-sinusoidal and trapezoidal with sloped rising and falling pulse on efficiency were almost equal (249 and 253 $\mu A^2 \cdot ms/cm^4$). Therefore, the smooth rise and fall of the defibrillation pulse lead to increased efficiency. However, the rectilinear pulse slightly inferior to the previous two (274 $\mu A^2 \cdot ms/cm^4$). Classic truncated exponential pulse has a low efficiency because of its long duration (308 $\mu A^2 \cdot ms/cm^4$). For comparison, the equivalent of truncated exponential modulated pulse (272 $\mu A^2 \cdot ms/cm^4$) was comparable to the rectilinear.

The highest threshold energy ratio was obtained from the truncated exponential modulated pulse (397 $\mu A^2 \cdot ms/cm^4$). The threshold energy ratio of smooth equivalent of truncated exponential modulated pulse was 1.47 times smaller. This effect is explained by the impact of the modulated electric signal to the low-pass filter, which is the membrane of cardiomyocytes. Thus, modulation of defibrillation pulse increases the defibrillation threshold energy. Similar results were obtained earlier by Blair RC-model [5], and in experiments on animals [6].

References

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