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Optimization of cardiac pacing stimulation by current configuration –a theoretical, numerical and experimental study.

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Approximately 600,000 pacemakers are implanted annually worldwide, and more than 3 million people already have implanted pacemakers. The existing pacemakers emit a stimulation current in the form of a rectangular wave form. Using optimal control theory we derive the best waveform that stimulates cardiac tissue using the least amount of energy. Our main hypothesis is that the myocytes is not a passive component but rather a dynamic element. Specifically, the myocyte ion-channels currents act as an additional source of charge that sums up with the external stimulating charge for stimulation purposes. Therefore, as the action potential emerges (exponentially), the external stimulating current can be reduced accordingly. We tested the theoretically predicted best wave form first in silco using a one dimensional cable with a state of the art ionic cell model of human ventricular cells and found that we could reduce the energy by 60%. Then we tested them in ex vivo hearts of cats and rabbits. We found that energy to stimulate and initiate an electrical wave could be reduced up to 85% from the square pulse.

This results could help save battery life and decrease tissue damage by continuous current stimulation.