Mathematical Modeling and Simulation of Cardiac Tissue Electrophysiology: Effect of Cardiac Deformation on Action Potential Duration

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The purpose of this project was to determine the effect of heart tissue deformation on cardiac action potential duration (APD). The hypothesis was that deformation of the heart tissue would cause the APD to increase. The levels of the independent variable were no deformation (control), and 1 to 5% stretch and APD was the dependent variable. A mathematical model calculating the variation of transmembrane potential during the heartbeat cycle was developed by solving the system of cardiac reaction-diffusion partial differential equations. A computer program in the C language solving the system of partial differential equations, using the forward Euler for time discretization, and center-difference methods for spatial discretization was created. The program calculated ion currents, stretch currents, and diffusion components for each node at every integration time step. The 1.05 deformation yielded the shortest APD while no deformation yielded the longest. The regression r-values were high for all deformation levels. Regression t-tests indicated that the difference in data between deformations and control was significant. The model was extended to study the effects of periodic deformation on spiral wave dynamics and APD using the S1-S2 stimulation protocol. A tip-tracking algorithm to locate points of phase singularities was developed to analyze periodic deformation amplitude and frequency parameters. An increase in amplitude and frequency of the deformation increased the chaos of the spiral waves and the abnormality of the heartbeat. The data collected does not support the hypothesis. This analysis could be extended to study the breaking and meandering of spiral waves.

Awards Won:

Serving Society Through Science: First Award of $500