MODELING OF ELECTROPHYSIOLOGICAL PROPERTIES OF HEART CELLS

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Abstract

Properties of different heart cells are modeled in this article. An action potential (AP) and its characteristics are simulated and evaluated in MATLAB. The action potential duration (APD) is different for different heart cells (atrial, ventricular, etc.) and its proper value is possible to achieve by the change of the model parameters.

1 Heart Cell Models

Electrophysiological activity of human atrial and ventricular cells may be modeled using various less or more complex models, e.g. the Courtemanche-Ramirez-Nattel model [1], the modified FitzHugh-Nagumo model [2]. The time change of the membrane potential V is given by:

$$\frac{dV}{dt} = \left[- I_{ionic} + I_{st} \right] / C_m \tag{1}$$

where I_{ionic} and I_{st} are the ionic current and stimulation current, C_{m} is the membrane capacity. The ionic current comprises different membrane currents, e. g. the fast sodium current, calcium and other membrane currents. Since very complex models of heart cells are not very practical for whole heart electrical signal computation, simplified models are searched for and used.

Complex models are simplified to models with only a few dependent variables. The modified FitzHugh-Nagumo model [2] could be used:

$$\frac{dV}{dt} = - k\, c_1 (V - B) \left(- \frac{(V - B)}{A} + a \right) \left(- \frac{(V - B)}{A} + 1 \right) - k\, c_2 R (V - B) + k\, I_{st} \tag{2}$$

$$\frac{dR}{dt} = k\, e \left(\frac{(V - B)}{A} - d\, R - b \right) \tag{3}$$

where V is the membrane potential, R is the recovery variable, a, b, c_1, c_2, d, e, k, A and B relates to cell properties and I_{st} relates to the stimulation current.

2 Results

If not mentioned otherwise, model parameters are: $a = 0.13$, $b = 0$, $c_1 = 2.6$, $c_2 = 1$, $d = 1$, $e = 0.0060$, $k = 1000$, $A = 0.14$, $B = -0.085$ and $I_{\text{st}} = 0.05$ (lasting for 0.002 s). Model was numerically solved using ode15s Matlab ODE solver.

As it is shown in Figure 1 to Figure 3, it is possible to obtain action potentials of different duration with changing of "e", "a" and "d" parameters. Effect of "A" model parameter change on the action potentials amplitude is shown in Figure 4.

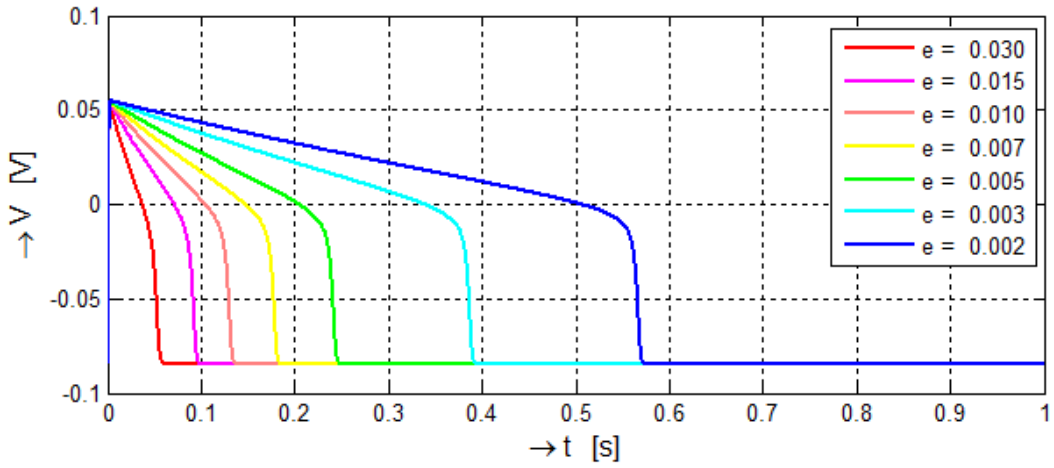

Figure 1: Control of action potential duration using model parameter (e)

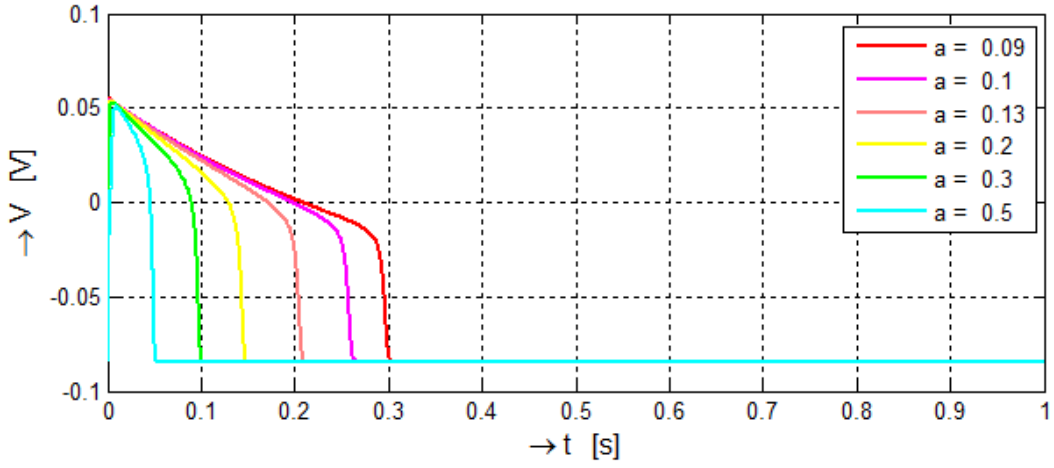

Figure 2: Control of action potential duration using model parameter (a)

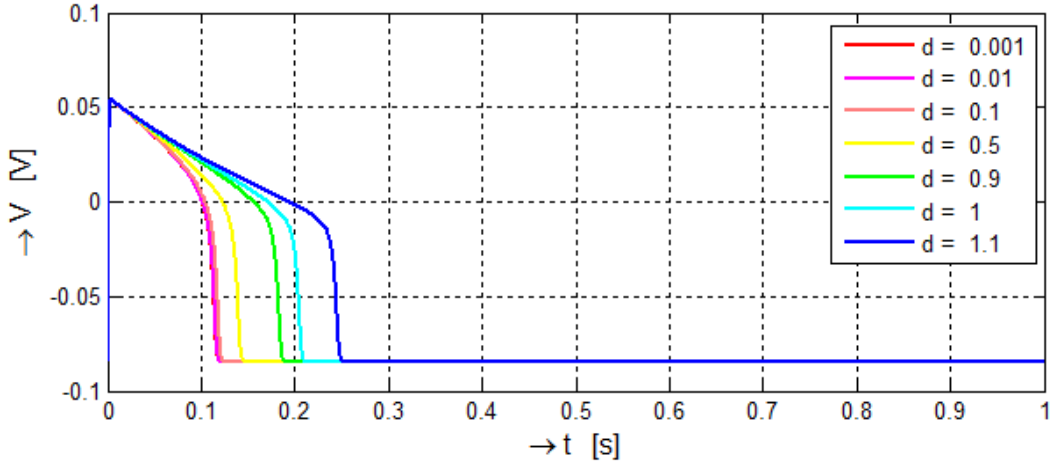

Figure 3: Control of action potential duration using model parameter (d)

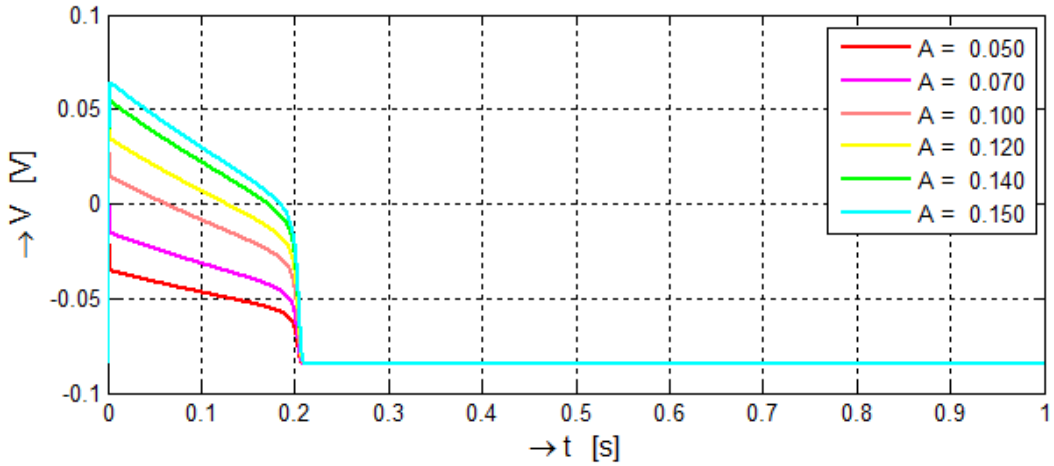

Figure 4: Control of action potential amplitude using model parameter (A)

3 Conclusion

Effects of model parameters change on the action potentials characteristics (amplitude and duration) are presented in the article. It is possible to obtain action potentials of different duration by means of changing the model parameters ("e", "a" and "d"), that is typical for various heart cell types.

Acknowledgement

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References

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