Influence of thermoelectric coupling on ectopic beats generated by mechano-electric feedback (MEF) in a one-dimensional cardiac fiber model

A. Collet[1], T. Desaive[1], L. Piérard[1], R. Boman[2], P. C. Dauby[1]

[1] Cardiovascular Research Center, University of Liège, Liège, Belgium

[2] Computational Mechanics Laboratory, University of Liège, Liège, Belgium

Introduction

Ectopic beats are common in cardiac tissue, and under certain conditions can cause significant changes in cardiac tissue properties, such as the action potential duration and refractory period duration of cardiomyocytes. On occasion, changes to these properties can induce cardiac arrhythmias, such as tachycardia, generated by functional re-entry. In this study, we examine the effects of thermal processes on ectopic beats generated by mechano-electric feedback (MEF).

Model

$$\frac{\partial V}{\partial t} = \frac{\partial}{\partial X^M}\left(\sqrt{C}C^{MN}\frac{\partial V}{\partial X^N}\right) + \eta(T)\left[f(V,w) - I_s\right]$$

$$f(V,w) = V(a-V)(V-1) - w$$

$$I_s = g(V-1)\left(\sqrt{C}-1\right)H(C-1)$$

$$\frac{\partial w}{\partial t} = \varepsilon\varphi(T)(kV - w)$$

$$\frac{\partial T_a}{\partial t} = \varepsilon\left(k_{T_a}V - T_a\right)$$

$$\frac{\partial}{\partial X^M}\left(S^{MN}\frac{\partial x^i}{\partial X^N}\right) = 0$$

$$S^{MN} = S_p^{MN}\left(C^{MN}\right) + S_a^{MN}\left(C^{MN}, T_a\right)$$

- V : Transmembrane potential (dimensionless)
- w : Gate variable
- C^{MN} : Components of the right Cauchy-Green deformation tensor
- C : Determinant of the right Cauchy-Green deformation tensor
- S^{MN} : Components of the second Piola-Kirchhoff stress tensor

- MEF via stretch-activated currents I_s
- Excitation-contraction coupling by linearly superimposing active stress components S_a^{MN} to the passive ones S_p^{MN}
- Thermoelectric coupling via temperature-dependent functions introduced in the electrophysiology model

Results

Increasing temperature

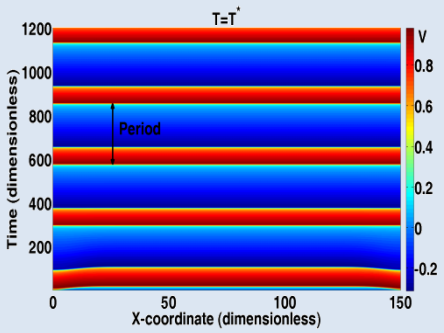

Fig.1

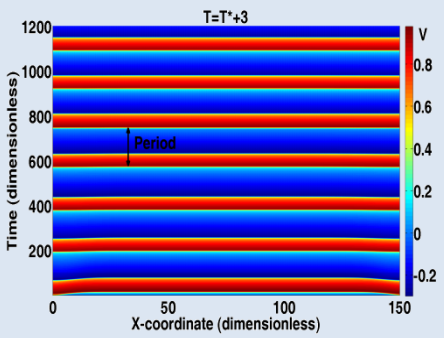

Fig.2

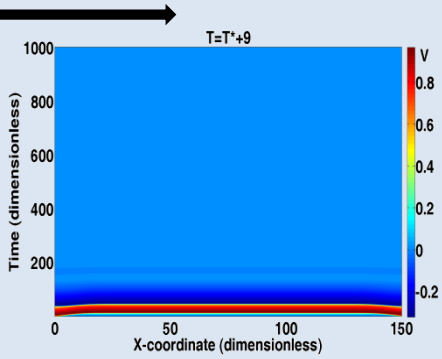

Fig.3

1. Period between 2 ectopic beats decreases when the temperature is raised (**Fig.1** and **Fig.2**)
2. Ectopic beats are not generated anymore when the temperature exceeds a critical value (**Fig.3**)

Conclusions

Numerical simulations highlight the influence of thermoelectric coupling on MEF. This influence is significant for ectopic beats generated by MEF. The influence of thermal processes on electrophysiology should be taken into account in further modeling works.

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Contacts

A.Collet@ulg.ac.be PC.Dauby@ulg.ac.be