2D Simulation of Cardiac Tissue

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Abstract

A two-dimensional atrial tissue model has been constructed to study the propagation of action potential and electrograms. The model presents the atrial electrograms recorded with a mapping catheter. The model can be stimulated to produce an action potential identical to a human electrogram, see picture 1.

COMSOL Multiphysics® software is used as the finite element modeling tool in this research to model the propagation of action potential in a 2D atrial tissue. see picture 2.

A 2D atrial tissue model is simulated using the Courtemanche et al. cell model equations. The electrical propagation of the cardiac impulse is obtained by solving a reaction diffusion system based on the ionic model. The propagation of action potential is modeled assuming monodomain equation 1. This equation is implemented in the PDE in coefficient form (equation 2) in COMSOL.

For each point, a system of 21 coupled nonlinear differential equations is solved in MATLAB® to compute I(ion) based on the Courtemanche et al. cell model equations. It then is linked to COMSOL to solve the PDE.

The 2D model can be stimulated with a single impulse and produces an action potential that moves through the 2D tissue, see picture 3.

The model is capable of being modified to study the effects of recording electrode size and location on electrograms. It also can be modified to study the action potential propagation during atrial ablation therapy.

The two-dimensional model of a myocardial sheet developed in this project can next be used to develop a three-dimensional model. Such a computer model can be beneficial prior to the ablation procedures to examine effects of ablation sites on treating arrhythmia such as atrial fibrillation.

Reference

Samineh R. Esfahani, Two-Dimensional Computer Model of Human Atrial Ablation, University of South Florida, 2011.

Figures used in the abstract

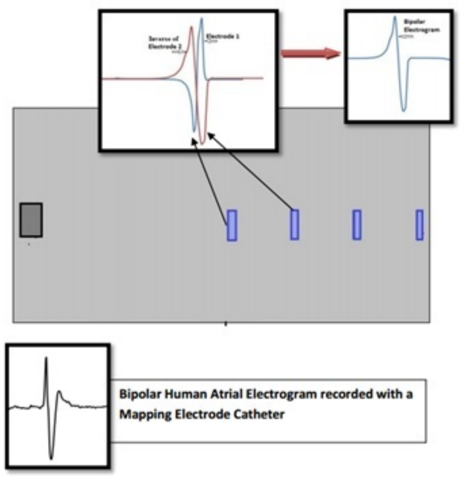

Figure 1: Electrogram Model.

$$C_m \frac{\partial V_m}{\partial t} = S_v^{-1} \nabla . \sigma \nabla V_m + I_{st} - I_{ion} \qquad \text{Equation 1}$$

$$e_a \frac{\partial^2 V}{\partial t^2} + d_a \frac{\partial V}{\partial t} + \nabla(-c\nabla V - \alpha V + \gamma) + aV + \beta \nabla V = f \qquad \text{Equation 2}$$

Figure 2: Computational methods.

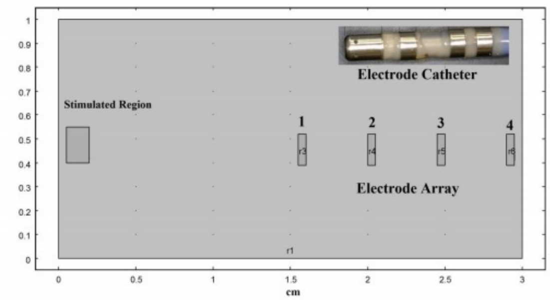

Figure 3: Electrode arrays to model atrial electrograms.

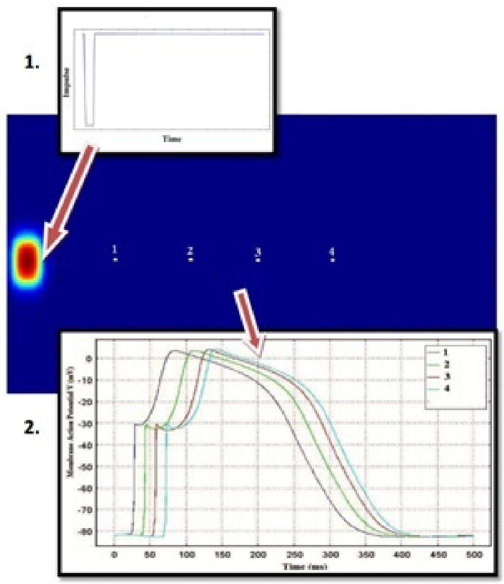

Figure 4: Action potential.