2D Simulation of Cardiac Tissue

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Introduction: Computational models of cardiac electrical activity and action potential propagation are important for understanding the development and propagation mechanisms of arrhythmias. During cardiac mapping, local atrial electrograms are recorded with a mapping catheter to analyze the electrical activity of the atrium. This work presents a numerical model of a two-dimensional slice of human atrial tissue using the complex Courtemanche, et al atrial cell model.

Computational Methods: The electric propagation of the cardiac impulse is described by a reaction-diffusion system assuming a monodomain model given by:

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

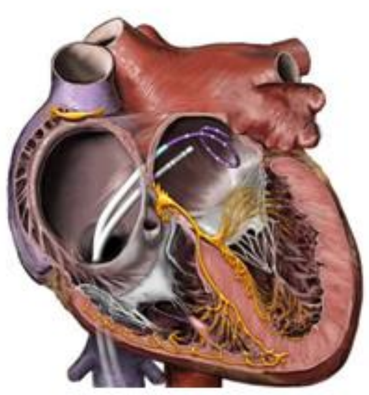
In COMSOL Multiphysics®, PDE in coefficient form was used:

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

Total of 21 nonlinear differential equations solved between Matlab and COMSOL.

Atrial electrogram was reproduced by implementing extracellular potential Φ_e in COMSOL.

$$\Phi e\,(x, y, t) = \frac{1}{4\pi\sigma_e} \sum \frac{I_m}{|r|}$$



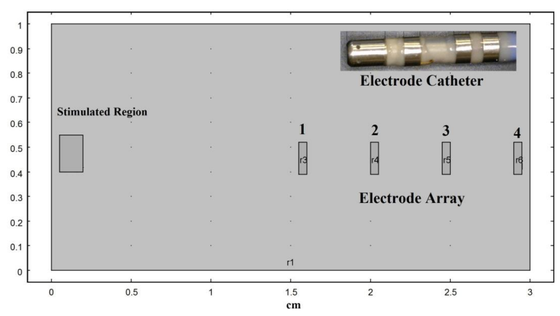


Figure 1. 2D tissue model with electrode arrays to model atrial electrograms.

Result: A rectangular stimulus impulse was applied to the electrode and the action potential propagation was calculated in the domain, Figure 2. The atrial electrogram model was compared with a human electrogram, Figure 3.

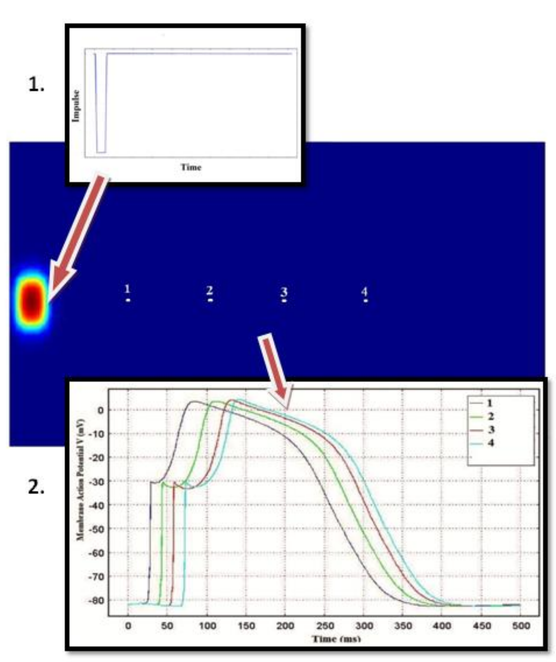


Figure 2. Action Potential

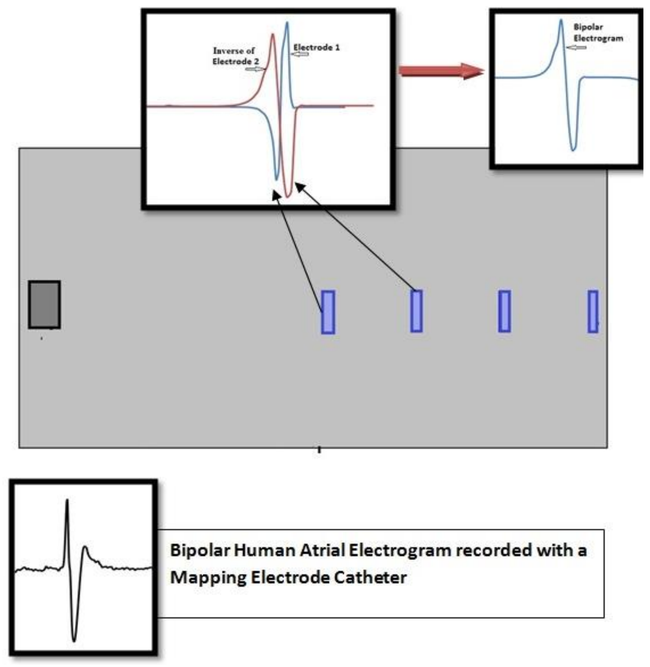


Figure 3.Electrogram Model

The model was used to study the effect of recording electrode size and location on electrograms.

The signal to noise ratio increased by increasing the electrode surface area A1, Figure 4. An increase in the distance of the recording electrode and the tissue decreased the amplitude of the signal, Figure 5.

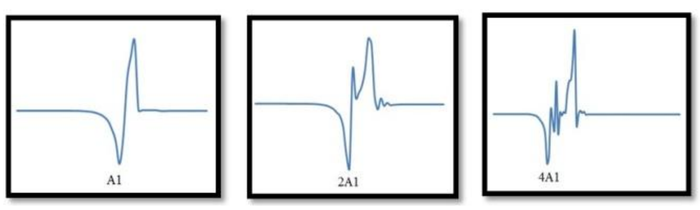


Figure 4.Various electrode sizes

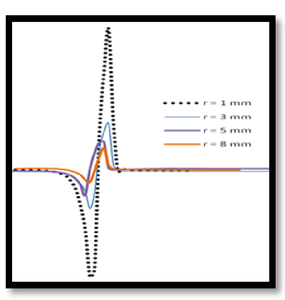


Figure 5. Various electrode distances

Conclusions: Atrial action potential propagation and electrogram were reproduced using COMSOL. The model was used to study the effect of recording electrode size and location on electrogram during cardiac mapping procedure.