Shock-Induced Termination of Cardiac Arrhythmias

Project Description

- Due to the wide variation in size of people experiencing cardiac arrhythmias, no protocol has been set.
- It has been determined that biphasic shocks are superior to monophasic shocks, however the reasoning for this is still not completely understood.[5,6]
- Extensive work has been done in this field, but the models used need to be expanded further as their applications are limited and computational costs high.[3, 4]
- We developed a one-dimensional numerical model based on a bidomain model.
- The new model works by testing how currents diffuse through a tissue network allowing for the success of the shock to be determined through the hyperpolarization/depolarization of the action potentials.
- The new model allows the testing of strong stimuli and the efficiency of defibrillation protocols with low computational costs.

Scientific Challenges

- When a heart experiences cardiac arrhythmias, a cardiac defibrillator is used to stop these chaotic cardiac action potentials. A challenge cardiac defibrillators face is that high energy levels, between 150-200 Joules, are needed to reliably cause defibrillation[1]. However, such high energy levels can potentially cause damage to the heart. Therefore, more efficient protocols are needed that lower the energy used while successfully causing defibrillation.

Potential Applications

- Determine which shock protocol is the most efficient: Monophasic, Asymmetric Biphasic, or Symmetric Biphasic.

- Finding a safe amount of energy to efficiently defibrillate a heart without causing cardiac tissue damage.

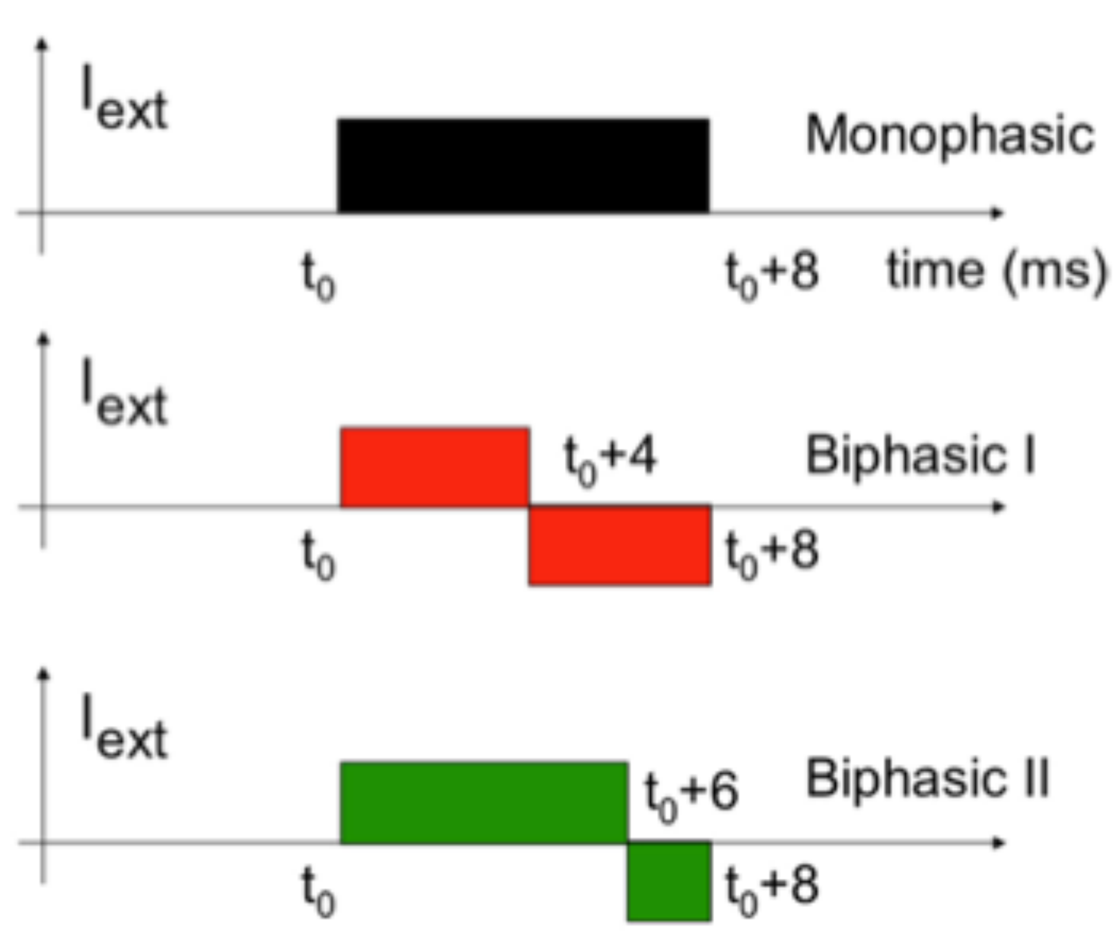

Figure 1. Diagram depicting the size of the current used with each protocol. The Monophasic protocol uses one shock to cause defibrillation. The Biphasic 1 protocol uses 2 shocks of equal size to cause defibrillation. The Biphasic II protocol uses 2 unsymmetric shocks to cause defibrillation. From Bregard 2013.

Team Members:

- Baltazar Chavez-Diaz
- Chen Jiang
- Sarah Schwenck
- Weide Wang
- Jinglei Zhang

Methodology

1. Referenced all of the unknown parameters listed in our main equation from past literature.

2. Solved for these parameters and inputted results into the main equation.

3. Solved main equation for membrane potential using MATLAB with the initial conditions $\Delta\Phi$ and Φ_b.

4. Plotted results.

1) $$\frac{\partial V_m}{\partial t} = -\frac{I_{BR} + I_{ep} + I_{fu}}{C_m} + \nabla \cdot (D_g \cdot \nabla V_m) + \nabla \cdot (D_g \cdot \nabla \varphi_e)$$

2) $$\nabla \cdot [(D_e + D_g) \cdot \nabla \varphi_e] = -\nabla \cdot (D_g \cdot \nabla V_m) - \frac{I_{ext}}{\beta C_m}$$

Figure 2. Partial differential equations such as equation 2 were used to solve for membrane potential in the ordinary differential equation, equation 1.

Results

1. Monophasic shocks were found to be the least efficient in terms of the amount of energy required for a successful defibrillation to occur.

2. Asymmetric Biphasic shocks were determined to be the most efficient in terms of the amount of energy required for a successful defibrillation to occur.

Glossary of Technical Terms

- Cardiac arrhythmias: The heart is experiencing an irregular heartbeat.
- Monophasic shock: Shock delivered to heart from 1 vector.
- Symmetric Biphasic shock (Biphasic 1): Shock with two equal phases delivered to heart via 2 vectors with the polarity switching during the shock.
- Asymmetric Biphasic shock (Biphasic 2): Shock with a larger 1st phase delivered to heart via 2 vectors with the polarity switching during the shock.
- $\Delta\Phi$: Size of the action potential introduced to the system.
- Φ_b: Location on the ring where the shock was introduced.

References

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