Shock-Induced Termination of Cardiac Arrhythmias

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Presentation Overview

- Background
- Model
- Equations & Parameters
- Analysis
- Conclusion

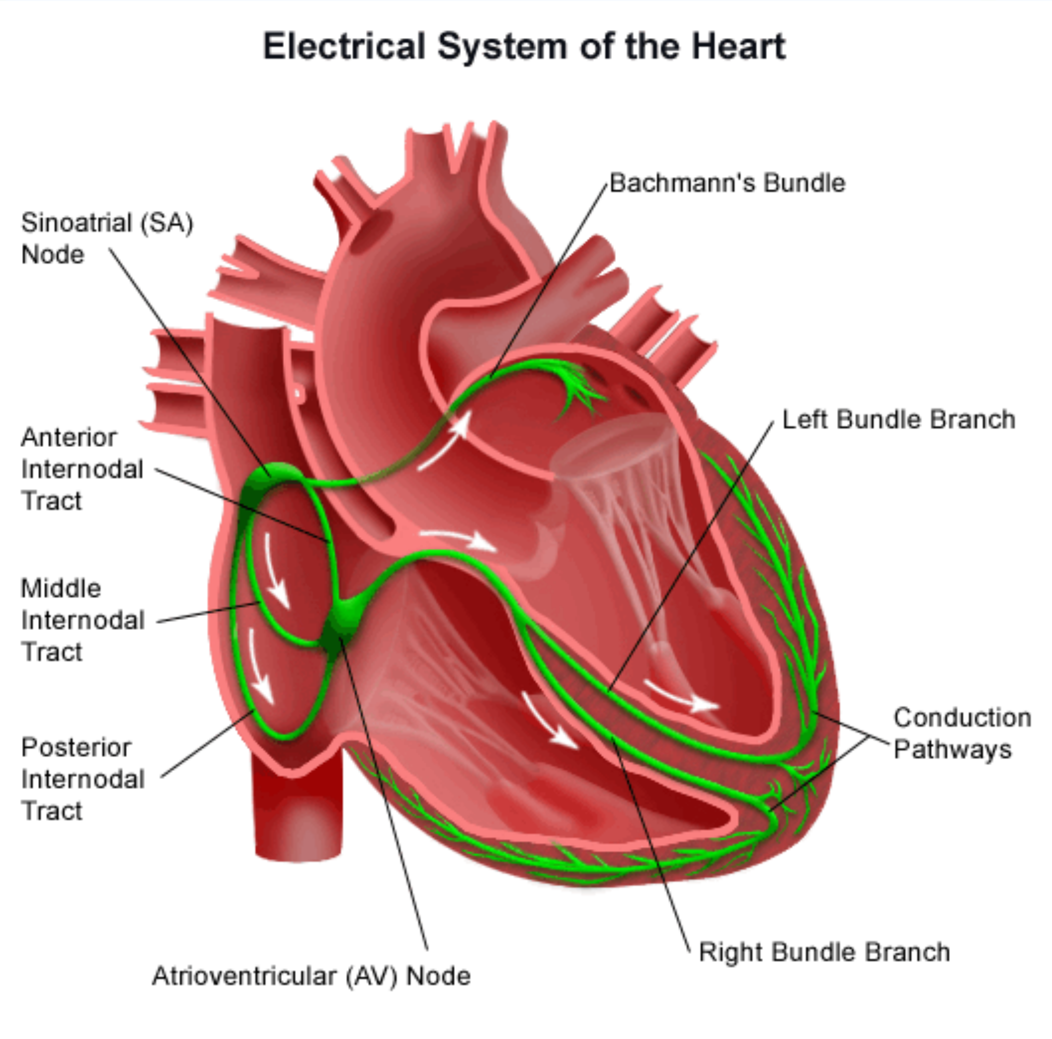
Cardiac Arrhythmias

Cardiac dysrhythmia or **irregular heartbeat**

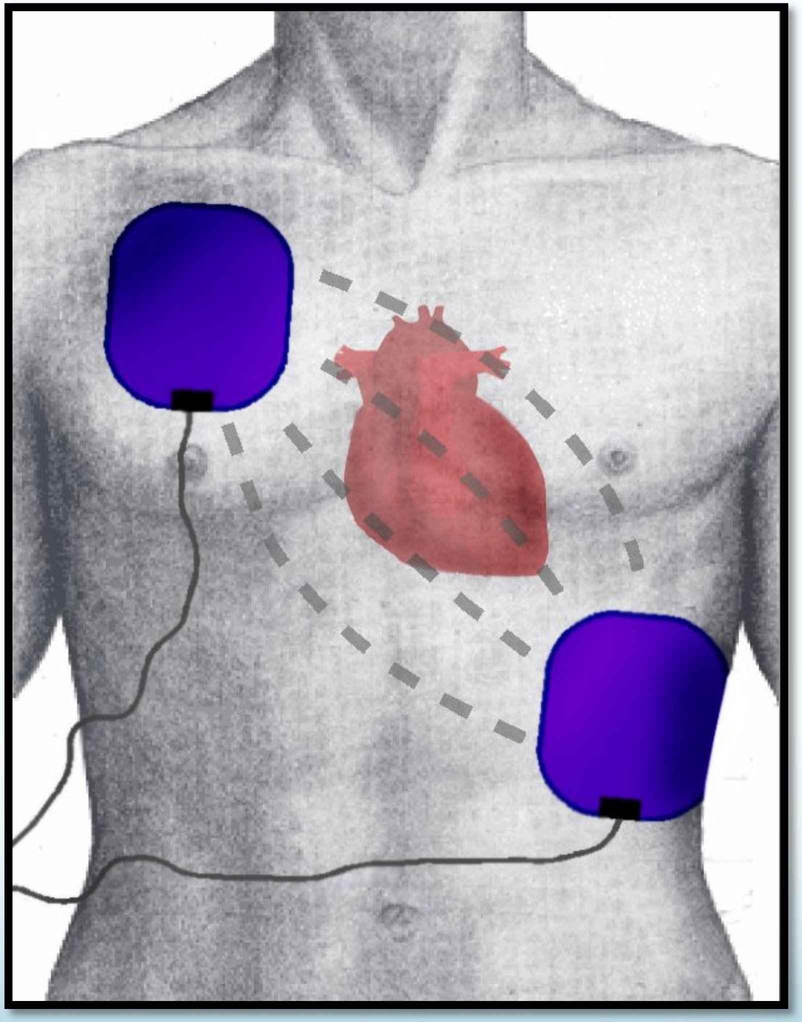
Irregular **Electrical** activity of the heart

Regular or irregular

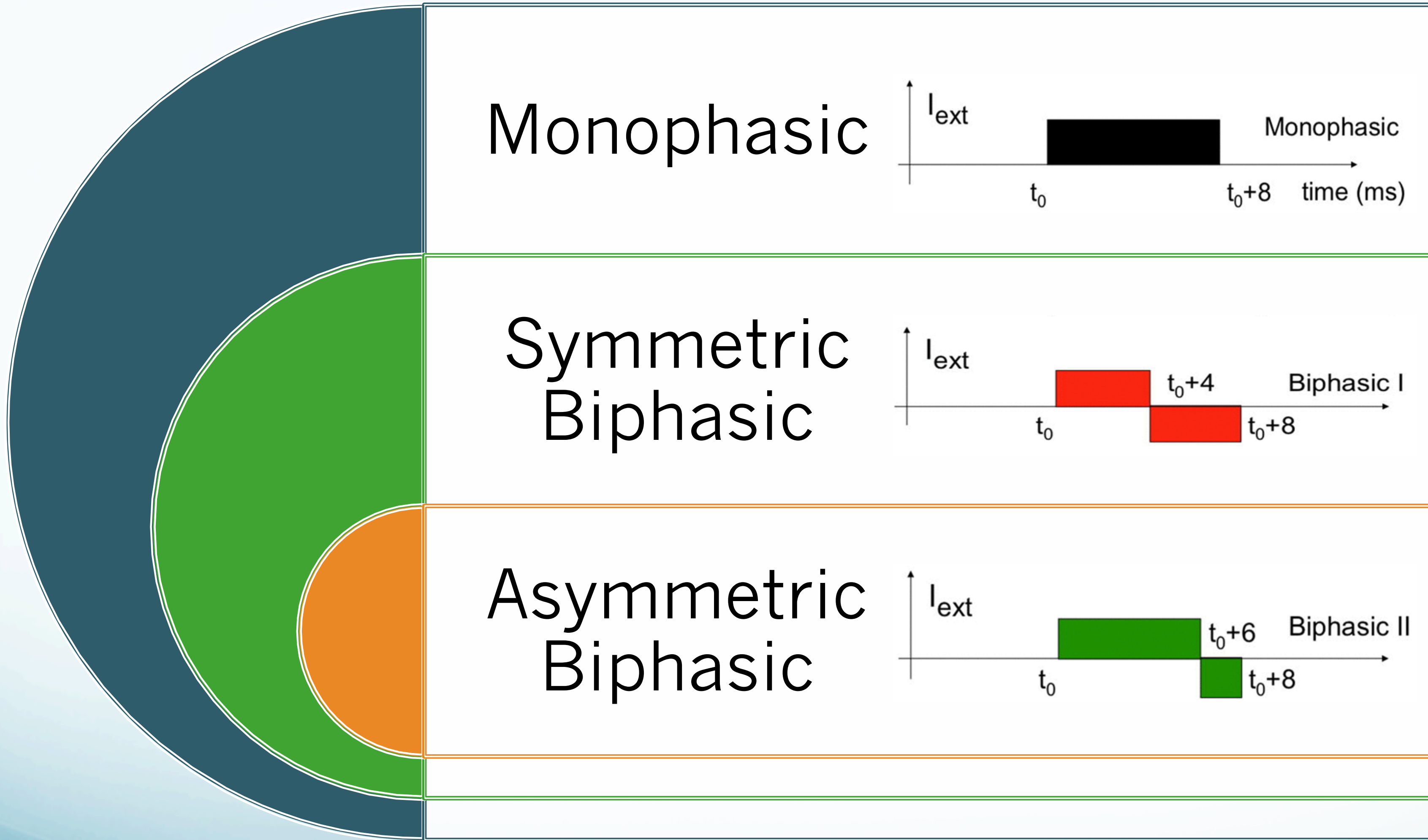
Cardiac Arrhythmias



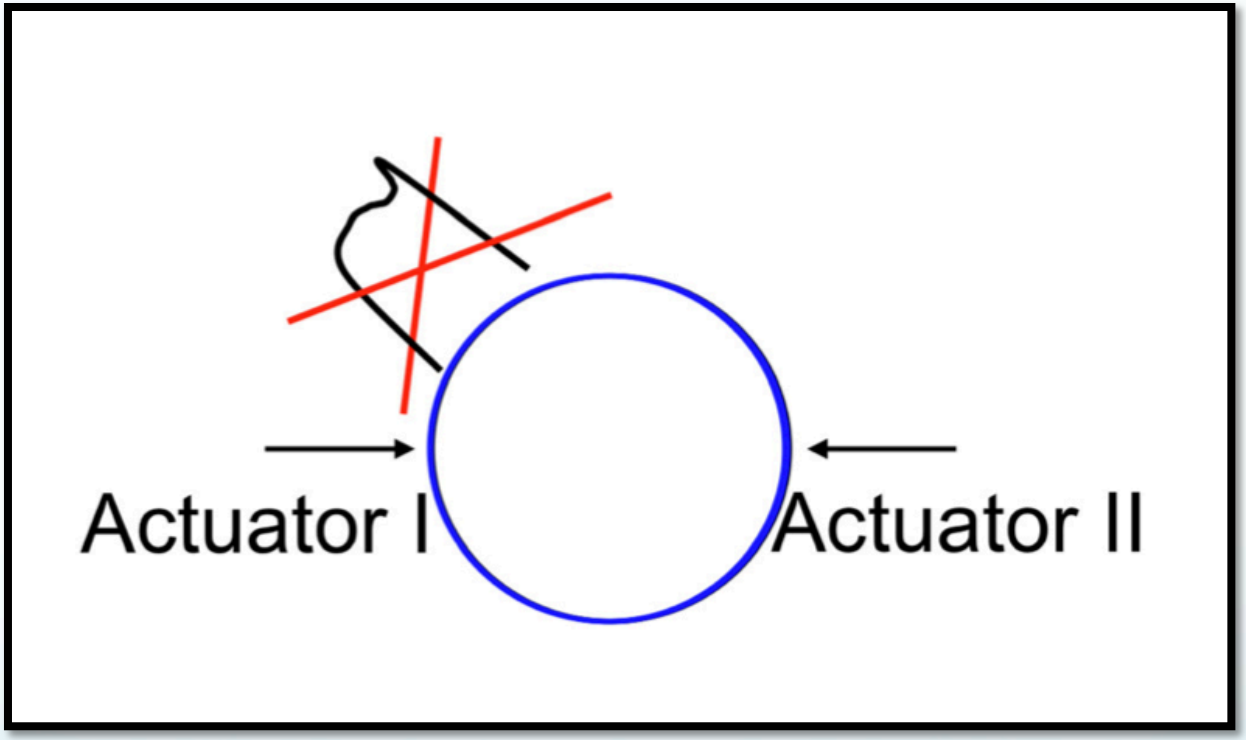
Defibrillators



Defibrillators



Model



Parameter influencing the defibrillation outcome

1) The shock waveform
2) The shock duration
3) The shock energy
4) Shock timing
5) Dynamical state at the time of the shock
6) Heterogeneity of the cardiac tissue
7) System size

Beeler-Reuter Equation

Describe the electrical activity of cardiac myocytes

Beeler-Reuter Equation

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

φ_e : extra – cellular potential
D_g : intra – cellular diffusion of the electrical potential
C_m : capacitance per surface area of the myocyte
V_m : membrane potential
I_{ep} : current associated with electroporation
I_{BR} : membrane current
I_{fu} : current associated with possible anode break stimulation

ODEs Influencing PDE

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

- Need to solve for each ODE
- Example:

$$I_{BR} = I_X + I_K + I_{Na} + I_s$$

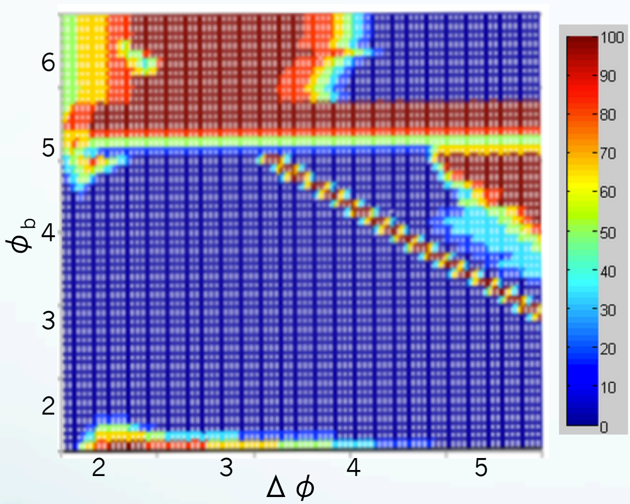
$$I_X = 0.8x * \frac{e^{0.04(V+77)} - 1}{e^{0.04(V+35)}}$$

$$\frac{dx}{dt} = \frac{x_\infty - x}{T_x} \qquad x_\infty = \frac{\alpha_x}{\alpha_x + \beta_x} \qquad T_\infty = \frac{1}{\alpha_x + \beta_x}$$

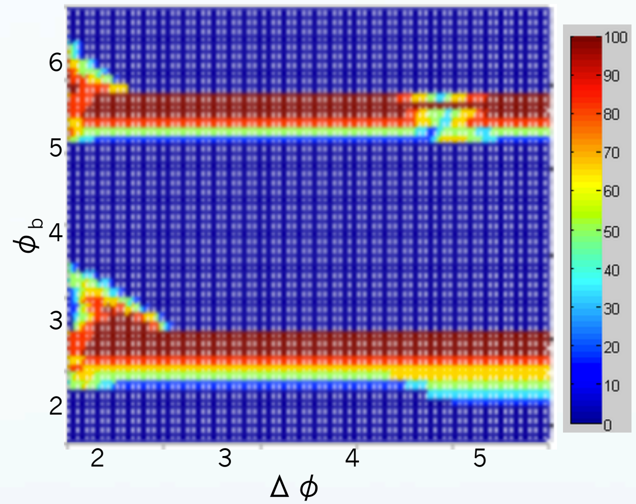
$$\alpha_x = \frac{0.0005e^{0.083(V+50)}}{1 + e^{0.057(V+50)}} \qquad \beta_x = \frac{0.0013e^{-0.06(V+20)}}{1 + e^{0.04(V+20)}}$$

E = 1 V/cm

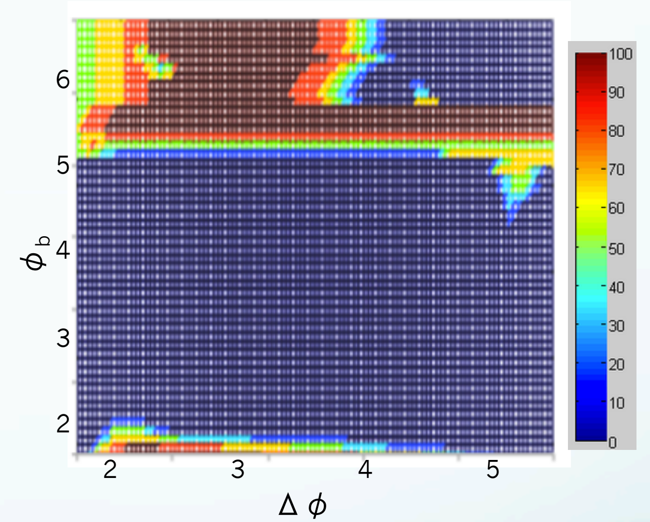
Monophasic



Symmetric Biphasic

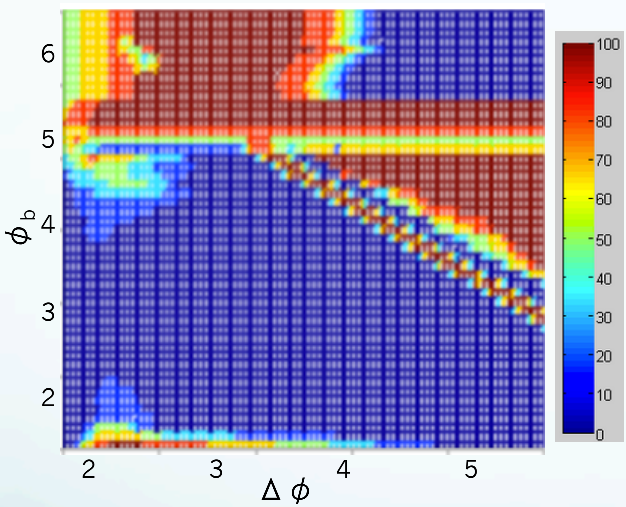


Asymmetric Biphasic

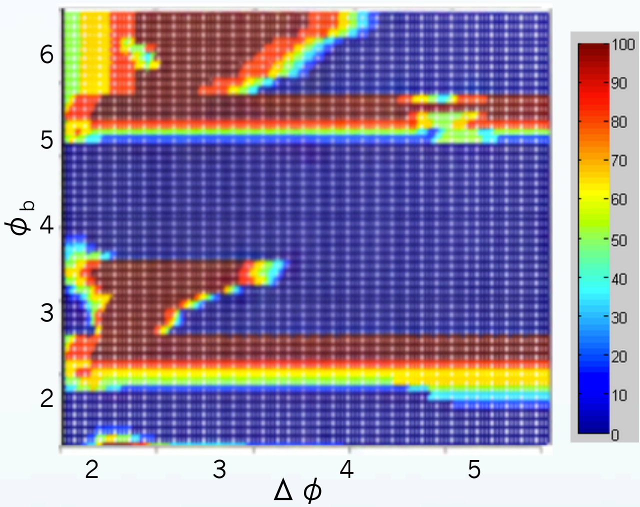


E = 3 V/cm

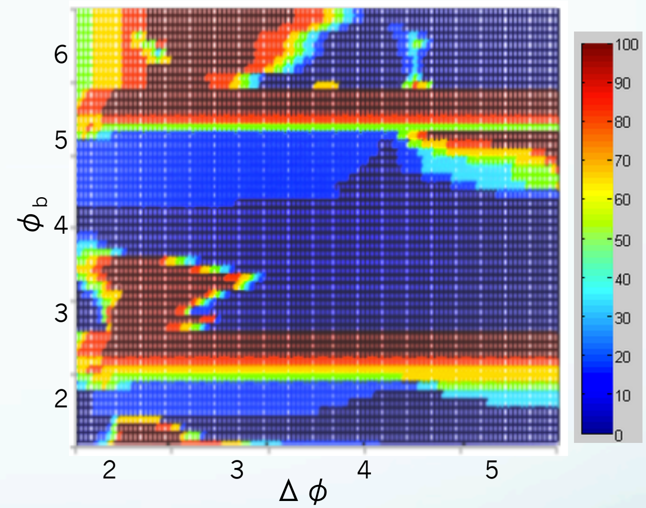
Monophasic



Symmetric Biphasic



Asymmetric Biphasic



Protocol efficiency varies with shock energy

E (V/cm)	Monophasic	Symmetric Biphasic	Asymmetric Biphasic
1	28	17	16
3	44	43	45
7	93	99	98
9	99	100	100

Conclusion

Monophasic is the most efficient at low energy

Asymmetric biphasic is the most efficient otherwise

Conclusion

High E → 90% success

- The analysis of the numerical data shows that when the energy is high (which E is 7V/cm here) all of these three protocols will achieve 90% success

Efficiency

$$Efficiency_{(biphasic\_II)} > Efficiency_{(biphasic\_I)} > Efficiency_{(monophasic)}$$

Limitations

- Only a 1 dimensional model
- Can't account for shocks that potentially cause fibrillation
- Focused on difference between monophasic protocols and biphasic protocols