Engineering involved in Cardiac Arrest Management

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Fascinating Facts:

424,000/year out of hospital CA's.

More than half of all cardiovascular deaths.

~25-30% achieve ROSC

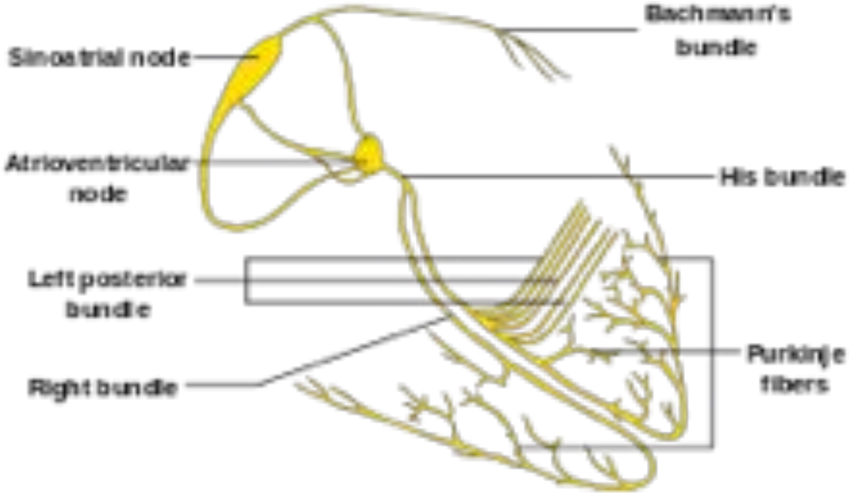
30 day survival rate is ~10%

Let’s talk about the Heart...

Four chambers:

- Right Atrium
- Right Ventricle
- Left Atrium
- Left Ventricle

Cardiac Neuroanatomy



<u>SA Node</u>

AV Node

Bundle of His

L & R bundle branche

Purkinje Fibers

What is cardiac arrest?

Arrhythmia vs. asystole

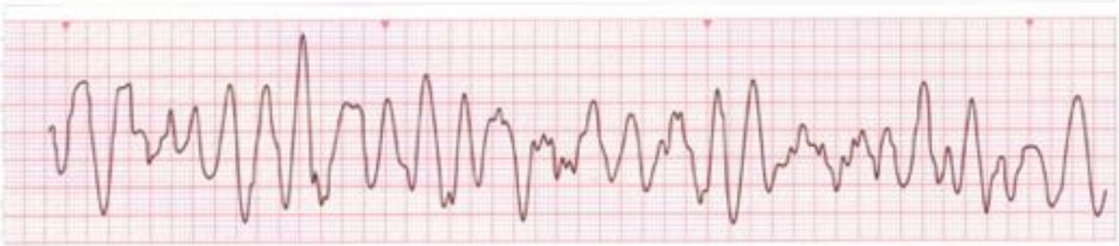
Blood not adequately pumped out

Causes of Cardiac Arrest

Ventricular Fibrillation & pulseless V-TACH

Not 100% understood

- Myocardial Infarction
- Congenital Heart Defects
- Cardiomyopathies
- Trauma (surgery)
- Commotio Cordis



Defibrillation

Delivering current through myocardium

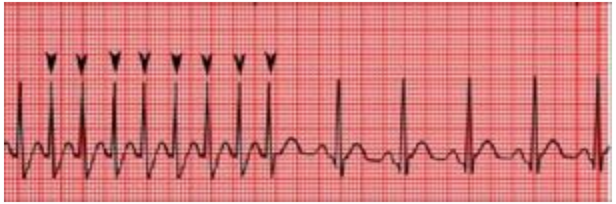
Depolarizes and terminates arrhythmia

Pacemaker of the heart (Sinoatrial node)

E  shes nor  us rhy 

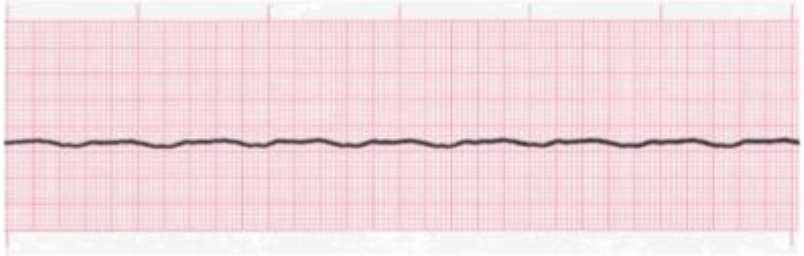
Defibrillation

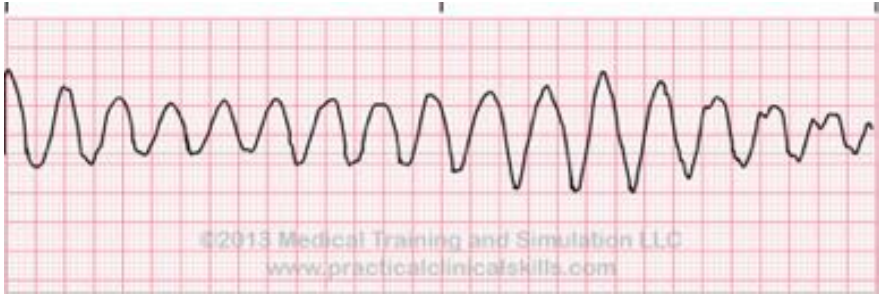
Pulseless Ventricular Tachycardia



Ventricular Fibrillation

Pop quiz: which one is shockable rhythm?



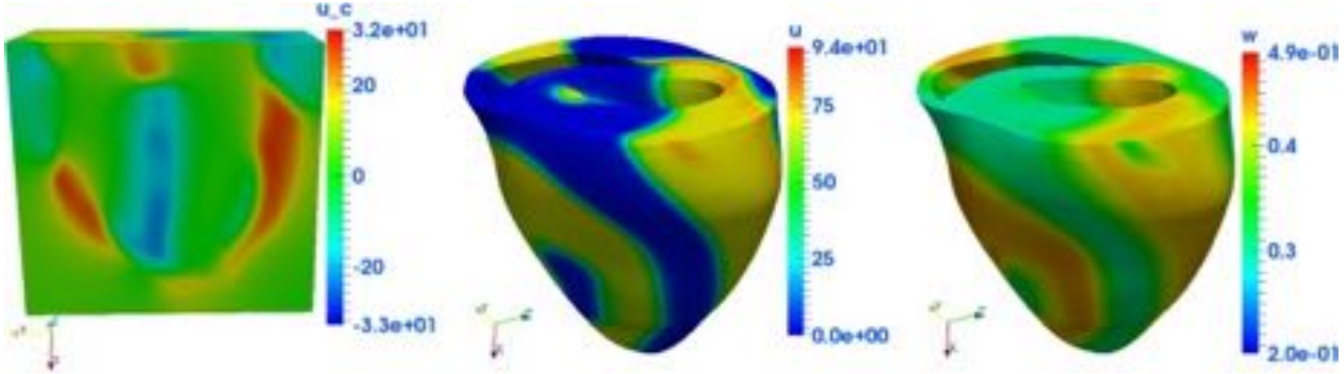


I forgot to say “clear”.

The Engineering

Defibrillators

Mapping of the heart

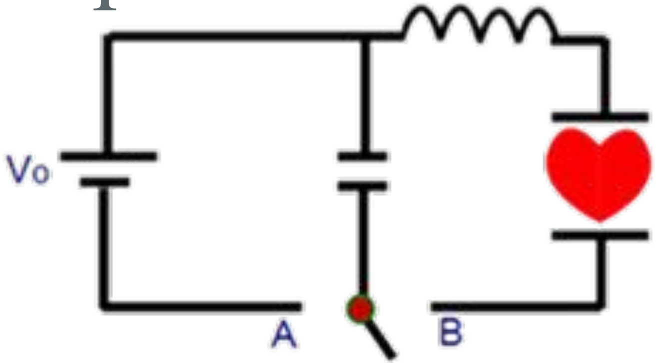


How Defibrillators Work

Electrodes assess electrical activity to determine if shockable rhythm.

If shockable rhythm, current is passed.

Heart stops. (Restarts?)



DC Defibrillators

Automated transformer charges capacitor.

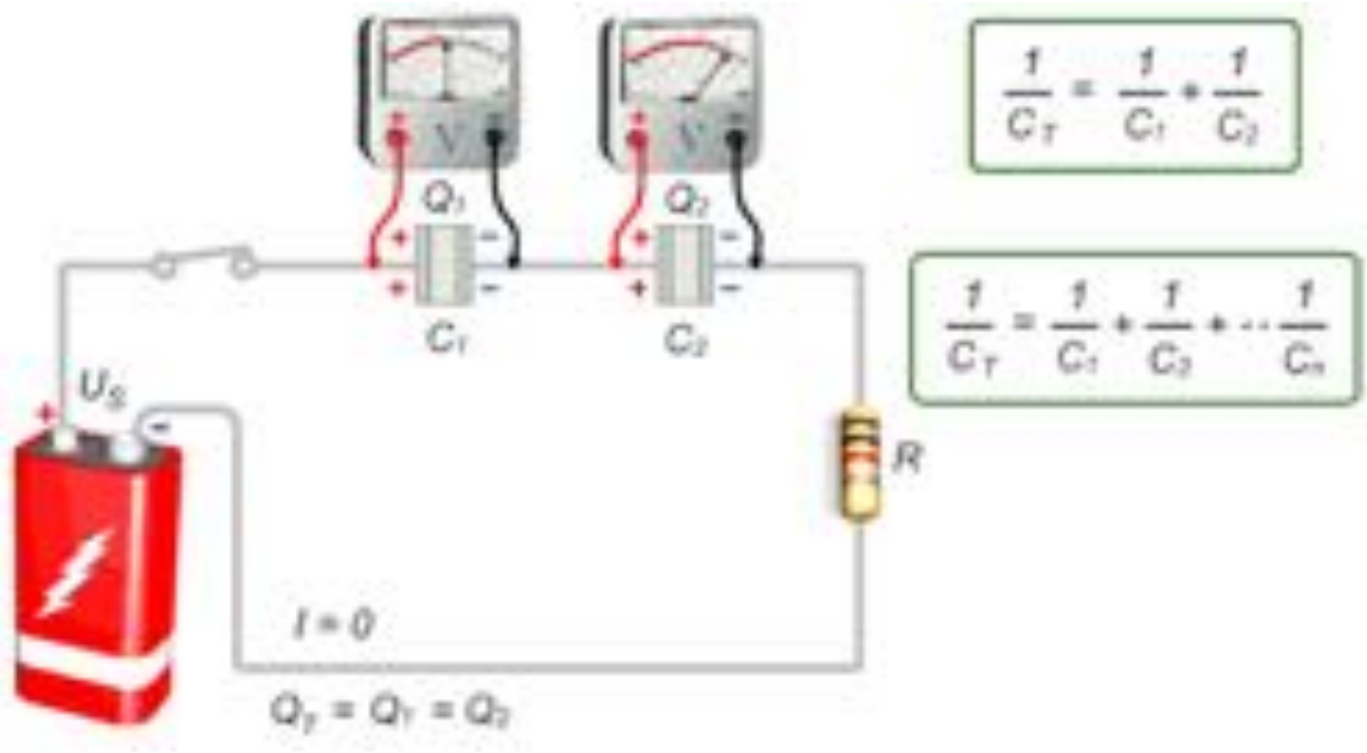
Rectifying diode allows current to flow in only one direction (DC).

Capacitor discharges voltage and produces current.

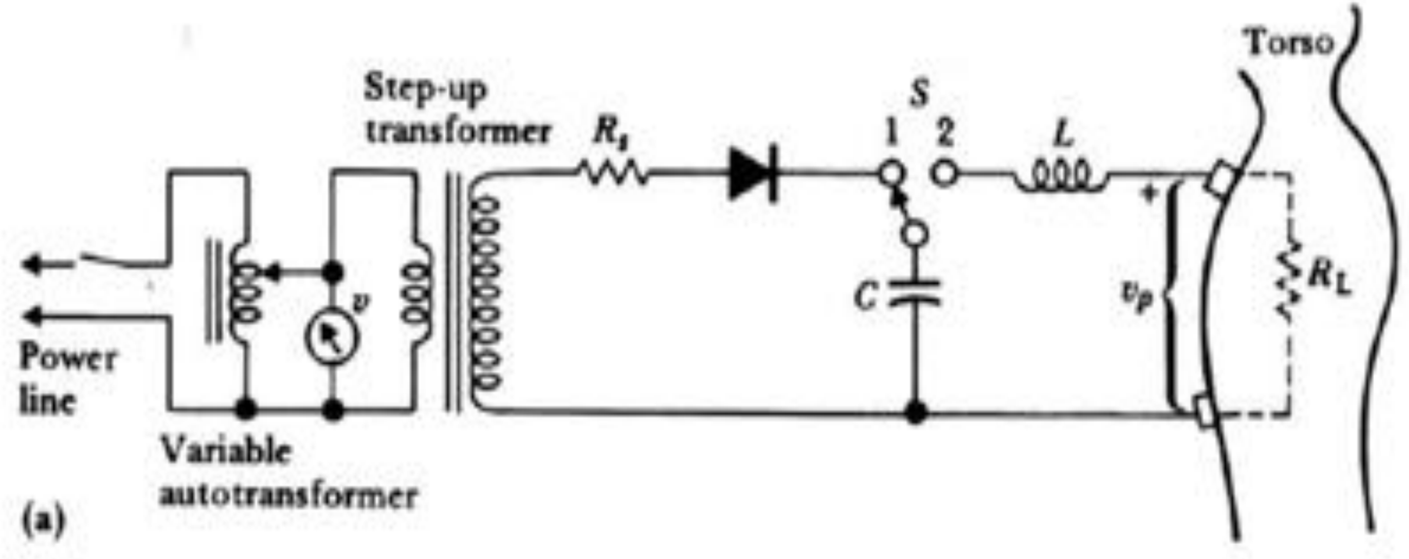
Inductor slows down discharge by counter-voltage.

- Better shock for patient.

Capacitors Review



DC Defibrillator Circuitry

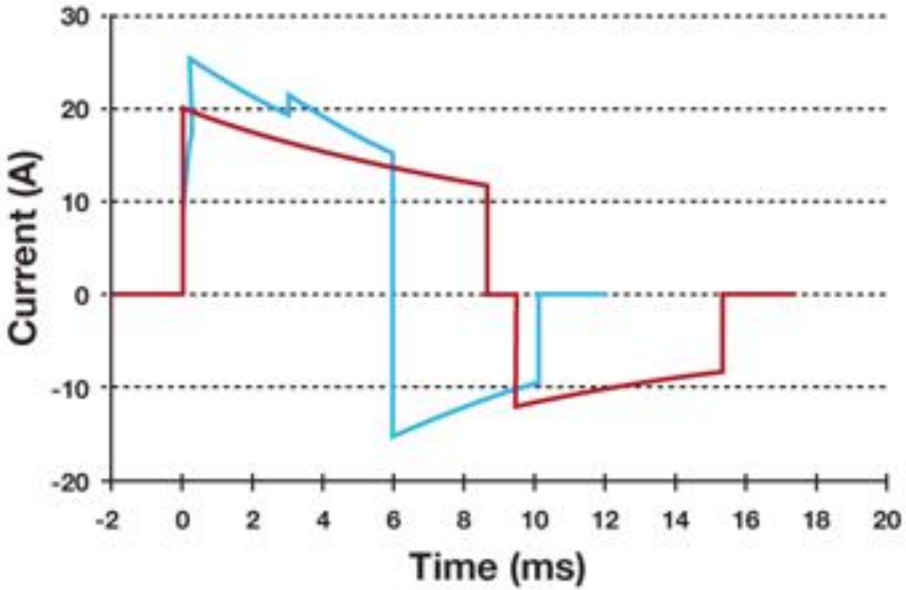


Monophasic and Biphasic Defibrillation

Monophasic delivers in one direction.

Biphasic delivers in two directions.

- Delivers depolarization effect to more myocardial fibers than monophasic.
- Less energy needed for same effect.



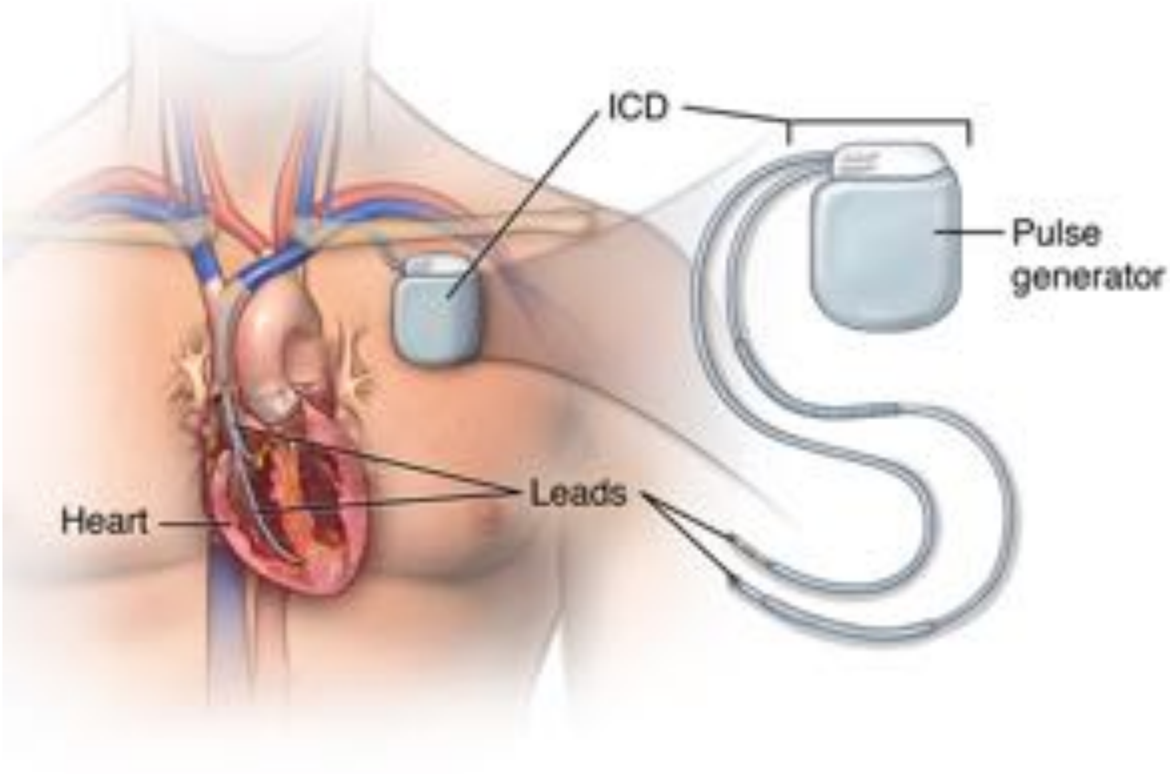
PHYSIO-CONTROL®	ZOLL®
200J 96% Efficacy (184/192)	200J 96% Efficacy (188/195)

Other Kinds Of Defibrillators

Implantable Cardioverter Defibrillator

- Prevents cardiac arrest in high risk patients.
- Placed under skin, monitors heart rate and rhythm.
- Pacemaker
  - When bradycardic, device sends tiny electrical signals.
  - When arrhythmic, device defibrillates.

Implantable cardioverter defibrillator (ICD)



Heart Mapping

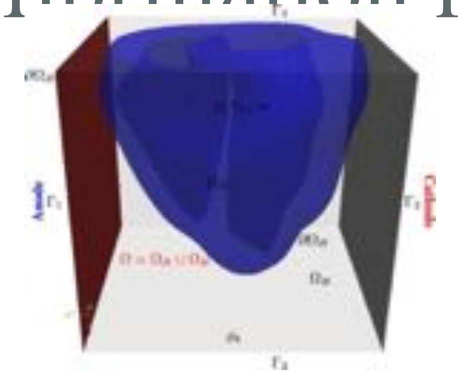
Journal of Mathematical Analysis and Application

- Mathematical models to predict bioelectric activity across cardiac tissue
- Used data to rigorously create a 3D model of the heart & current flows

Heart Mapping

Better understanding of neuroanatomy, and gap-junction interconnection.

Help improve defibrillation methods.



$$\|p_n\|_{L^\infty(t,T;L^2(\Omega_H))} + \sum_{j=i,e} \left\|\sqrt{\varepsilon} p_{n,j}\right\|_{L^\infty(t,T;L^2(\Omega_H))} + \|p_{w_n}\|_{L^\infty(t,T;L^2(\Omega_H))} \le c_1,$$

$$\sum_{j=i,e} \|\nabla p_{n,j}\|_{L^2(t,T;L^2(\Omega_H))} + \|\nabla p_{n,s}\|_{L^2(t,T;L^2(\Omega_B))} \le c_2.$$

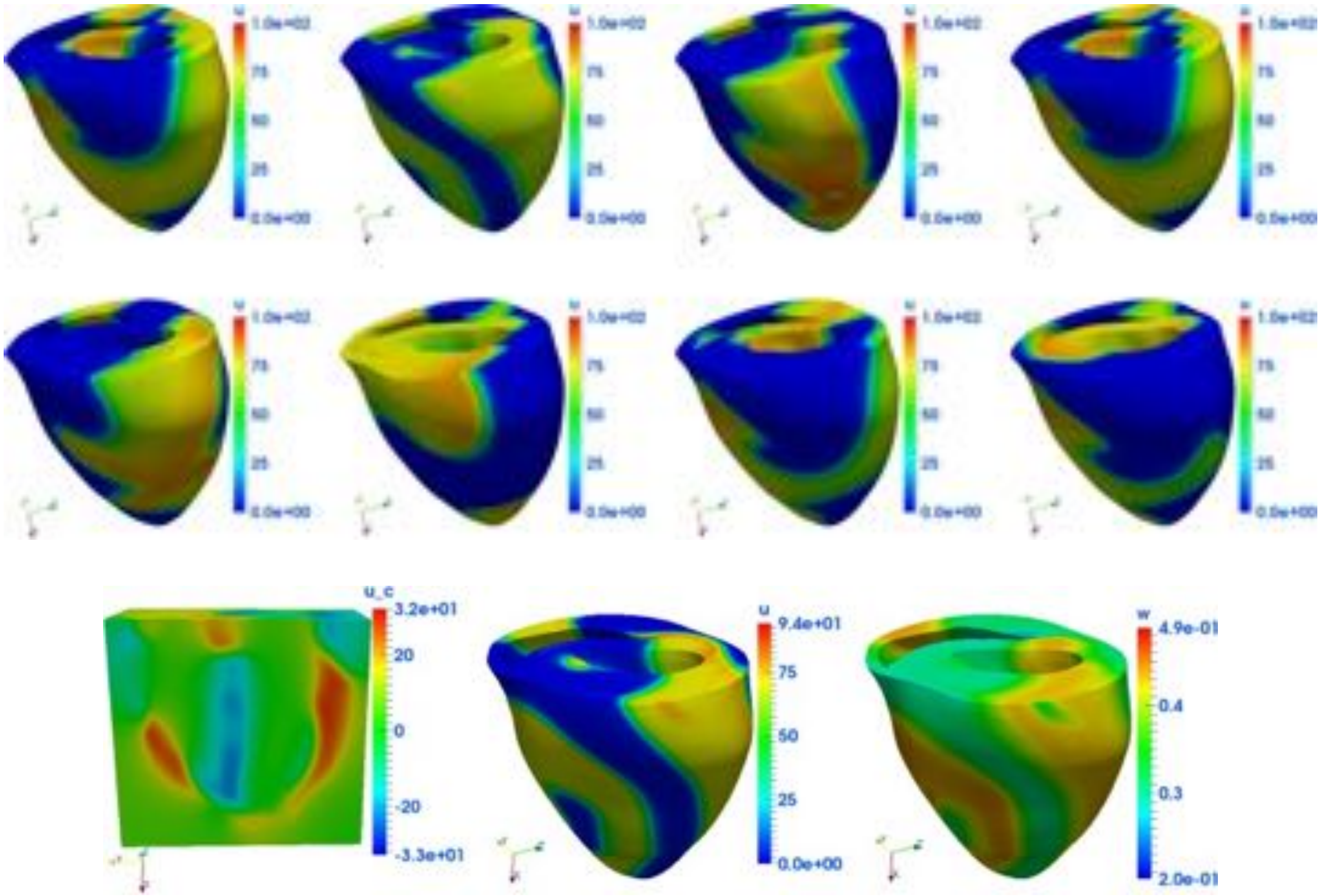
$$\|\partial_t p_n\|_{L^2(t,T;L^2(\Omega_H))} + \sum_{j=i,e} \left\|\sqrt{\varepsilon} \partial_t p_{n,j}\right\|_{L^2(t,T;L^2(\Omega_H))} \le c_3.$$

$$\begin{cases} \Big(-\beta c_m \partial_t p_n - \varepsilon \partial_t p_{n,i} - \nabla\cdot(\mathrm{M_i}\nabla p_{n,i}), e_k\Big)_{L^2(\Omega_H)} = \Big(H_u(u,w)p_{w_n} - \beta I_{\mathrm{ion}\,u} p_n + -2(u-u_d), e_k\Big)_{L^2(\Omega_H)}, \\ \Big(-\beta c_m \partial_t p_n + \varepsilon \partial_t p_{n,e} + \nabla\cdot(\mathrm{M_e}\nabla p_{n,e}), e_k\Big)_{L^2(\Omega_H)} = \Big(-H_u(u,w)p_{w_n} - \beta I_{\mathrm{ion}\,u} p_n + 2(u-u_d), e_k\Big)_{L^2(\Omega_H)}, \\ -\Big(\nabla\cdot(\mathrm{M_s}\nabla p_{n,s}), e_k\Big)_{L^2(\Omega_B)} = 0, \\ (-\partial_t p_{w_n}, e_k) = \Big(H_w(u,w)p_{w_n} + \beta I_{\mathrm{ion}\,w} p_n, e_k\Big)_{L^2(\Omega_H)}, \end{cases}$$

$$\iint_{\Omega_{T,H}} -\beta c_m \partial_t p \phi_i + \iint_{\Omega_{T,H}} \mathrm{M_i}(x)\nabla p_i \nabla \phi_i + \iint_{\Omega_{T,H}} \beta I_{\mathrm{ion}_u}(u,w) p \phi_i$$

$$- \iint_{\Omega_{T,H}} H_u(u,w) p_w \phi_i + \iint_{\Omega_{T,H}} 2(u-u_d)\phi_i = 0,$$

$$\iint_{\Omega_{T,H}} -\beta c_m \partial_t \phi_e - \iint_{\Omega_H} \mathrm{M_e}(x)\nabla p_e \nabla \phi_e + \iint_{\Omega_B} \mathrm{M_s}(x)\nabla p_s \nabla \phi_s$$


u_c
3.2e+01
20
0
-20
-3.3e+01
u
9.4e+01
75
50
25
0.0e+00
w
4.9e-01
0.4
0.3
2.0e-01

Final Note

CPR chest compressions and breaths are the most important.

-10% / minute survival following CA

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Questions?