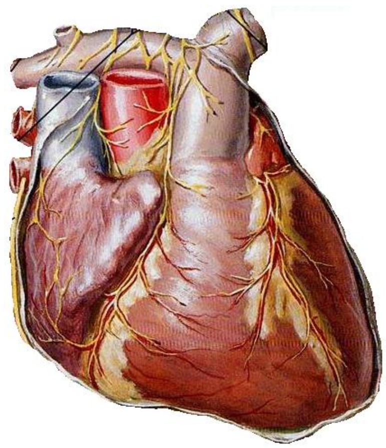
CARDIAC DEFIBRILLATION

Hilton M Kaplan, MD



University of Southern California

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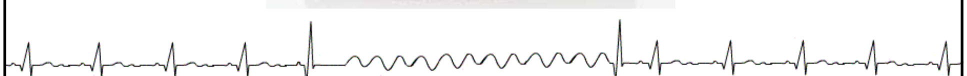

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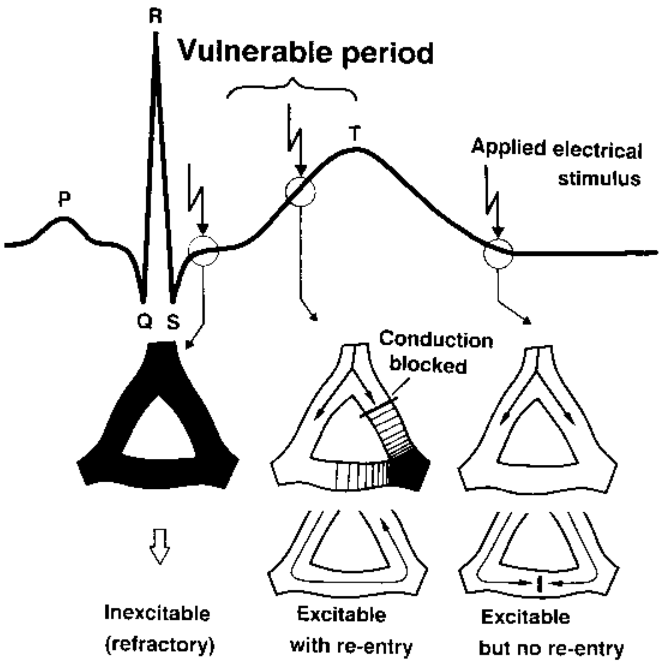
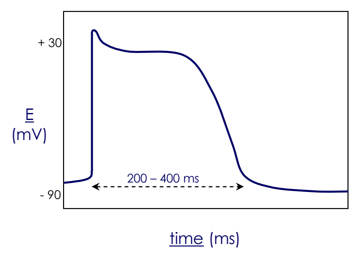


re-entry loops

prevented by 1) long refractory period (300 ms)



2) fast conduction velocity (1 m/s)

1 m/s for 300 ms → 30cm refractory zone

! shortening of either → re-entry loops !

re-entry loops

refractory period ↓ (50%)

1. ↑ HR (interval dependant)
2. ischemia (shorter AP's)
3. adjacent conduction block

   speeds repolarization of active membrane

conduction velocity ↓ (90-99%)

1. K^+ & epinephrine

   K^+ → slows repolarization; slows fast inward current (Na^+)

   epi → enhances slow inward current (Ca^{++})

   "slow response AP" = 0.1 m/s ; Purkinje re-entry loop < 15 mm
2. ischemia (inexcitable segments)

   "slow response AP" = 0.01 m/s ; Purkinje re-entry loop < 3 mm
3. anisotropy

   conduction velocity varies with direction

re-entry loops

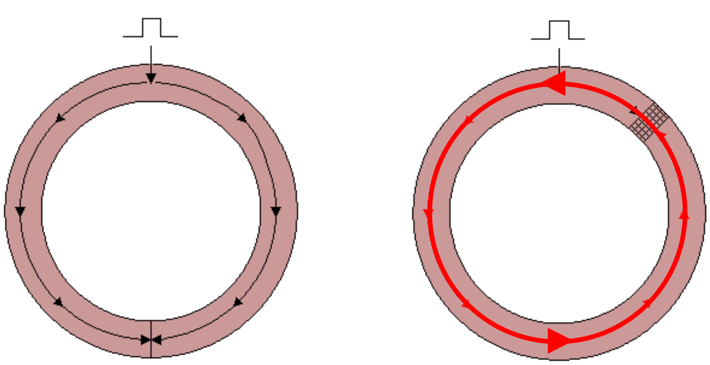
Mines, 1913

Normal

collision & annihilation (refractory) prevents reentry

Reentry

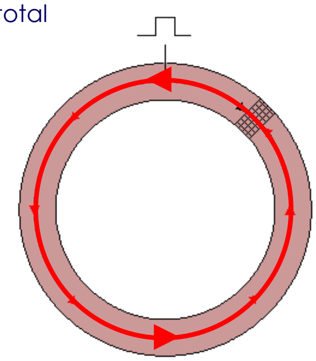
'unidirectional' block allows reentry & arrhythmia



re-entry loops

conditions for reentry

1. area of unidirectional block
2. propagatation along alternate path
3. propagation time greater than total refractory period in block



wavelength

(conduction velocity x refractory period)

the distance traveled during the refractory period

pathophysiology

re-entry pathways

chaotic electrical excitation

causes

MI (myocardial infarction / ischemia)

drug toxicity (digoxin)

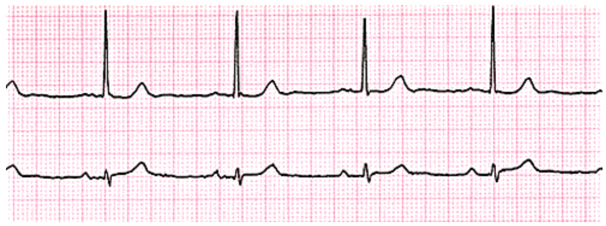
electrolyte imbalances (K^+)

hypothermia

electric shock (household a.c.)

sinus rhythms

sinus bradycardia

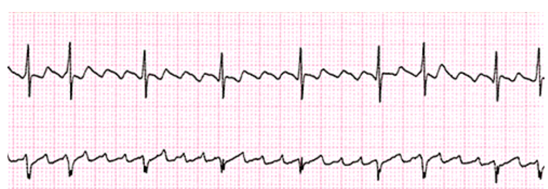


sinus tachycardia

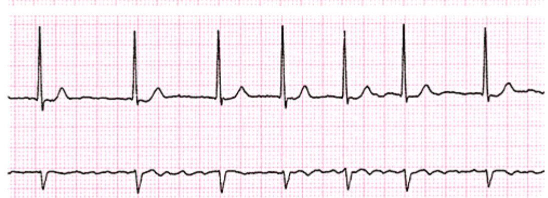
atrial arrhythmias

supraventricular tachycardia (SV-Tach.)

atrial flutter (A-Flutter)

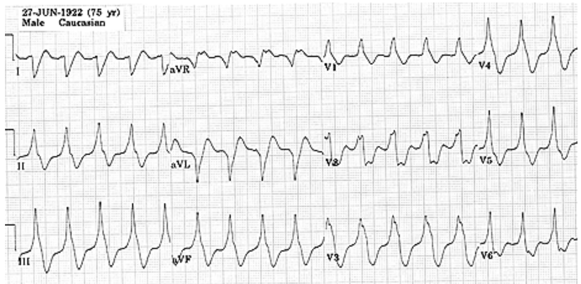


atrial fibrillation (A-Fib.)

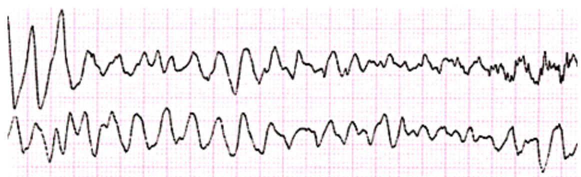


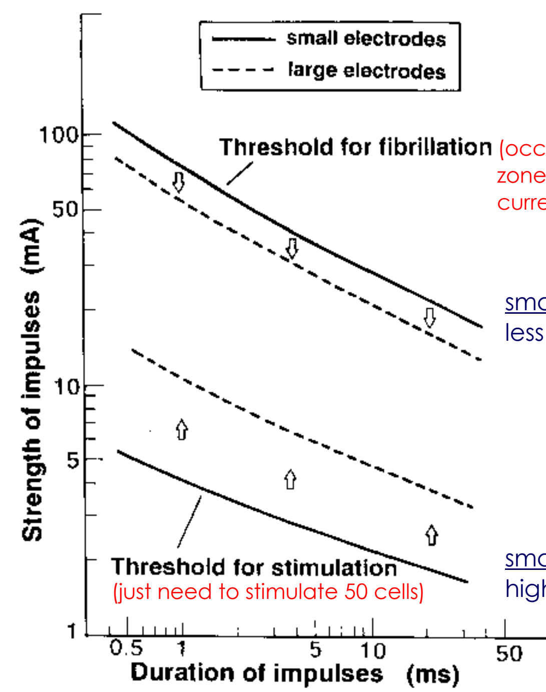
ventricular arrhythmias

ventricular tachycardia (V-Tach.)



ventricular fibrillation (V-Fib.)





(occurs during irregular refractory zones (just before T-peak) → high current requirement)

small:
less extensive current spread

small:
higher current density

defibrillators

strong "countershock"

inefficient tachyarrhythmias → slower efficient rate

emergent or elective

elective for pathological rhythms

cardiac arrests

500,000 pa – 70% d.t. arrhythmias

amenable to R_x with defibrillators, but …

V-Fib. = 10% mortality/min !

terminology

most serious

V-Fib. - "defibrillation"

more organized

V-Tach.
SV-Tach.
A-Flutter
A-Fib.
} "cardioversion"

mechanism of defibrillation

strong electric shock / "countershock"

simultaneously depolarizes *all* cardiac cells

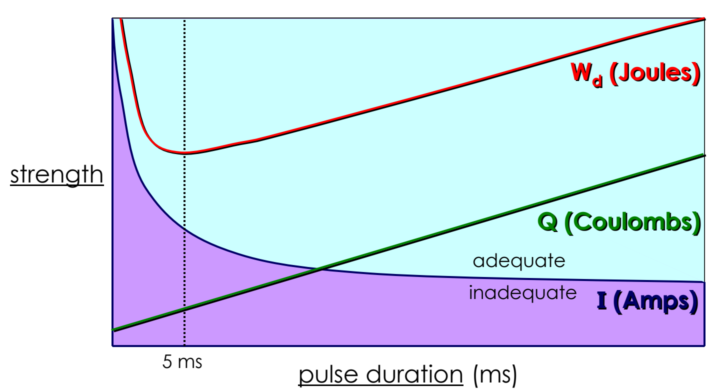
regain order by …

relying on autorhythmicity / pacemaker

"countershock" must be of …

adequate *strength* & *duration*

strength-duration curves



too short very high I → damages myocardium

too long refibrillation risk

parameters

pulse length	3-10 ms
pulse strength	20 A , 2 kV
energy	50-360 J (selectable)

influenced by

- arrhythmia / disease state
  - type (more organized → ↓ E)
  - duration
- drugs
- electrode application

clinical defibrillators

! V-Fib. → mortality = 10% / min !

MAX carts — portable, battery driven

clinical defibrillators

! V-Fib. → mortality = 10% / min !

MAX carts — portable, battery driven

AED's (Automatic External Defibrillators)
1° responders
min. training

E-storage

capacitors

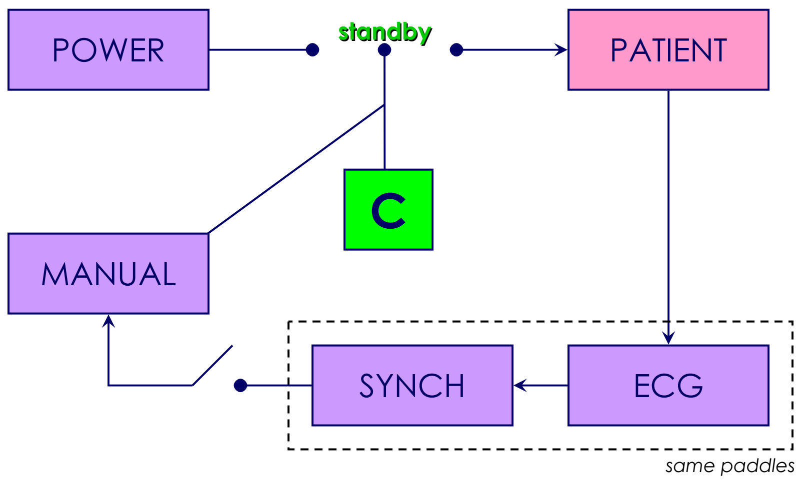
? small size
? light weight (several lb's)
? sustain kV's
? multiple Q-∅ cycles

W_s (E stored): $W_s = \frac{1}{2} C E^2$

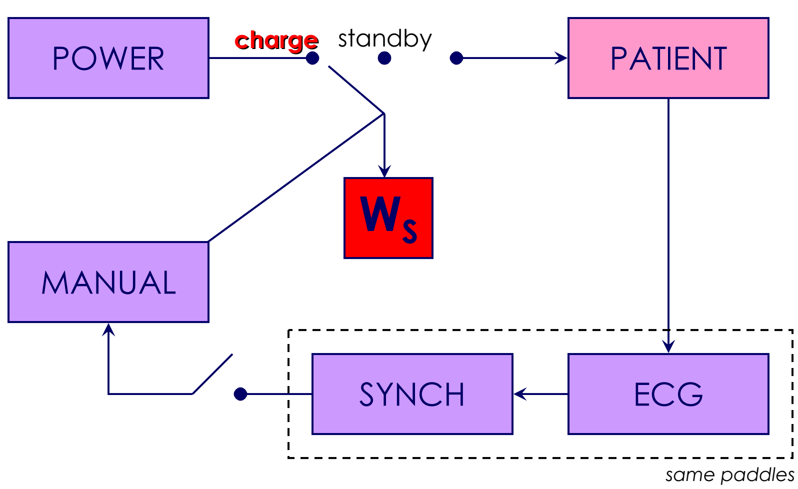
W_d (E delivered): $W_d = W_s \left({}^{R}/_{R_i + R} \right)$

R = pt R_Ω
R_i = device R_Ω

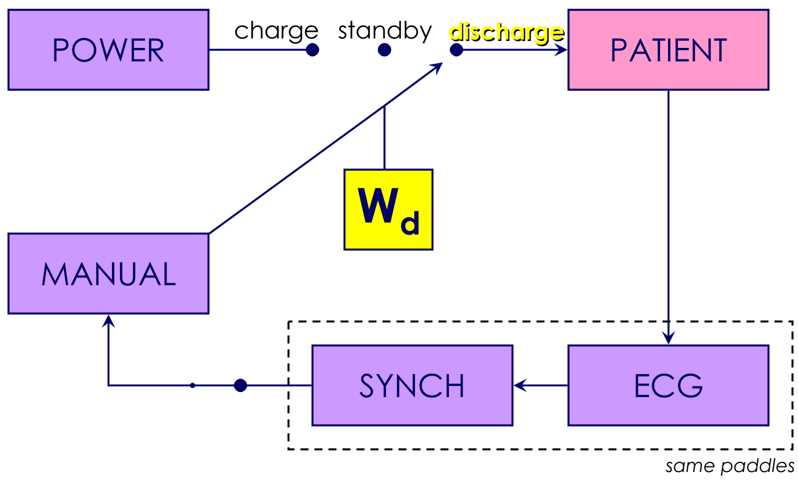
design algorithm



design algorithm

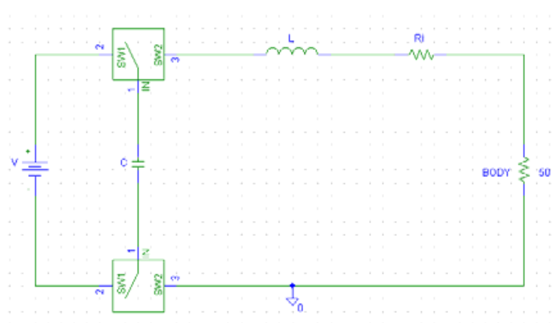


design algorithm

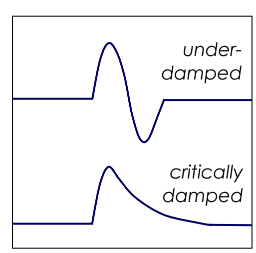


circuit diagrams

RCL defibrillators:



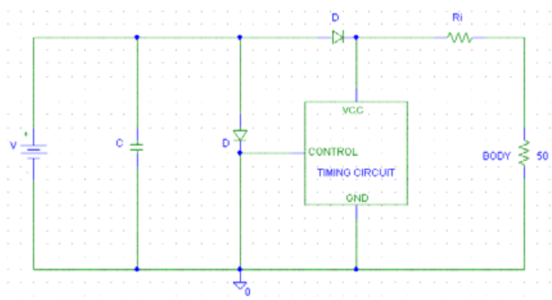
DAMPED SINUSOIDAL



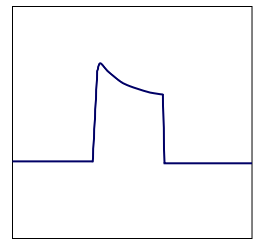
KVL $\rightarrow$ 2nd Order ODE: $$L\frac{d^2I}{dt^2}+(R_i+R)\frac{dI}{dt}+\frac{1}{C}I=0$$

circuit diagrams

trapezoidal wave defibrillators:



TRUNCATED EXPONENTIAL DECAY



described by:

$$W_d = 0.5 \cdot I_i^2 \cdot R \left[\frac{d}{\ln\left(\frac{I_i}{I_f}\right)} \right] \cdot \left[1 - \left(\frac{I_f}{I_i}\right)^2 \right]$$

circuit diagrams

implantable defibrillators:

biphasic exponential decay
reduces shock intensity

all have selectable W_d:

50-360 J small pt.s
pediatric pt.s
easily converted arrhythmias

3-6 ms

25-150 Ω (controls damping)

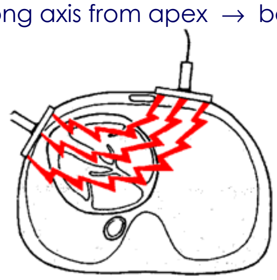
electrodes

SA 70-100 cm^2

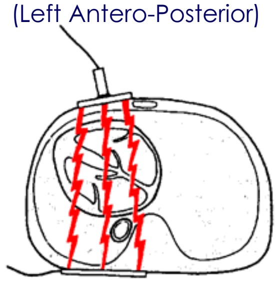
type handheld paddles (liquid / gel)
adhesive (repeated shocks / monitoring)

placement

precordial:
(along axis from apex → base)



LAP:
(Left Antero-Posterior)



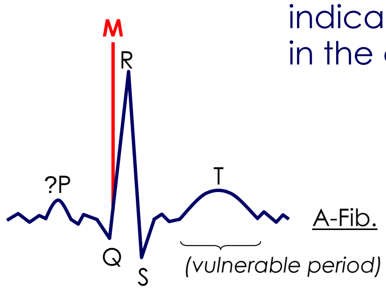
synchronization

sensing circuit — avoid T-wave shocking (→ V-Fib.)

triggering circuit — during QRS

synch. mode — timing mark 'M'

indicates where shock will be applied in the cardiac cycle



AED's (automatic external defibrillators)

! recognize & treat tachyarrhythmias !

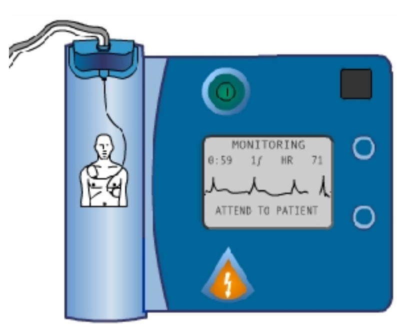
automatic signal processing

- no need to assess ECG for rhythms requiring shock
- adhesive electrodes
- home / office / community-based

semi-automatic signal processing

- operator must confirm AED's advice to deliver shock

AED's (automatic external defibrillators)



safety

patient — unsynchronized shocking

excessive shocking — duration, number, strength

defibrillator failure

operator — "stand clear"