INTRO TO EP

Going through the paces of cardiac rhythm generation

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UVMMC Cardiology

OBJECTIVES

- Review the basic pathophysiology of native rhythm generation and propagation
- Learn why and how we take over pacing in certain ways
- Achieve the above in a way that can improve your knowledge base and subsequent practice of medicine

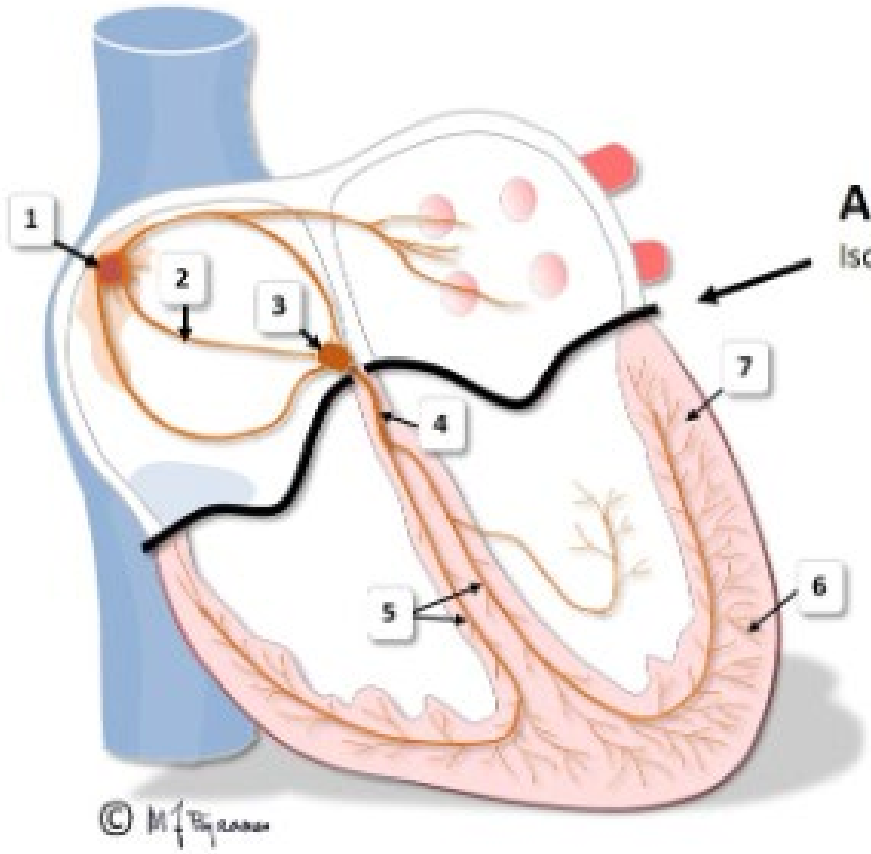
DISCLOSURES

- None

NATIVE PACING

THE CONDUCTION SYSTEM

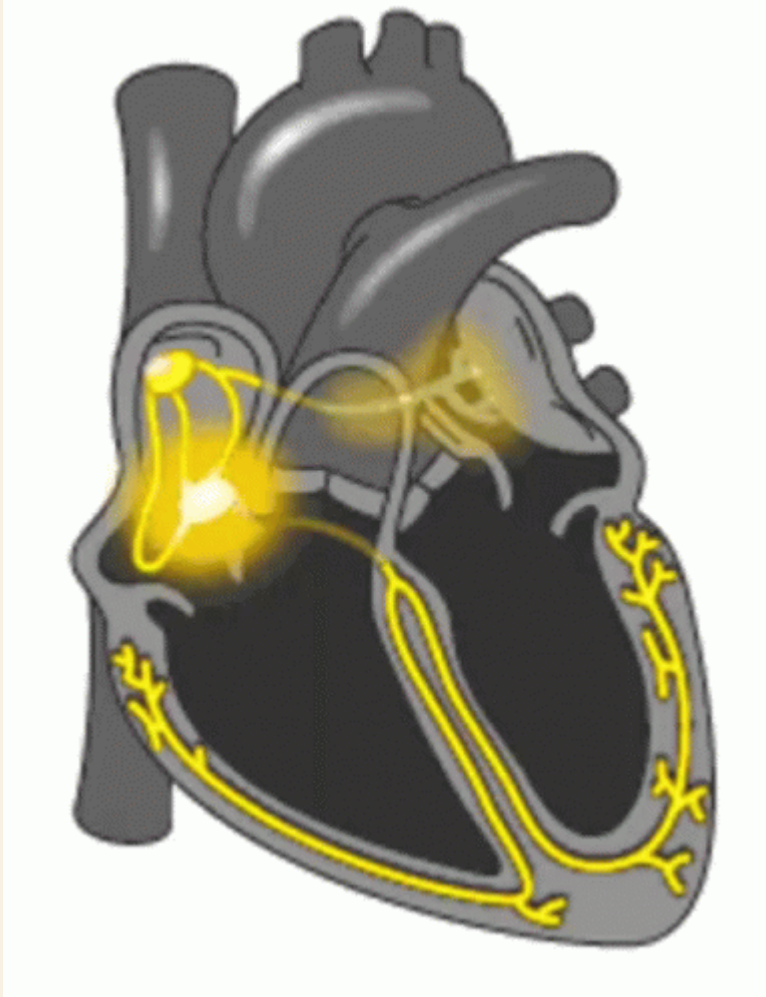
		Frequency Beats per min
1	Sinoatrial node	60 - 100
2	Atrial pathways	55 - 60
3	**Atrioventricular node**	45 - 50
4	Bundle of His	40 - 45
5	Ventricular fascicles	40 - 45
6	Purkinje fibres	35 - 40
7	Myocardium	30 - 35



Annulus fibrosus

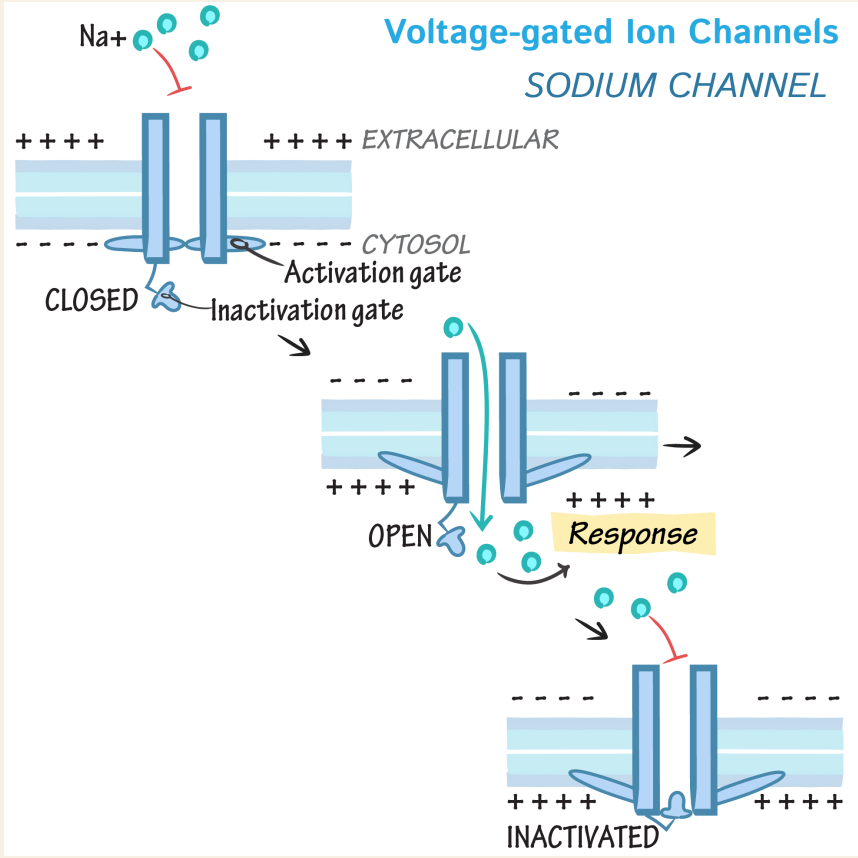
Isolating barrier between atria and ventricles

THE CONDUCTION SYSTEM



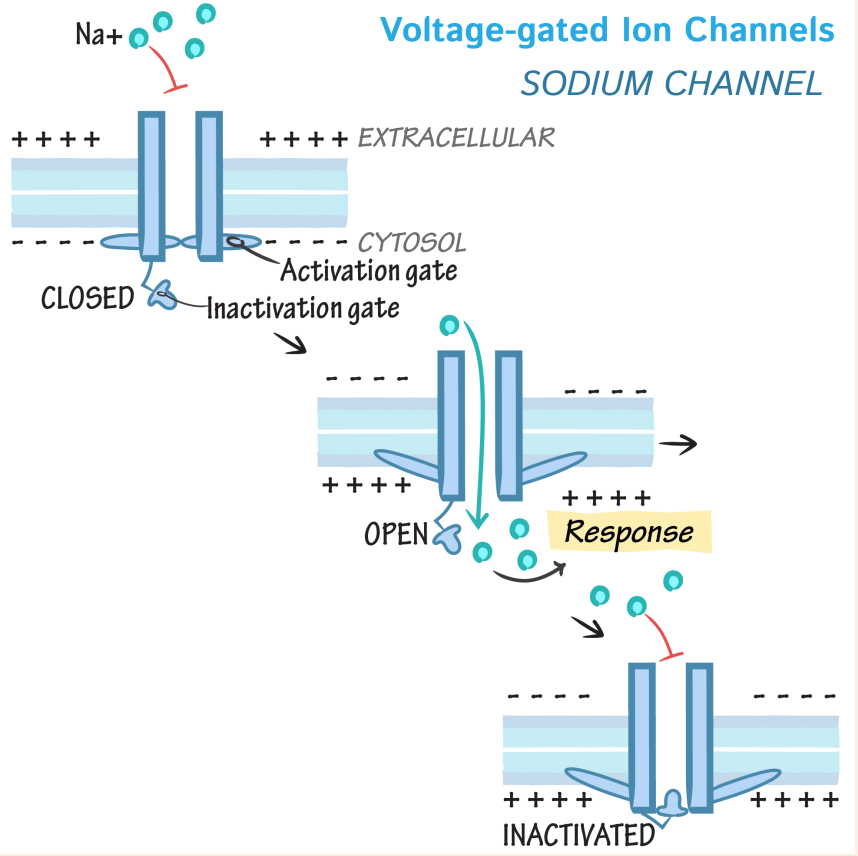
HOW IS ELECTRICITY CONDUCTED THROUGH CARDIAC CELLS?

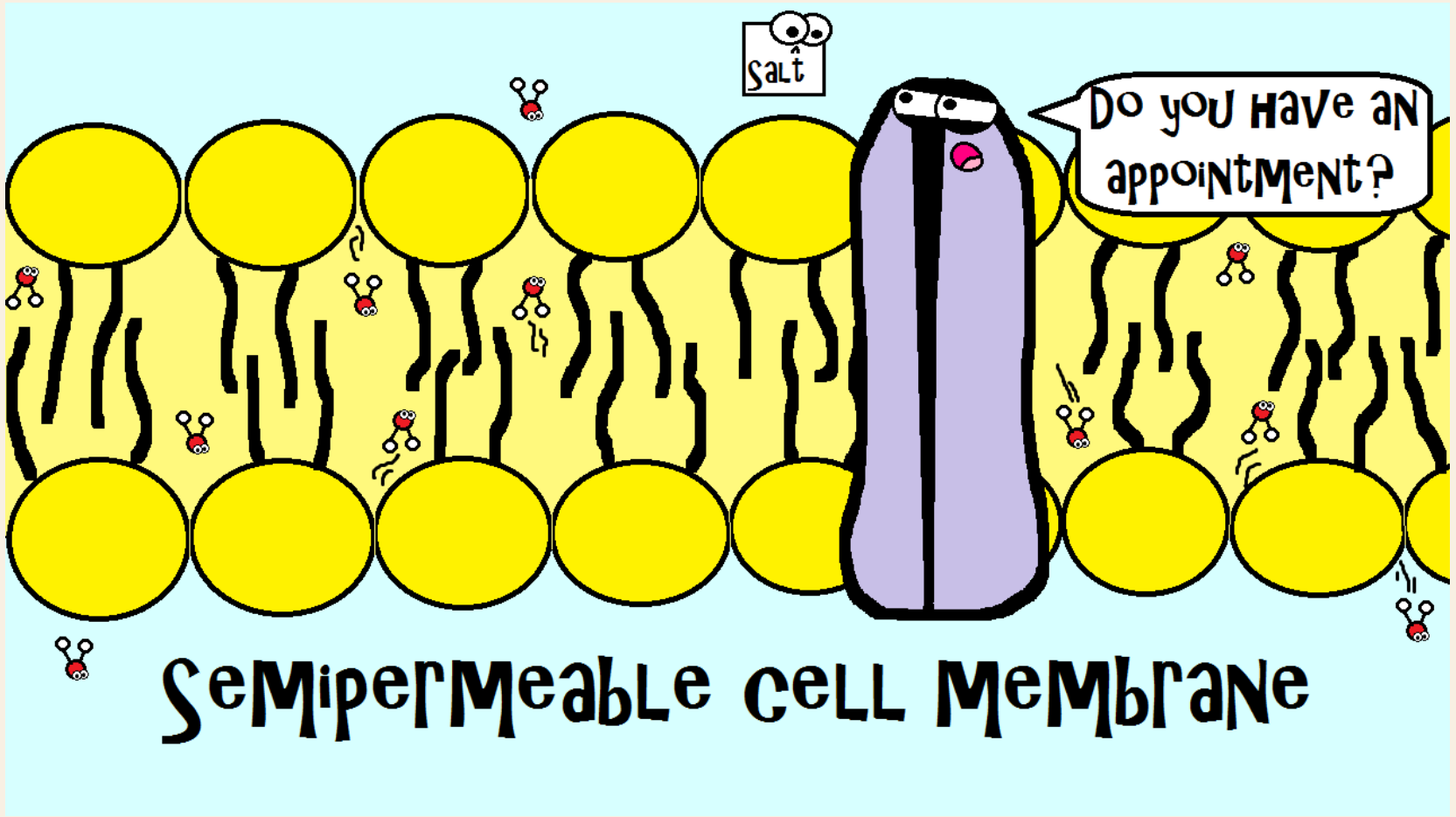
- Properties of cardiac cells
  - Automaticity
  - Excitability
  - Conductivity
  - Contractility
- Semipermeable membranes!
  - Lipid bilayer
  - Complex protein structures w/ regulatory function between the intracellular and extracellular space
  - Allows for transmembrane voltage (membrane potential)
- Electrogenic mechanisms:
  - ion channels
  - electrogenic transporters
  - current flow



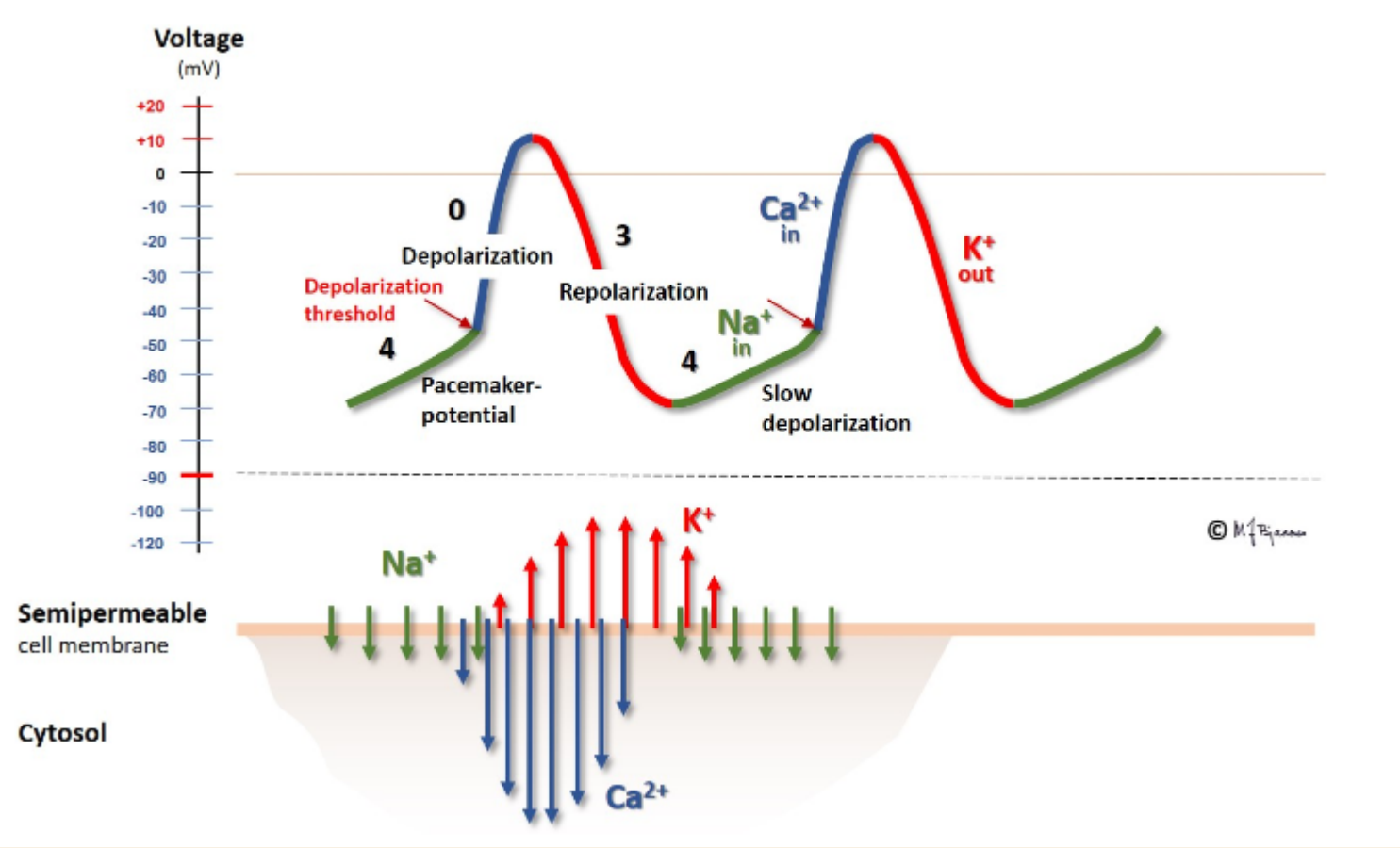
ION CHANNELS

- Complex structures of membrane proteins
- Properties
  - Ion selectivity: Na+, K+, and Ca2+
  - Gating
  - Conductance
- Electrical gradient between inside and outside of the cell
- Depolarization and Repolarization
- Action potential
  - Resting membrane potential
  - Voltage gated channels

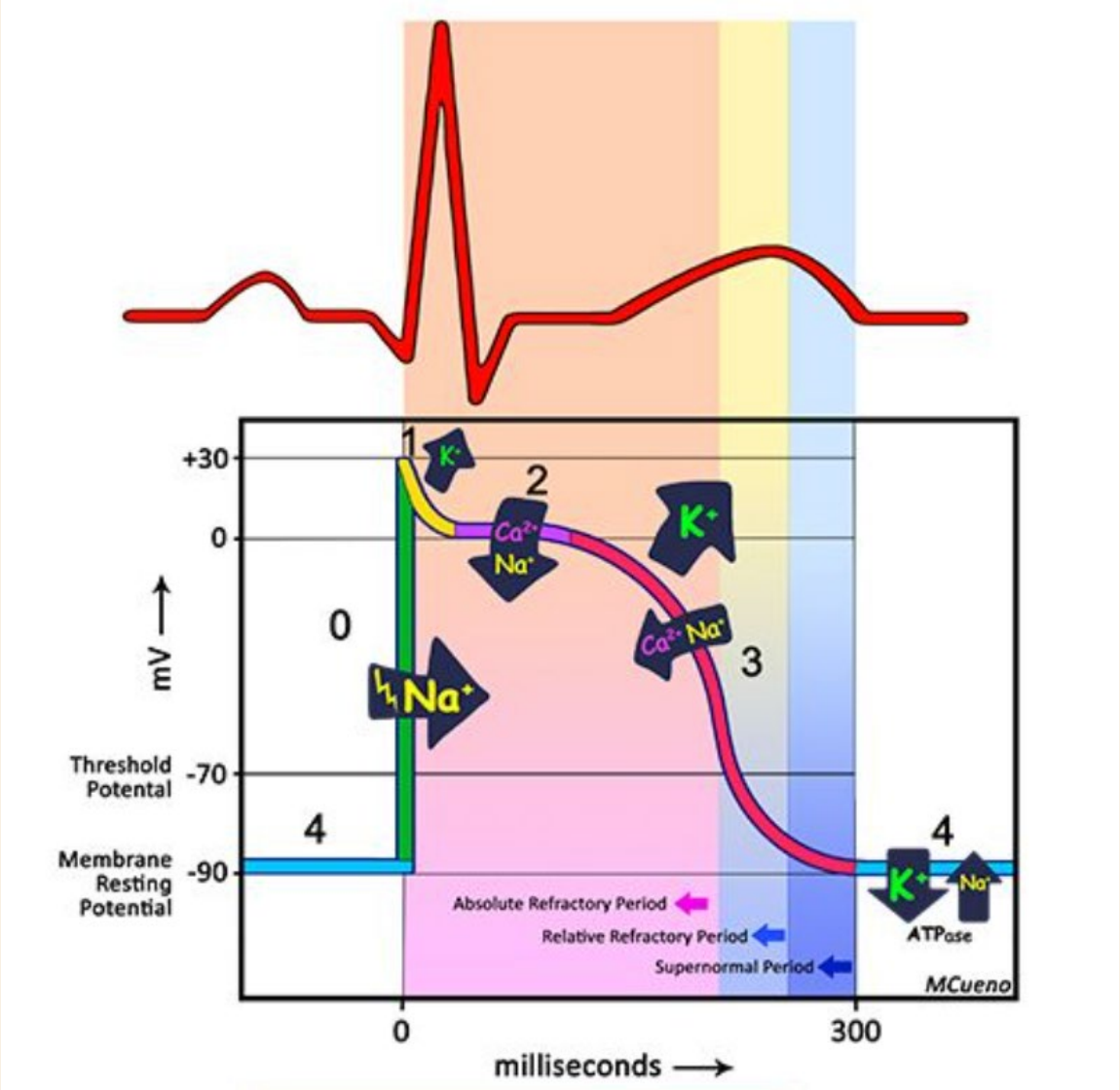



Salt
Do you have an appointment?
SemipermeableCell Membrane

PACEMAKER ACTION POTENTIAL (AP)



VENTRICULAR ACTION POTENTIAL (AP)



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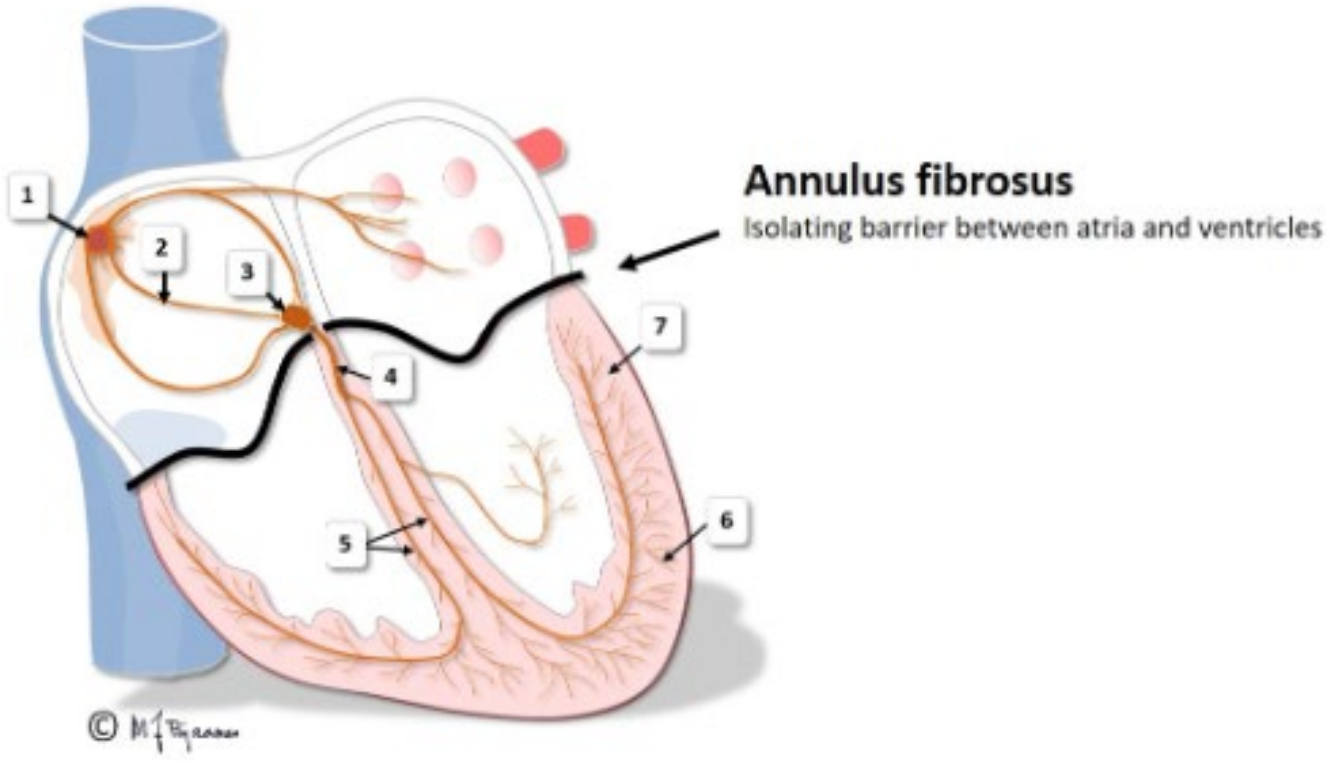
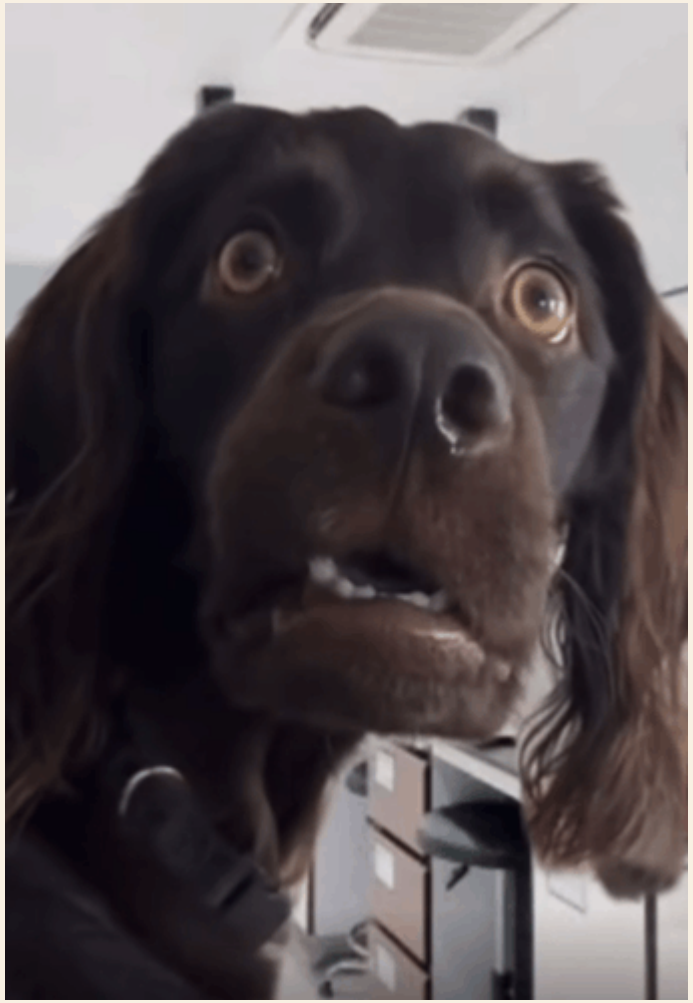


YOU'RE NOT ALONE



WHAT CAN GO WRONG?
AKA PATHOLOGY

BRADYARRHYTHMIAS

Roger is a relatively active 83 year old male with a PMHx of hypertension, pre-diabetes, obesity and obstructive sleep apnea intolerant to CPAP who presents to your clinic because of multiple sinus pauses up to 4 seconds overnight identified on a 48 hour holter monitor ordered for occasional very mild palpitations. Daytime palpitations correlate to isolated and rare PVCs. No other complaints. How would you advise Roger about the next steps?

a. Placement of a permanent pacemaker
b. Start metoprolol for his PVCs
c. Reassurance
d. None of the above

BRADYARRHYTHMIAS

Suzy is a 78 yo female with a past medical history of coronary artery disease s/p single vessel PCI 4 years ago, well treated hypothyroidism, remote breast cancer in remission, and hyperlipidemia who presents to your clinic after suffering multiple recent near syncopal and syncopal episodes. Her medications are levothyroxine and atorvastatin. An echocardiogram was normal. Below are rhythm strips that correlated to her symptoms on recent event monitor:

Should we offer Suzy a permanent pacemaker?

And if so, what type? Why?

BRADYARRHYTHMIAS

Etiologies of Sinus Node Dysfunction and AV Conduction Disease

Reversible or Transient Causes	• Increased vagal tone • Drugs • Infections • Inflammatory or infiltrative conditions • Ischemia • Electrolyte abnormalities
Non Reversible Causes	• Fibrosis • Degeneration • Genetic • Traumatic/iatrogenic (surgical or percutaneous) • Ischemia • Rheumatic

BRADYARRHYTHMIAS

Common indications for PPM:

Symptomatic bradycardia

SA node disease

- Sick sinus syndrome
  - sinus pauses
  - chronotropic incompetence

AV Block

- 2nd degree AV block type II
- Complete heart block
- Alternating BBB

Tachycardia bradycardia syndrome with atrial arrhythmias

Some types of heart failure

When medications that may result in bradycardia are required

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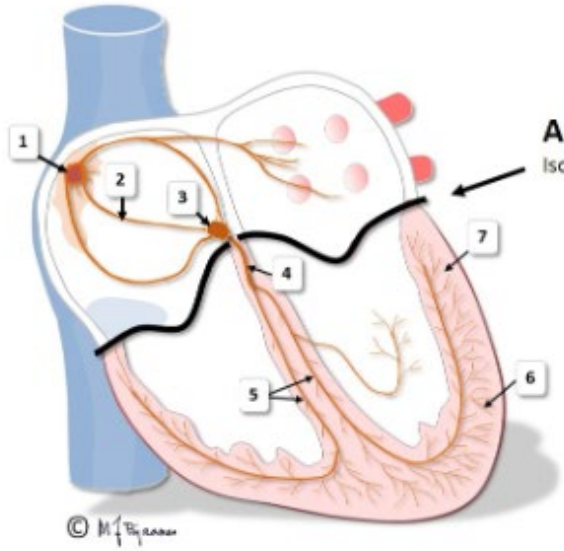
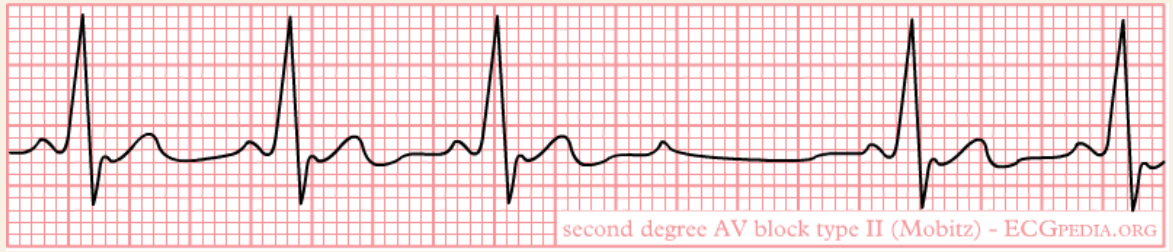
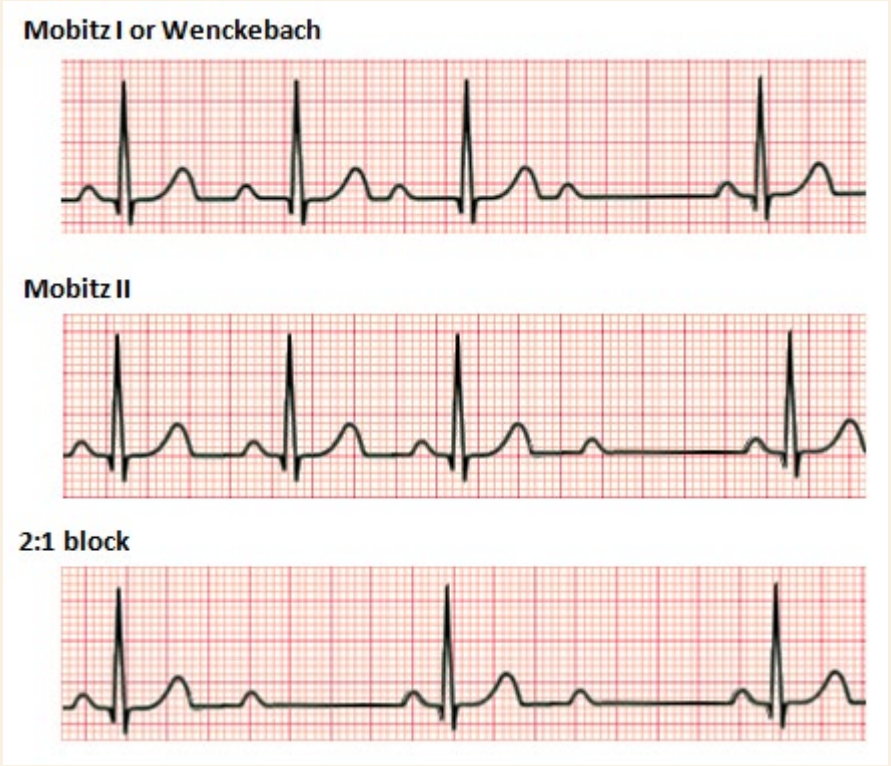


SECONDARY DEGREE AV BLOCK

Type I vs II – what's the big deal?

- Risk of progression
  - Where in the AV node
    - Failure of impulse propagation in AVN tissue
    - His-Purkinje system (intra- or infra-Hisian block)
- Look for clues!
  - Narrow or wide QRS
  - Other conduction disease
- Consider testing
  - Exercise
  - EP study (not common)





WHAT NOT TO DO

Recommendations for General Principles of Chronic Therapy/Management of Bradycardia Attributable to SND
Referenced studies that support recommendations are summarized in Online Data Supplements 22 and 23.

COR	LOE	RECOMMENDATIONS
III: Harm	C-LD	1. In asymptomatic individuals with sinus bradycardia or sinus pauses that are secondary to physiologically elevated parasympathetic tone, permanent pacing should not be performed (S5.4.1-1–S5.4.1-7).
III: Harm	C-LD	2. In patients with sleep-related sinus bradycardia or transient sinus pauses occurring during sleep, permanent pacing should not be performed unless other indications for pacing are present (S5.4.1-1–S5.4.1-7).
III: Harm	C-LD	3. In patients with asymptomatic SND, or in those in whom the symptoms have been documented to occur in the absence of bradycardia or chronotropic incompetence, permanent pacing should not be performed (S5.4.1-5–S5.4.1-7).

Also → First rule out reversible causes of bradycardia!

E.g. elective drug therapy, Lyme disease, autonomic dysfunction, metabolic diseases, acute ischemia

SUMMARY FOR REFERENCE

Indications for Permanent Pacing for Sinus Node and AV Conduction Disease

Sinus Node Disease	**Class I**	• Symptomatic sinus bradycardia and pauses • Symptomatic chronotropic incompetence • Symptomatic sinus bradycardia due to required drug therapy
	Class IIa	• Heart rate <40 bpm and symptoms consistent with bradycardia but clear association between bradycardia and symptoms is undocumented • Unexplained syncope and abnormal sinus node function on EP study
	Class IIb	• Minimally symptomatic patients with chronic heart rate <40 bpm while awake
	Class III	• SND in asymptomatic patients • SND in patients with symptoms documented in absence of bradycardia • Symptomatic bradycardia due to non-essential drug therapy
AV Conduction Disease	**Class I**	• CHB or ASDB with bradycardia and symptoms or ventricular arrhythmias presumed due to block • CHB or ASDB with arrhythmias or other conditions requiring drug therapy resulting in bradycardia • CHB or ASDB with pause >3 seconds, escape rate <40 bpm or below the AV node • CHB or ASDB with atrial fibrillation and pause >5 seconds • CHB or ASDB after catheter ablation of the AV junction • CHB or ASDB after cardiac surgery not expected to resolve • CHB or ASDB associated with neuromuscular disorders • Second-degree AV block of any type with symptomatic bradycardia • Second- or third-degree AV block with exercise without ischemia • CHB with HR >40 bpm in the setting of cardiomegaly or LV dysfunction or site of block is below the AV node • Asymptomatic Mobitz II block with wide QRS
	Class IIa	• CHB with HR >40 bpm in asymptomatic individuals without cardiomegaly • Asymptomatic second-degree AV block with intra- or infra-Hisian block found on EPS • First- or second-degree AV block with symptoms • Asymptomatic Mobitz II block with narrow QRS
	Class IIb	• AV block of any degree in the setting of neuromuscular disease with or without symptoms • AV block in the setting of drug toxicity that may recur even when drug is withdrawn
	Class III	• Asymptomatic first-degree AV block • Asymptomatic Mobitz I or Wenckebach block • AV block that is expected to resolve (reversible drug effect, Lyme disease, transient increase in vagal tone or during hypoxia and sleep apnea)

Credit: ACC's ACCSAP

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DEVICES AND THERAPIES

HOW DOES A PACEMAKER TREAT?

- Designed to treat bradycardia
- Single, dual or biventricular
- Pacemaker components combine with body tissue to form a complete circuit that
  - Senses the hearts intrinsic beats
  - Paces or inhibits at the programmed interval (rate)
  - Additional features discussed later

ANATOMY OF A PACEMAKER

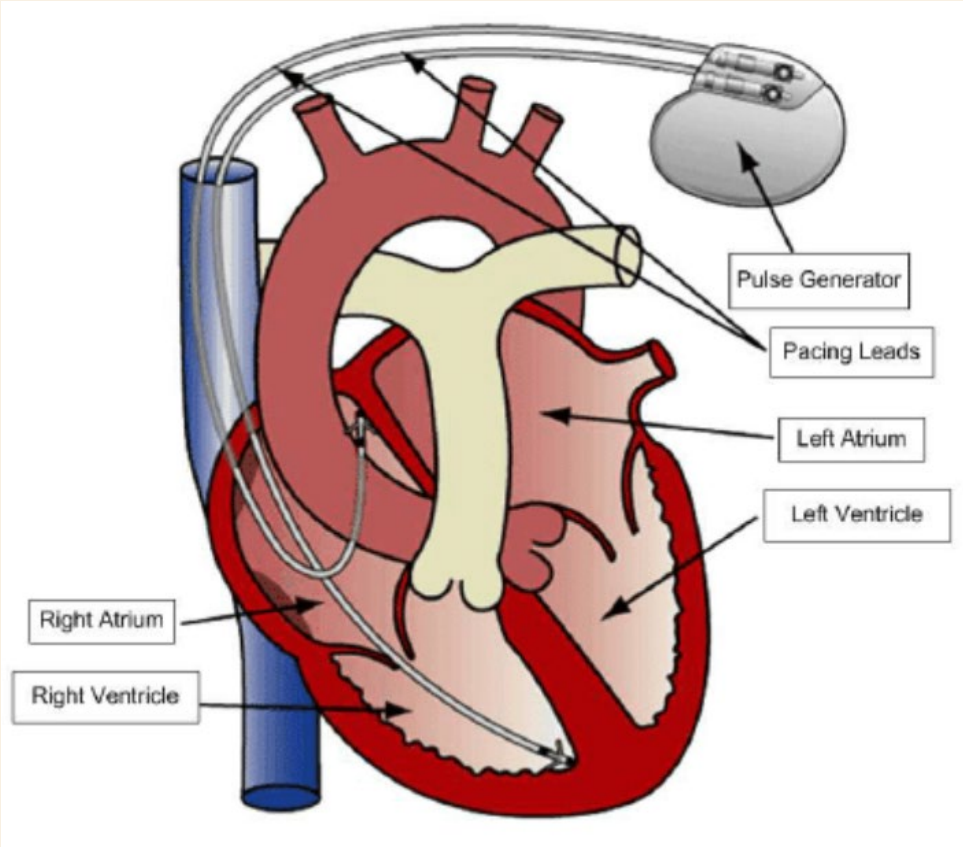
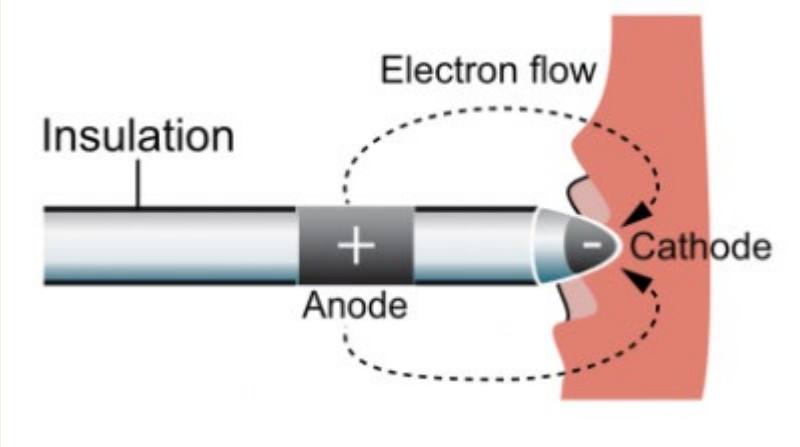
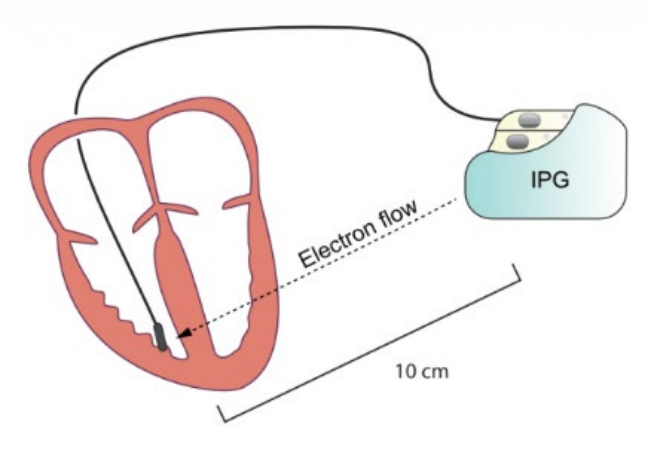


Photo credit: https://www.researchgate.net/figure/Placement-of-pacemakers-probes-inside-a-human-heart_fig2_253239295

UNIPOLAR V BIPOLAR PACING



Bipolar pacing
- Electrons travel from the positive pole (anode) to the negative pole (cathode) on the tip of the lead



Unipolar pacing
- Electrons travel from the IPG (anode) to the tip of the electrode (cathode)

TYPES OF DEVICES

Devices
Classic transvenous pacemakers
Cardiac Resynchronization Therapy (CRT): RA + RV + LV
Conduction system pacing
leadless pacemakers
Defibrillators
Subcutaneous Defibrillators

Single chamber: RA or RV

Dual chamber: RA + RV

Photo credit: Image: https://www.statnews.com/2021/07/02/temporary-pacemaker-heart-disease/

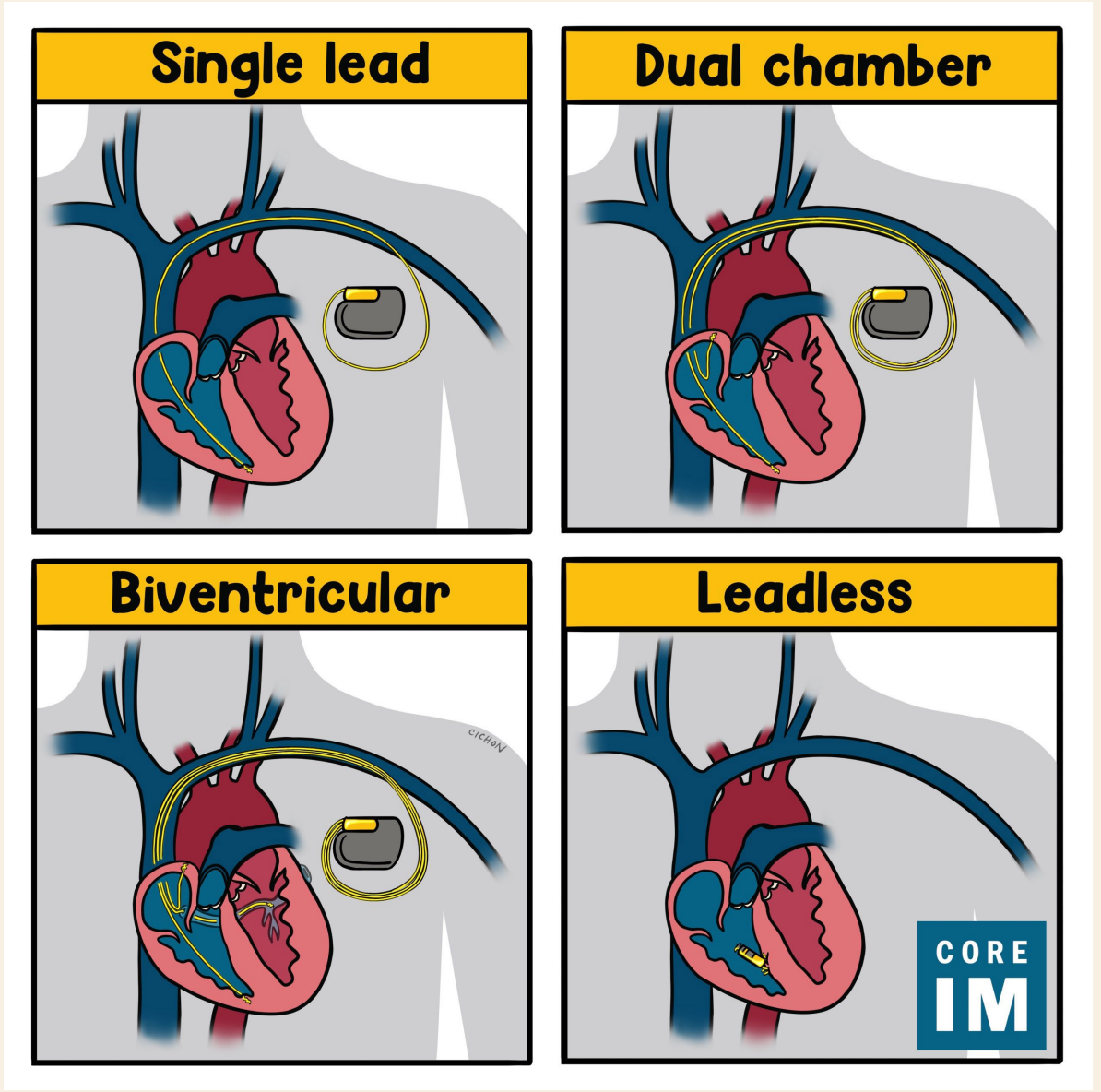
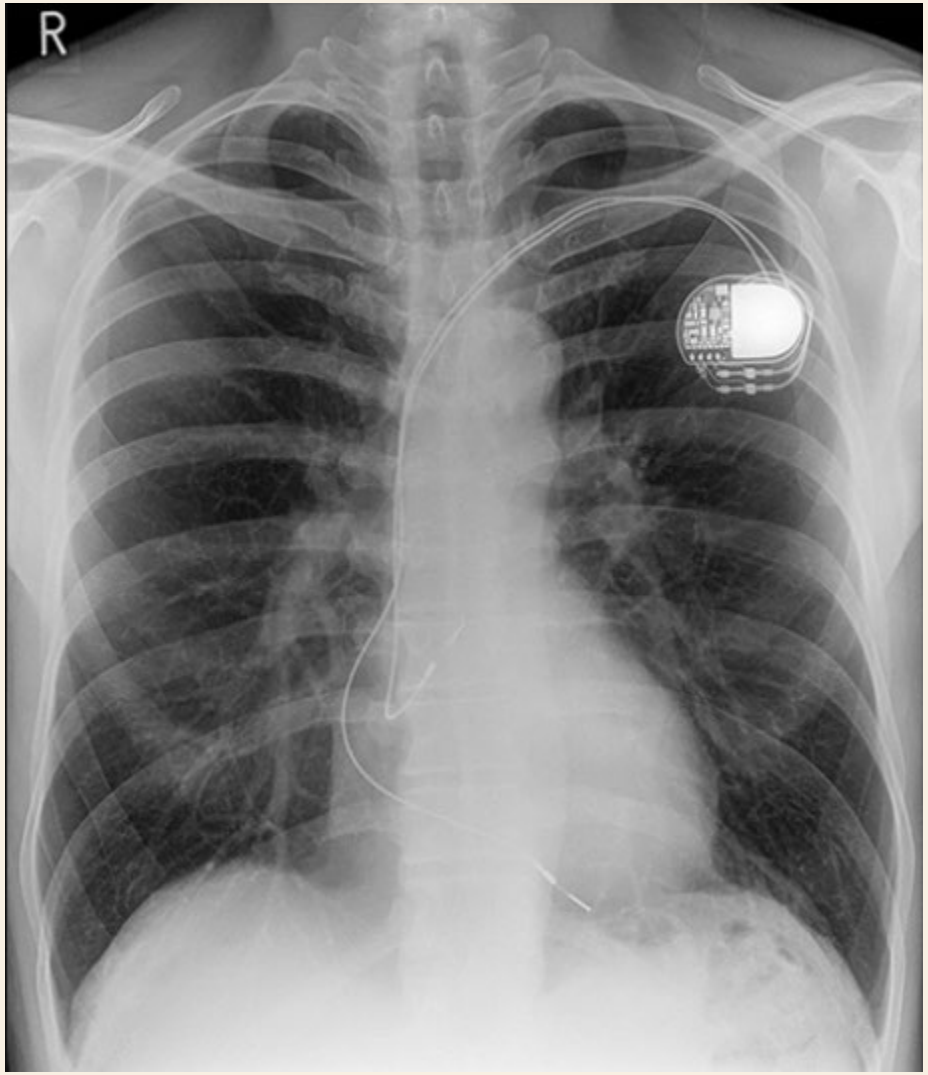


Photo credit: https://www.coreimpodcast.com/2023/04/12/pacemakers-icds/

DUAL CHAMBER PPM



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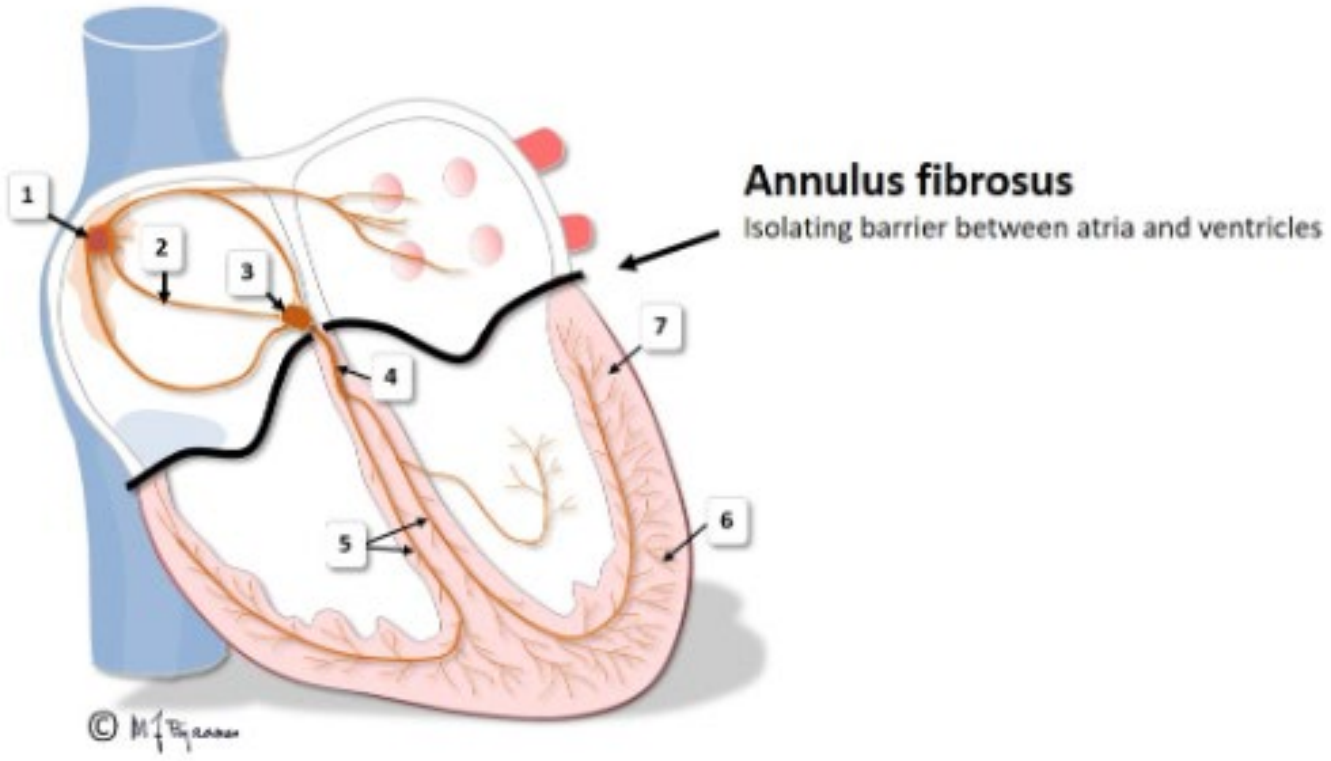

HOW TO DESCRIBE A PACEMAKER

"Pacemaker Code" Just four letters capture the mode aka what it's actively doing

I	II	III	IV
Chamber(s) **paced**	Chamber(s) **sensed**	**Response** to sensing	**Rate adaptive**
O = none	O = none	O = none	O = none
A = atrium	A = atrium	I = Inhibited	R = rate adaptive
V = ventricle	V = ventricle	T = Triggered	
D = dual	D = dual	D = dual	

So what does AAIR mean? VVIR? DDDR?

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And if so, what type? Why?

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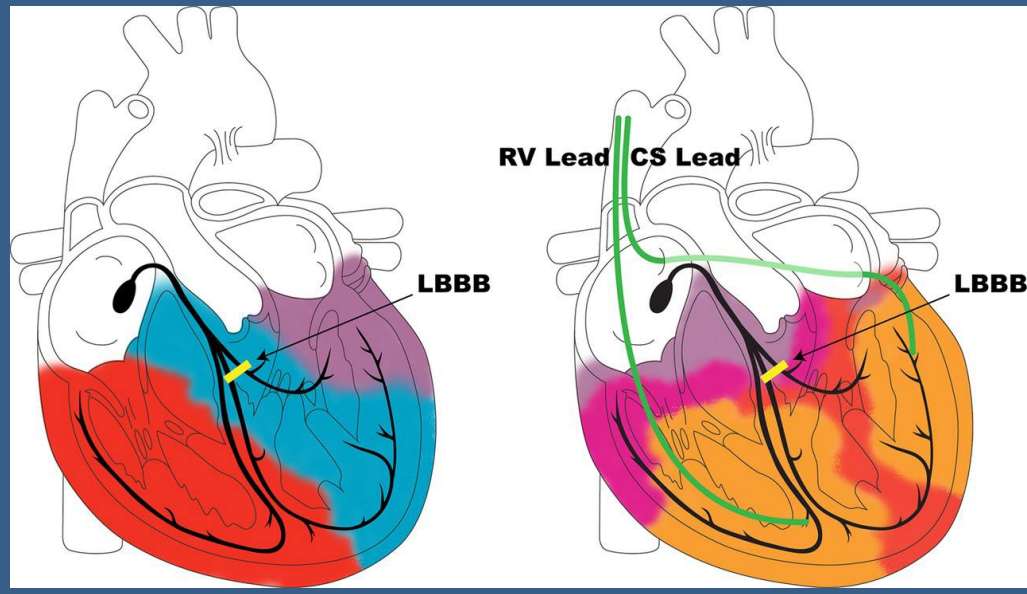
CARDIAC RESYNCHRONIZATION THERAPY

Three lead pacing to mimic native conduction in patients with HFrEF and wide QRS (mostly LBBB)

- CRT improves mortality rates, hospitalization rates and stimulates favorable LV remodeling (MADIT-CRIT)
- May be appropriate in narrow QRS but need for chronic pacing (BLOCK-HF, BIOPACE)
- Dependent upon >90% BiV pacing
  - Can be interfered with by AF, frequent PVCs, device programming

Can be utilized with or without a defibrillator



CARDIAC RESYNCHRONIZATION THERAPY

Recommendations for CRT Implantation

QRS Morphology	NYHA CHF Class	QRS Width (msec)	Recommendation
LBBB	≥II	>150	Class I
LBBB	≥II	120-149	Class IIa
LBBB	I	>150	Class IIb
Non-LBBB	III-IV	>150	Class IIa
Non-LBBB	III-IV	120-149	Class IIb
Non-LBBB	II	>150	Class IIb
Non-LBBB	II	<150	Class III
Paced	Any	Any	Class IIa

Photo credit: ACC ASSAP

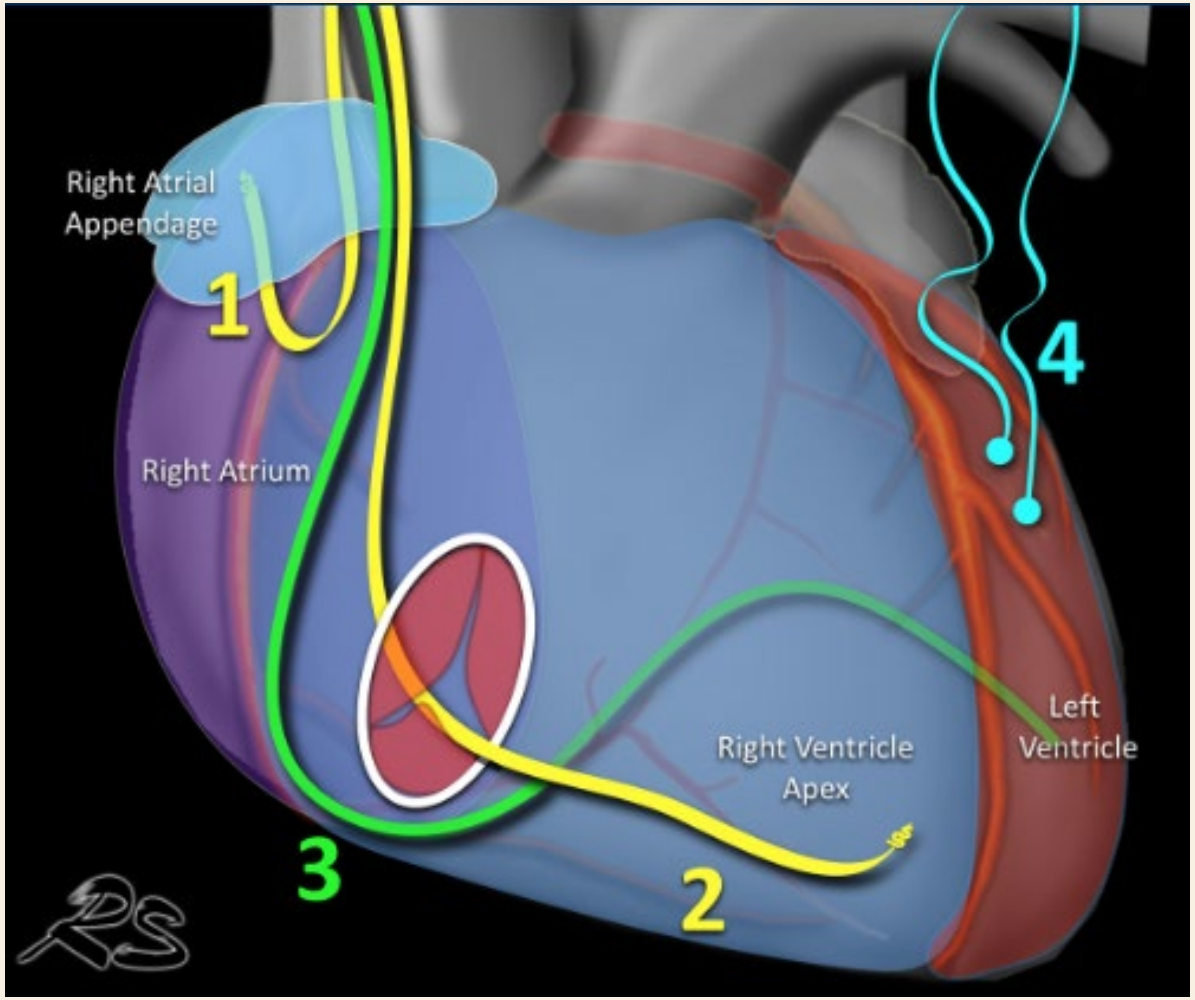
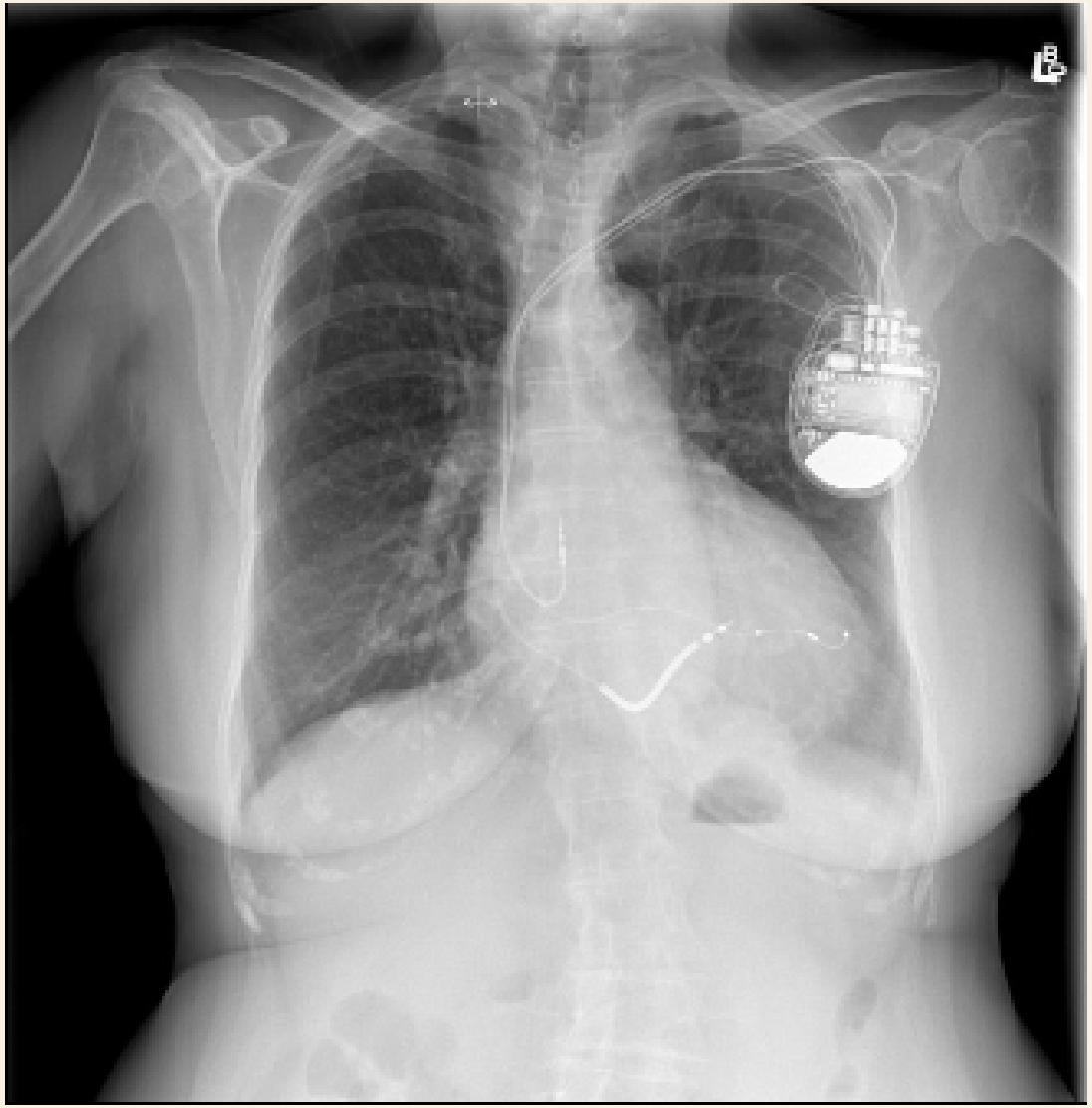


Photo credit: https://radiologyassistant.nl/cardiovascular/devices/cardiovascular-devices



PHYSIOLOGIC PACING

His bundle or left bundle region (LF)

- Alternative to RV apical pacing, BiV
- Suspected to be superior, final outcome studies pending

Pros

- Produces narrower QRS, greater synchrony than RV pacing
- Avoid pacemaker mediated CHF

Cons

- Often higher capture thresholds
- Operator skill

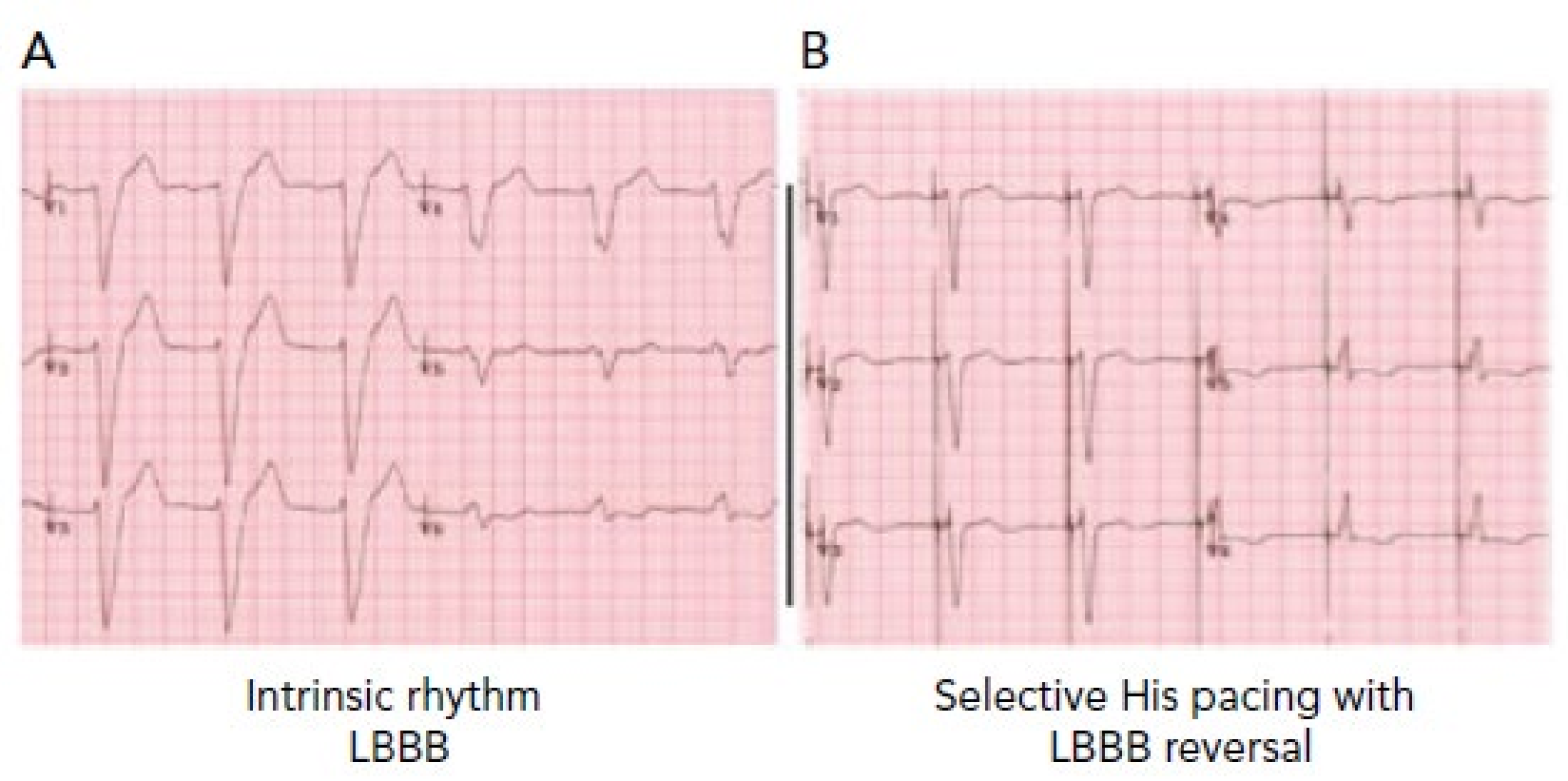


Photo credit: https://www.aerjournal.com/articles/his-bundle-pacing-new-frontier-treatment-heart-failure

LEADLESS PACING

- Direct fixation to RV endocardium
- Ideal candidates: those unable to get traditional devices, at risk for pocket infection, lead dislodgement etc
- Con
  - No direct atrial tracking
  - Less features
  - Risks: device dislodgement, cardiac perforation, elevated pacing threshold
- Pros
  - No risk of pocket hematoma or infection, lead dislodgement
  - Less activity restrictions

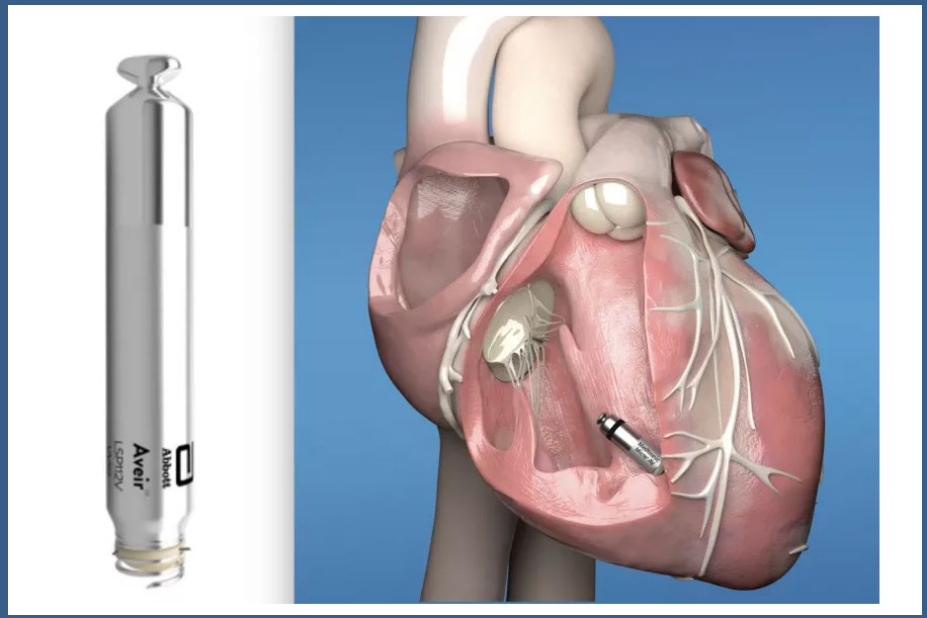


Photo credit: https://cardiovascularbusiness.com/topics/cardiac-imaging/ep-lab/leadless-pacemaker-technology-moves-toward-dual-chamber-pacing

ICD/DEFIBRILLATORS

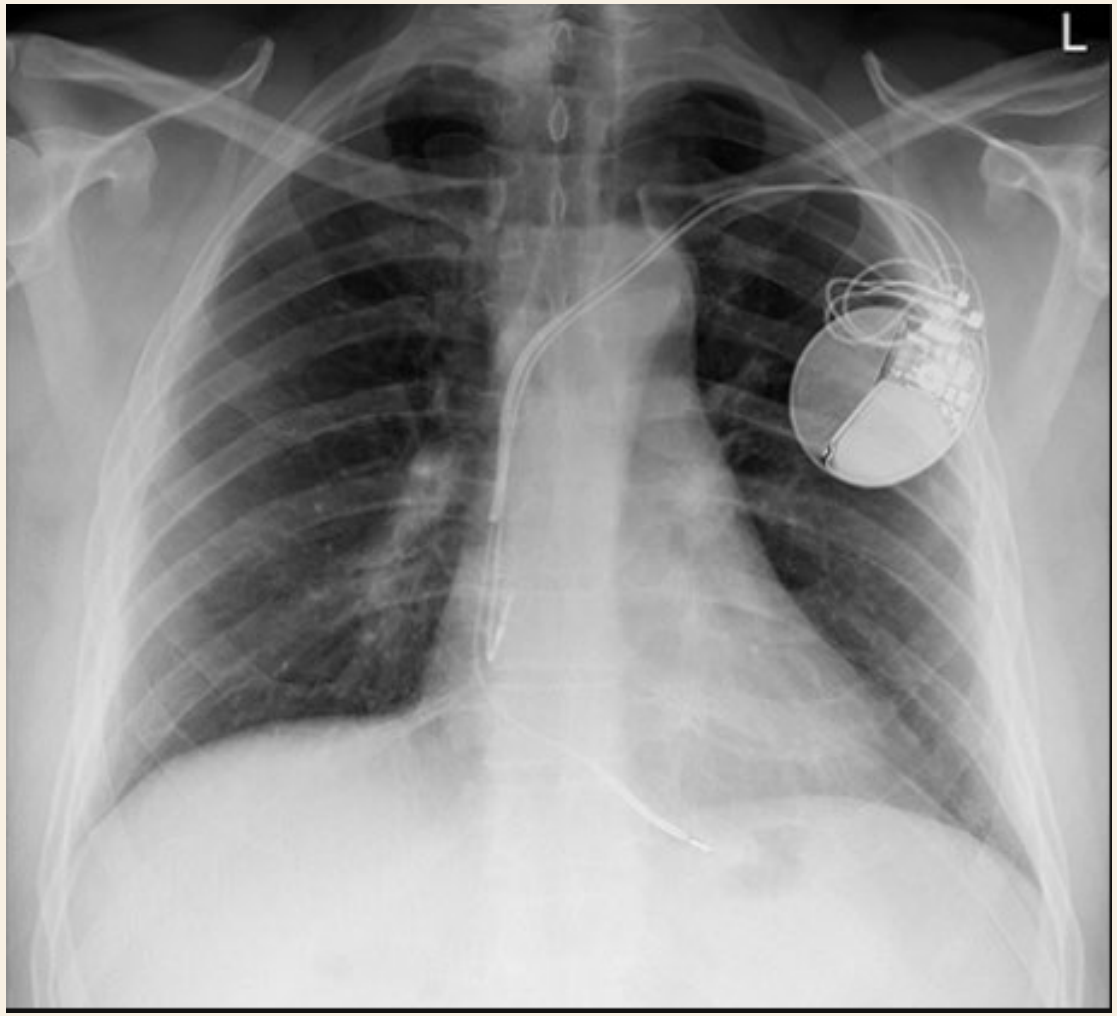
- ICDs are designed to do what pacemakers do and MORE
  - Bradyarrhythmias
  - Tachyarrhythmias

- Features
  - Providing a large direct current to the myocardium to treat ventricular tachycardia or ventricular fibrillation
  - Anti-tachycardia pacing

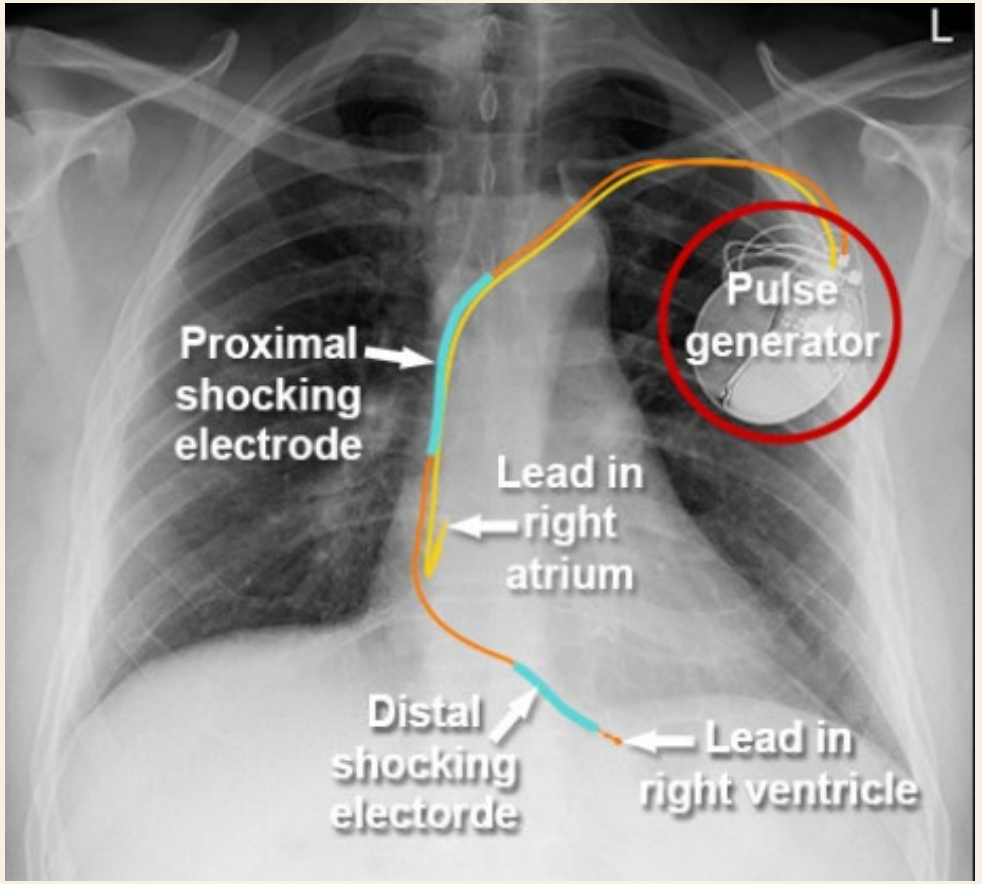
The only defibrillator that cannot pace is the Subcutaneous ICD

Indications:
- Primary prevention
  - At risk for ventricular arrhythmias e.g. chronic HFrEF, HOCM etc
- Secondary prevention
  - Non-reversible history of cardiac arrest, ventricular arrhythmia

ICD



ICD


L
Pulse generator
Proximal shocking electrode
Lead in right atrium
Distal shocking electorde
Lead in right ventricle

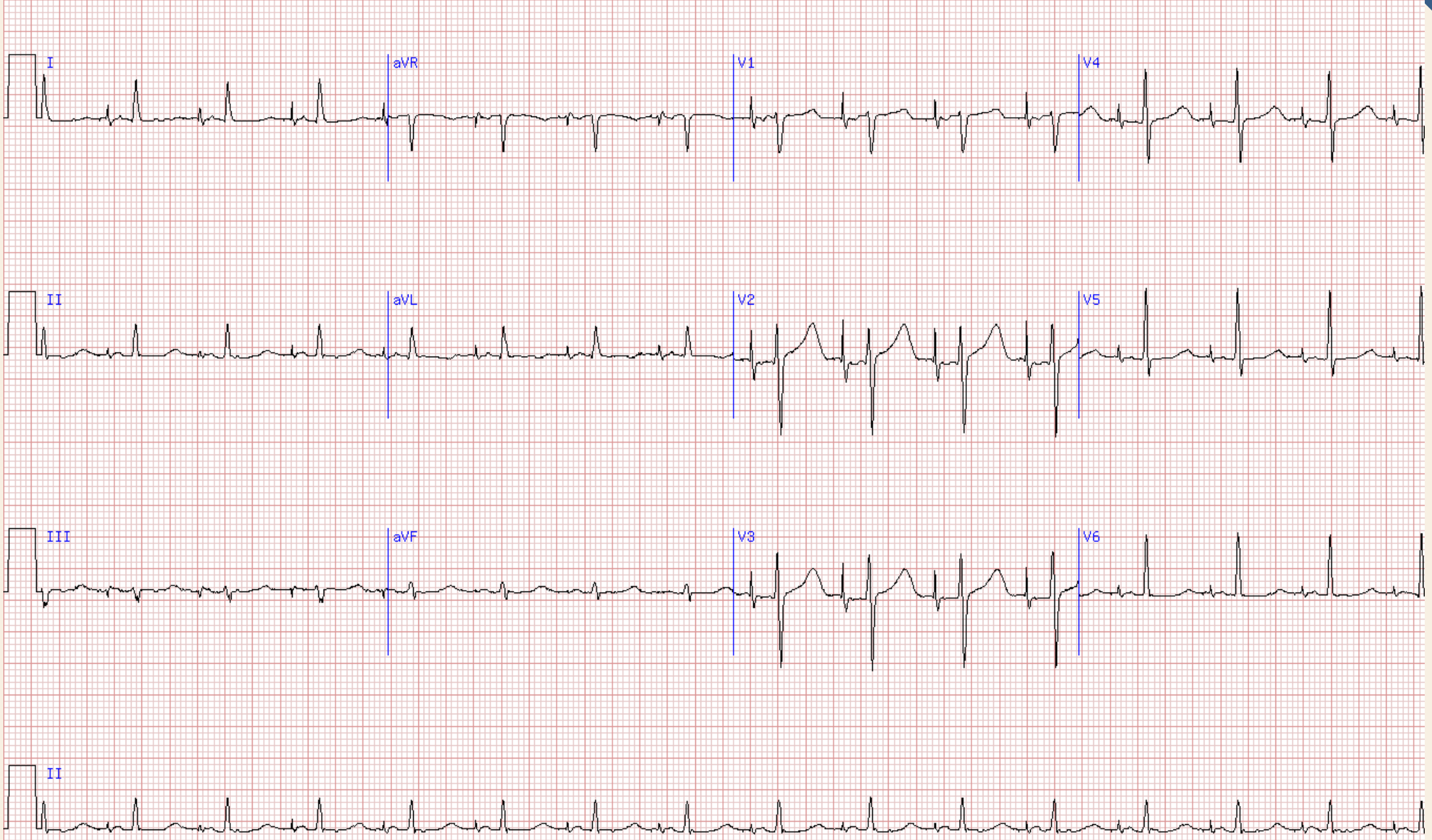


Photo credit: https://ecg.bidmc.harvard.edu/mavendata/images/case277/1350x900.gif

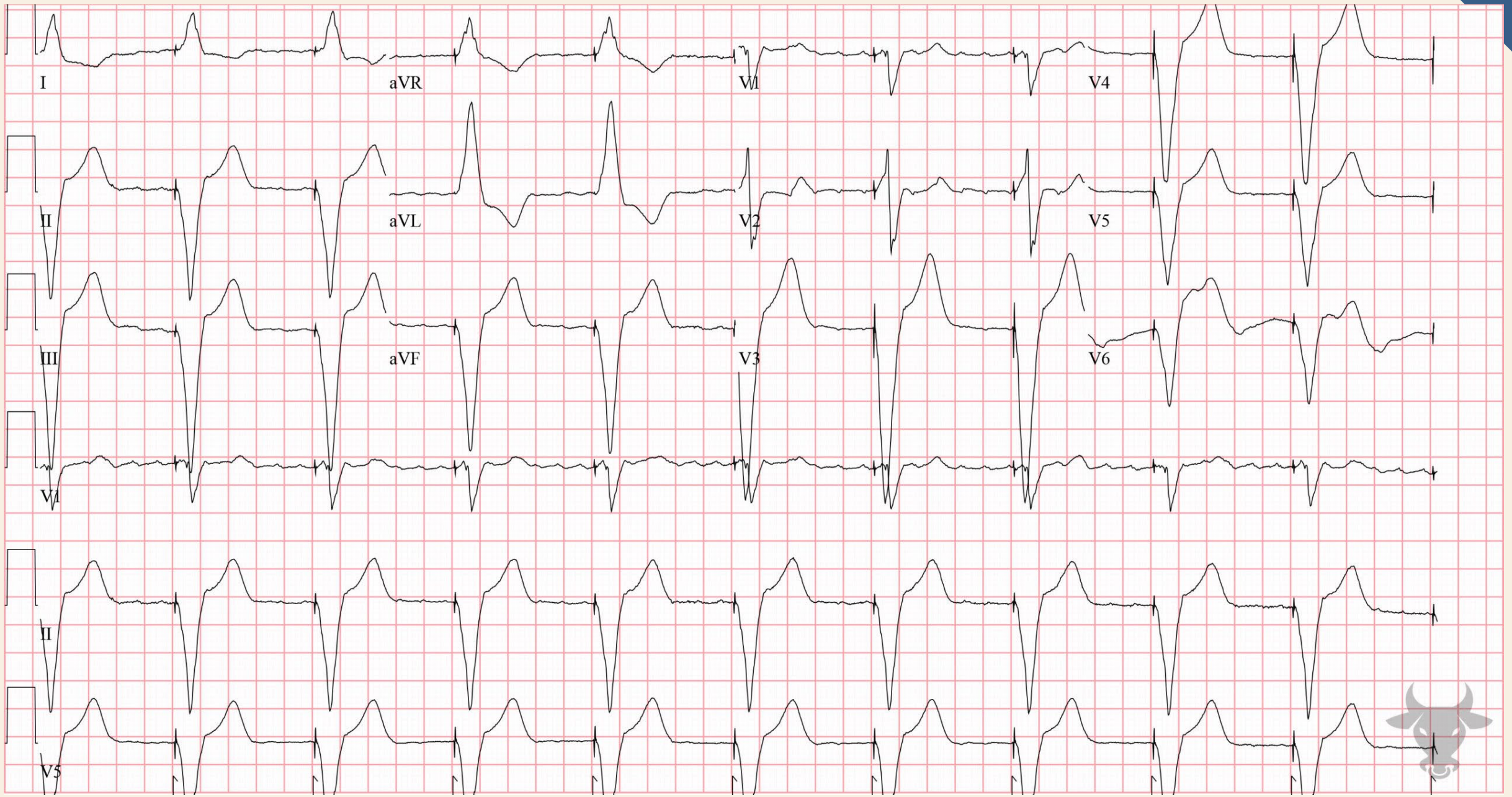


Photo credit: https://www.ecgstampede.com/glossary/paced-rhythms/

MISCELLANEOUS GOOD TO KNOW

TIMING CYCLES

- Lower rate limit
    - Minimum pacing rate
- A-V interval
    - Absolute blanking period
    - The cross-talk safety window
    - The alert period
- Upper rate behavior
    - Max tracking interval (‘upper rate limit’)

Photo credit: https://drsvenkatesan.com/2013/11/16/what-is-the-role-of-magnet-in-pacemaker-evaluation/

MAGNET APPLICATION

- Results in asynchronous pacing
- Indications
  - Temporarily during electrocautery
  - Termination of PPM mediated tachycardia
- Elective replacement indicator (ERI)
  - Duration
  - Loss of functionality
    - DDD to VVI
- End of Life (EOL)
  - Limited capabilities

What about with ICDs?
- All anti-tachycardia functions are suspended

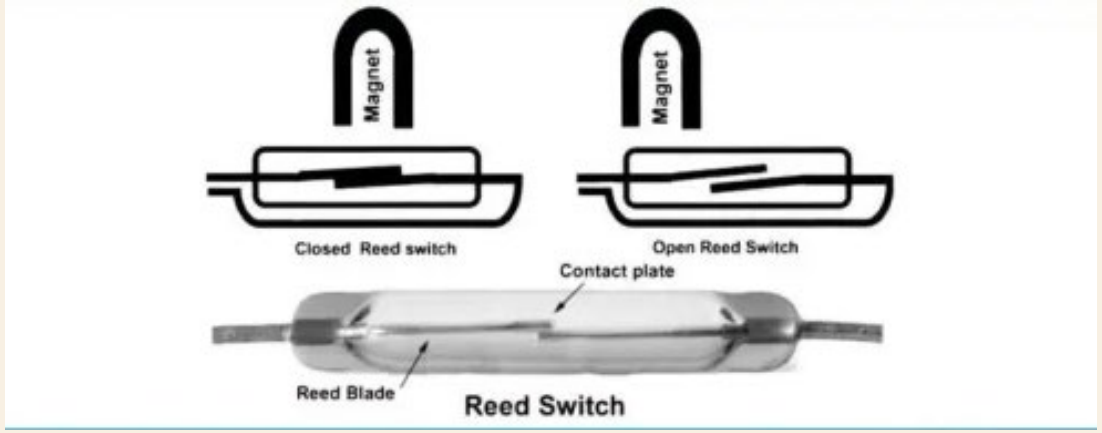


Photo credit: https://drsvenkatesan.com/2013/11/16/what-is-the-role-of-magnet-in-pacemaker-evaluation/

"It's just a backup system for your pacemaker."

Photo credit: https://www.gocomics.com/herman/2013/01/07#.UoZotR9L5ag

PACEMAKER IMPLANTATION

THE PROCEDURE

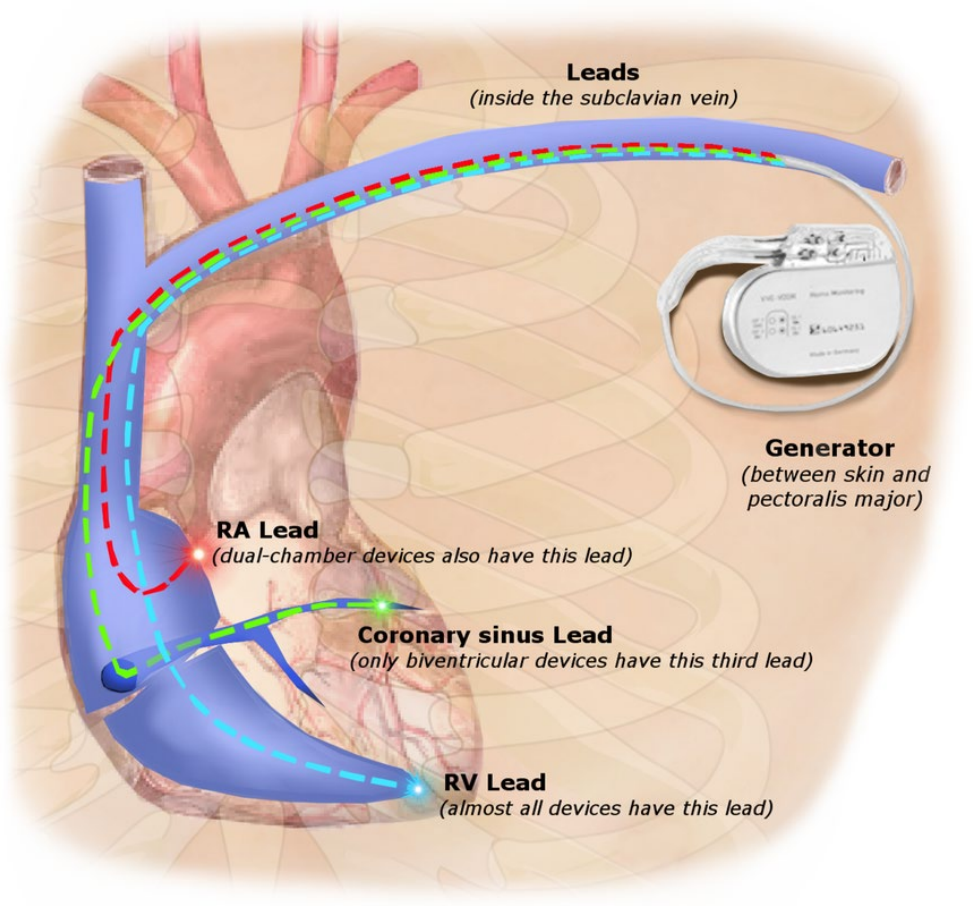


Photo credit: https://mriquestions.com/pacemaker-terminology.html

Photo credit:
https://www.medpagetoday.com/surgery/thoracicsurgery/103873

POTENTIAL COMPLICATIONS

Surgical complications

- Pneumothorax
  - hemothorax
- Hematoma
- Infection
- Inflammation
- Thrombosis
- Perforation/pericardial effusion

Device related/over time

- Rejection phenomena
- Erosion through the skin
- Muscle or nerve stimulation
  - E.g. hiccupping from diaphragmatic stimulation
- Oversensing
- Failure to detect and/or terminate arrhythmia episodes
- Lead fracture/dislodgement

Photo credit: https://www.intechopen.com/chapters/38318

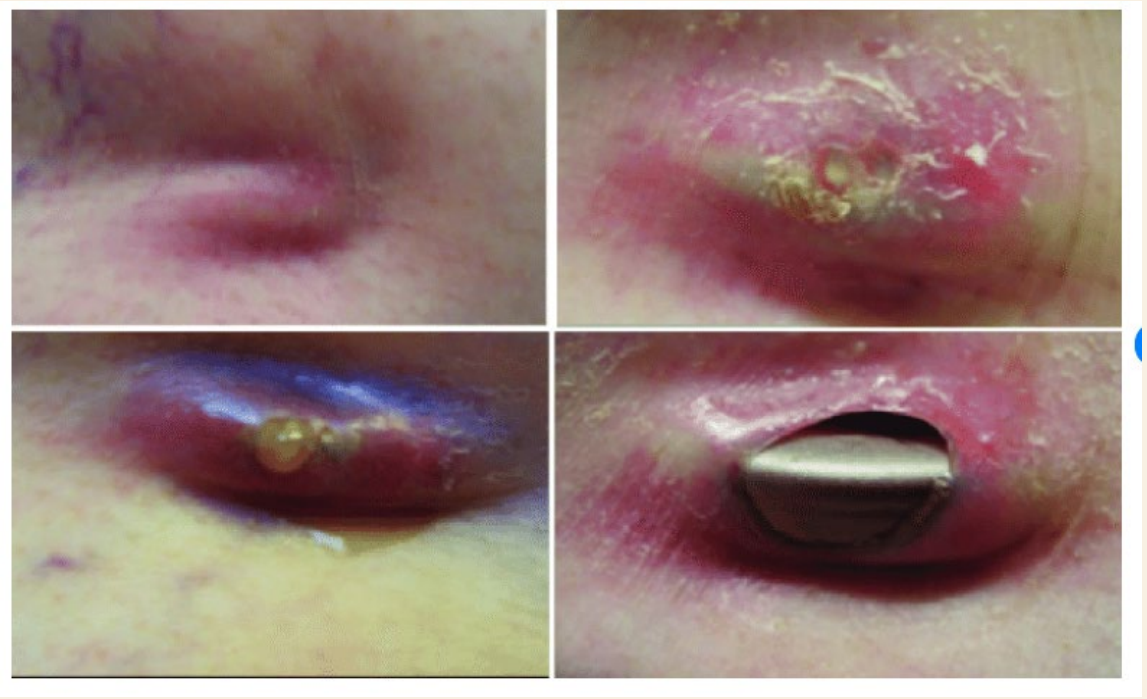
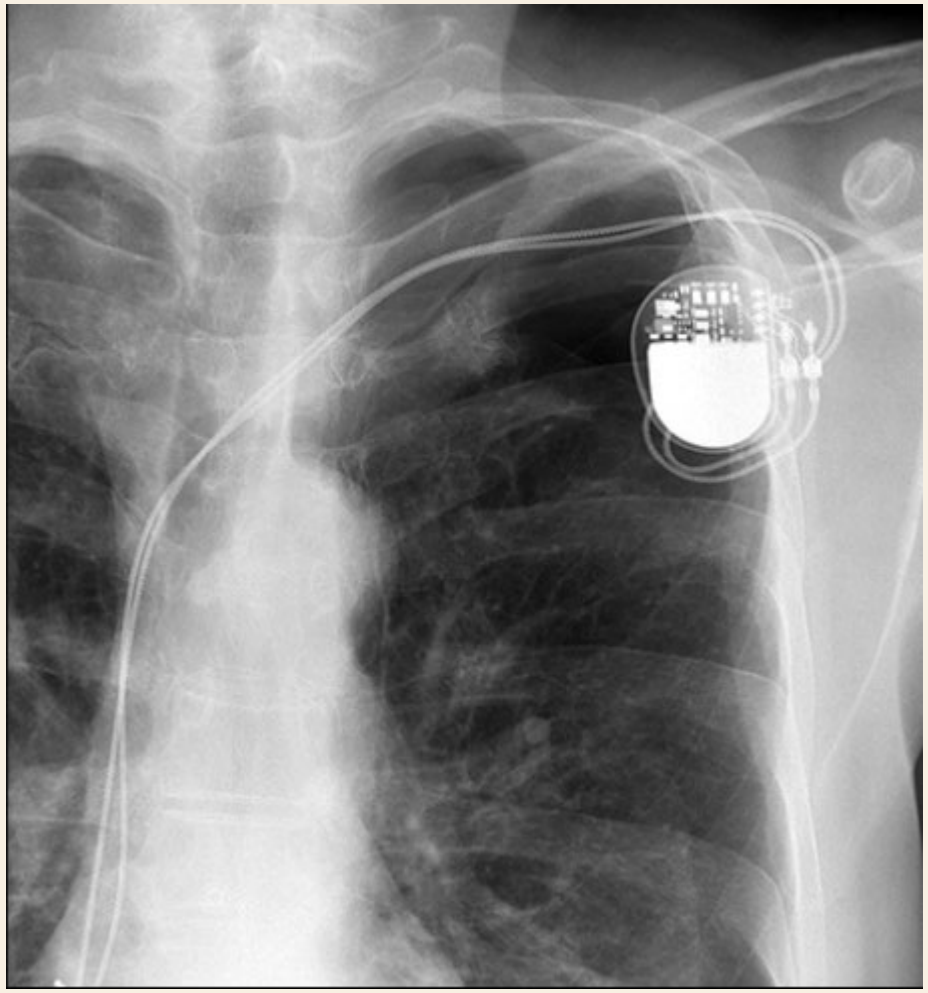


Photo credit: https://www.researchgate.net/figure/Images-of-Pocket-Infection-Over-Two-Years_fig1_303424886

81 yo with sick sinus syndrome s/p dual chamber pacemaker a few hours ago, describes worsening shortness of breath. What's the etiology?



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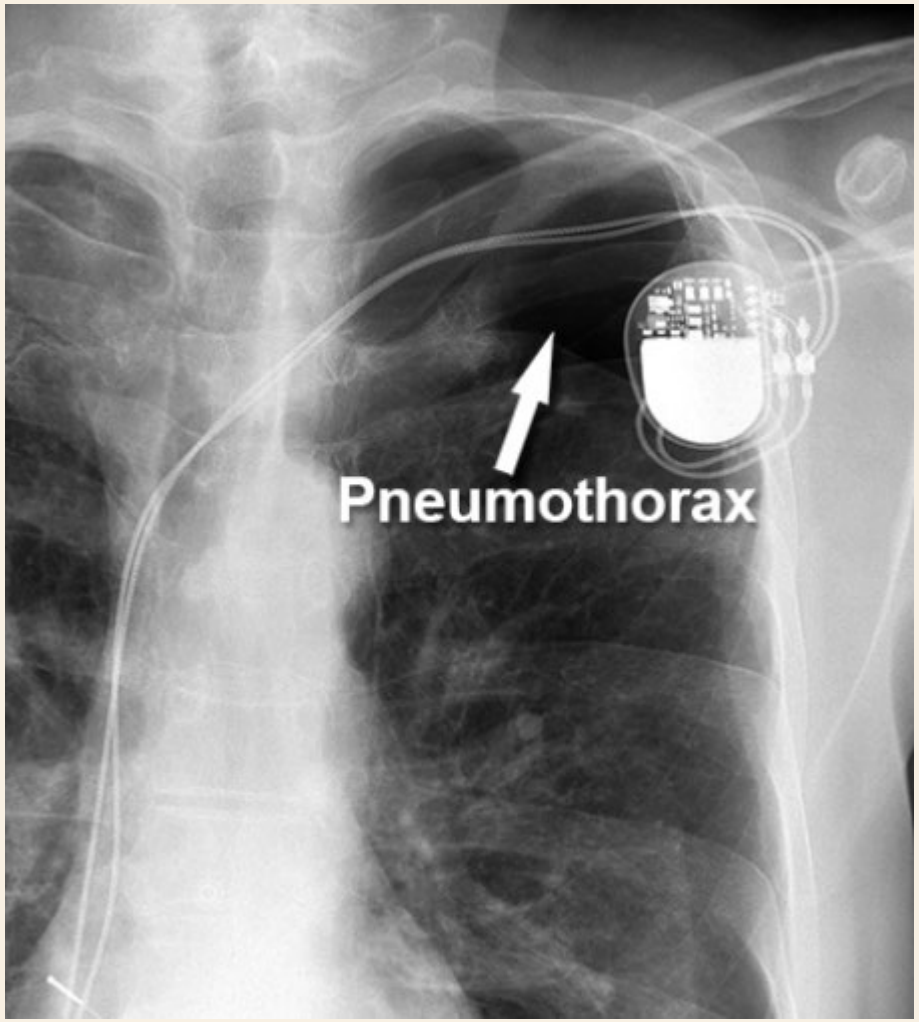

LIVING WITH A PACEMAKER: PATIENT EDUCATION

POST IMPLANT RESTRICTIONS

Typical – but can vary each case

- 4 weeks arm beneath shoulder level
- No repetitive motion with that arm
- No lifting greater than 10 lbs
- Ok to use shoulder/do not keep in sling within reason
- There will be directions when to resume anticoagulation (if on PTA)
- Will have temporary vendor card, permanent will be mailed
- Wound care – at UVM mostly closed with skin glue – leave it alone! Bathing restrictions until healed

DEVICE CHECKS

Monitoring

- Function
- Lead integrity (through impedance)
    - E.g. high lead impedance >2000 ohms -> lead fracture or <250 ohms -> insulation break
- Rhythm monitoring
- CHF diagnostics

Devices are routinely followed by device clinic

- ID abnormalities of function
- Identify ERI
- Ensure adequate safety margins (capture, optimize battery)

Self Checks

- Modern PPMs with automatic threshold testing, adjustment of outputs

Home monitoring device

- Routine interrogation info and results of auto testing
- Decreased ED visits
- Increased access to care

Cons: connectivity issues (rural), integration w/ EMR, alert fatigue

CAN I GO NEAR THE MICROWAVE?

Pacemakers these days are designed with everyday life in mind

- Pacemaker card
- Ask the company (Medtronic, St Jude etc)

Strong magnets/magnetic fields

- MRI
- Cell phones
- Chainsaws
- Welding

Protect the device

- Do NOT placed defib pads over the device
- Do not expose device to direct cancer radiation tx

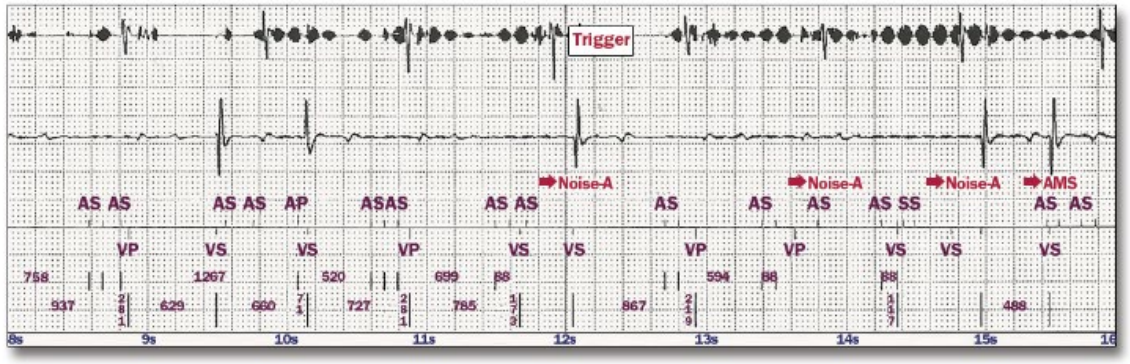

Photo credit: ACC ASSAP

REFERENCES

- ACC/AHA guidelines
- ACC ASSAP
- Graphic credits and websites as listed under photos

THANK YOU

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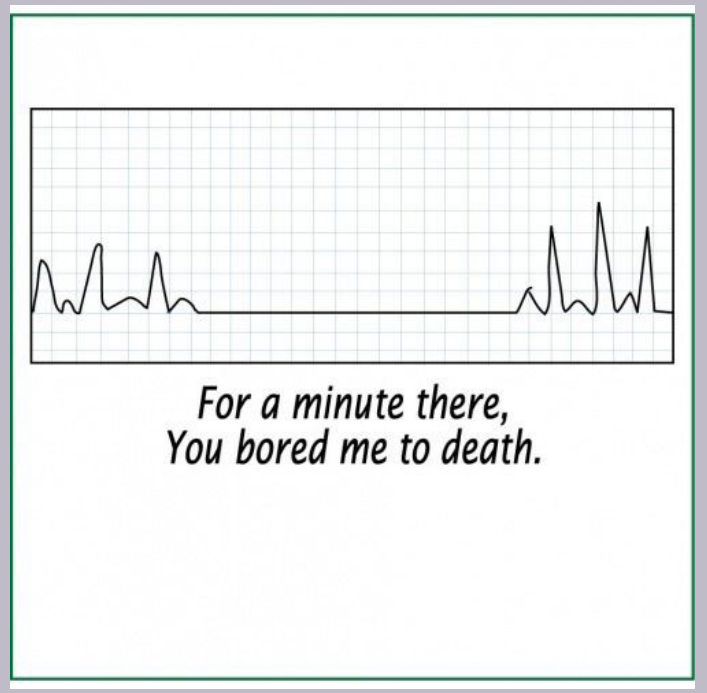
QUESTIONS?



QUESTIONS?