Essentials of Pacemakers and ICD's

Rajesh Banker, MD, MPH

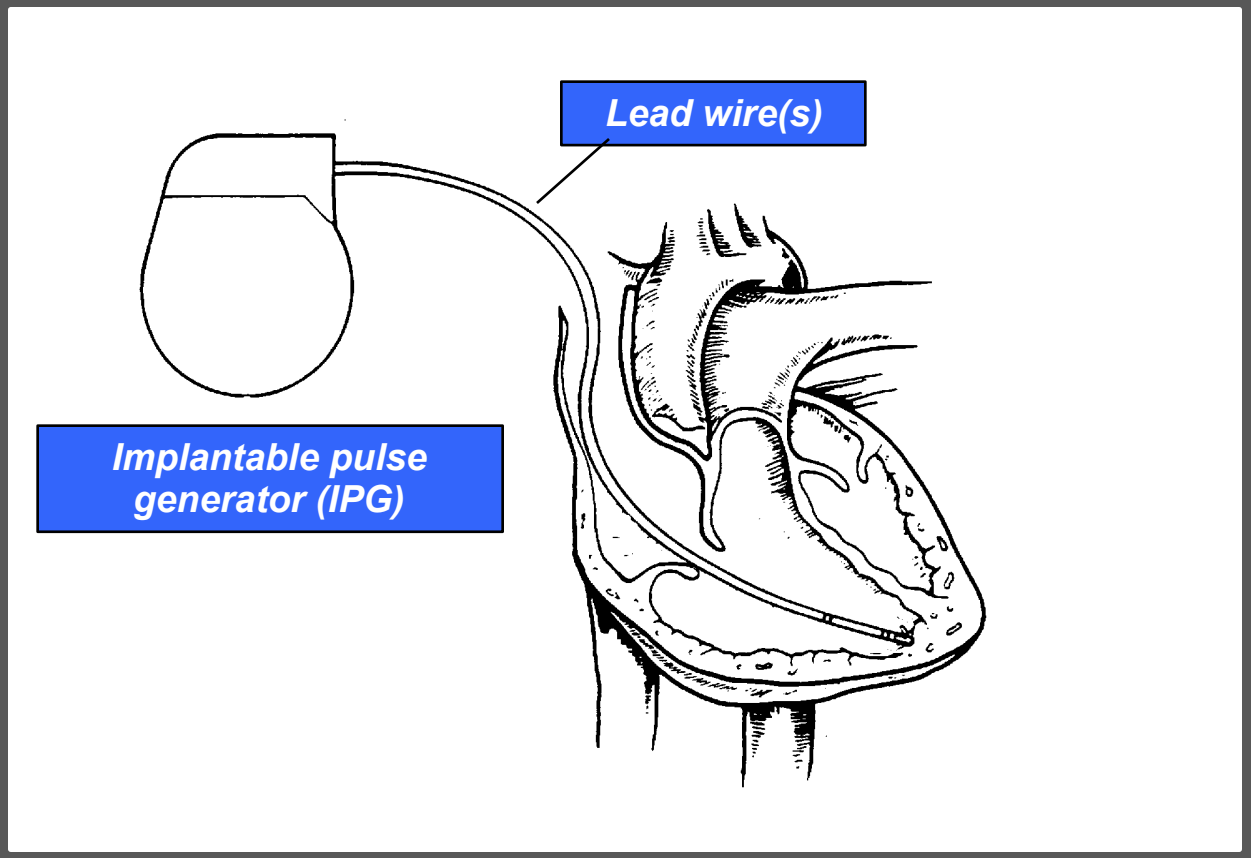
Pacemakers have 4 basic functions:

- Stimulate cardiac depolarization
- Sense intrinsic cardiac function
- Respond to increased metabolic demand by providing rate responsive pacing
- Provide diagnostic information stored by the pacemaker

Pacemaker Indications:

- Indications are primarily symptom based:
  - Symptomatic Sinus Node dysfunction
  - Symptomatic 2nd or 3rd degree heart block
- More uncommonly, prophylaxis can be considered as well
  - Sinus Nodal dysfunction or high grade heart block with very low baseline heart rates (<35)
  - Bradycardia dependent ventricular tachyarrhythmia

Components



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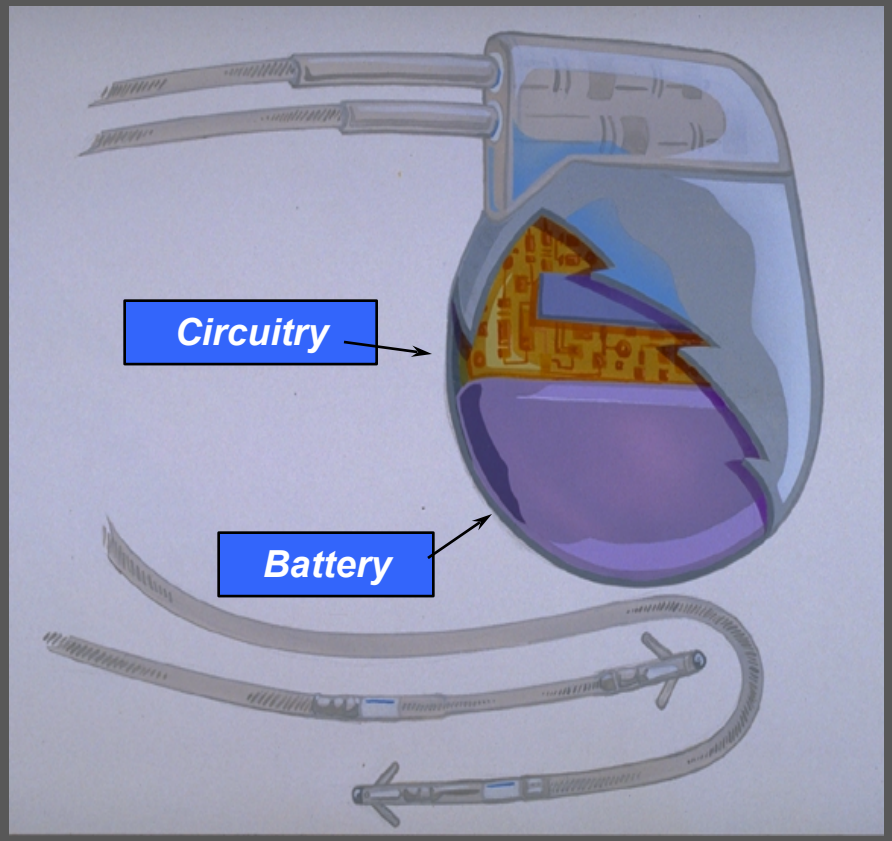
The Pulse Generator:

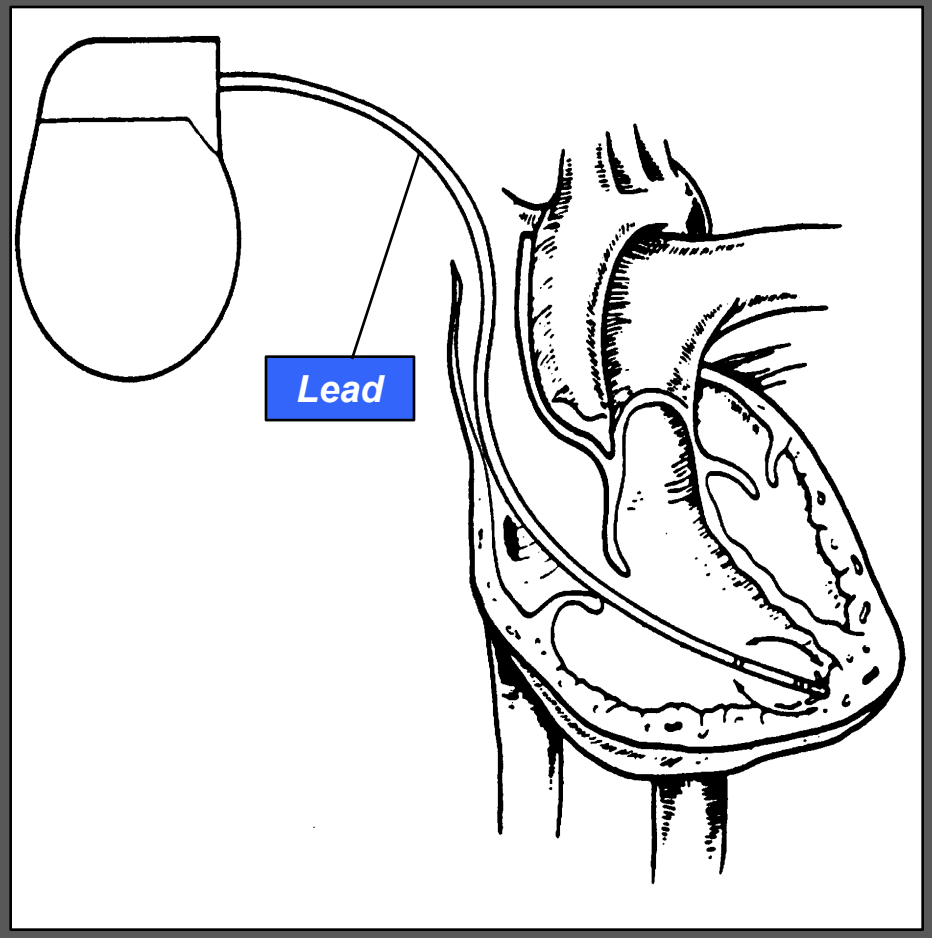
- Contains a battery that provides the energy for sending electrical impulses to the heart
- Houses the circuitry that controls pacemaker operations



Courtesy www.medtronicacademy.com

Leads Are Insulated Wires That:

- Deliver electrical impulses from the pulse generator to the heart
- Sense cardiac depolarization



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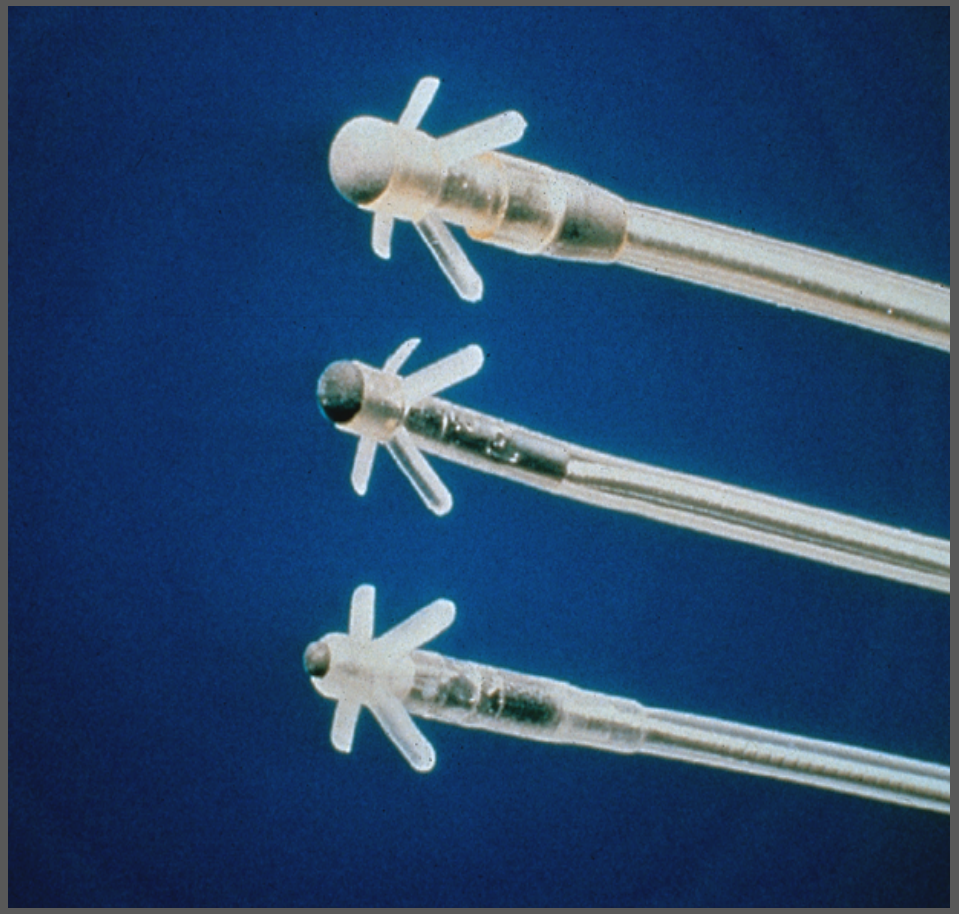
Types of Leads

- Endocardial or transvenous leads
- Myocardial/Epicardial leads

Transvenous Leads Have Different "Fixation" Mechanisms

- Passive fixation
  - The tines become lodged in the trabeculae of the heart



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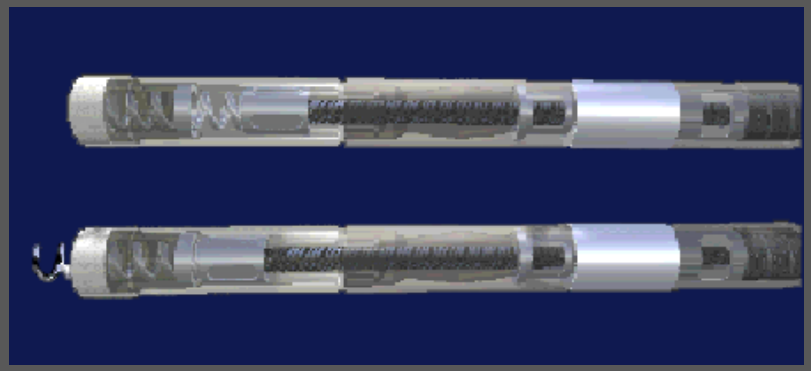
Transvenous Leads

- Active Fixation
  - The helix (or screw) extends into the endocardial tissue
  - Allows for lead positioning anywhere in the heart's chamber



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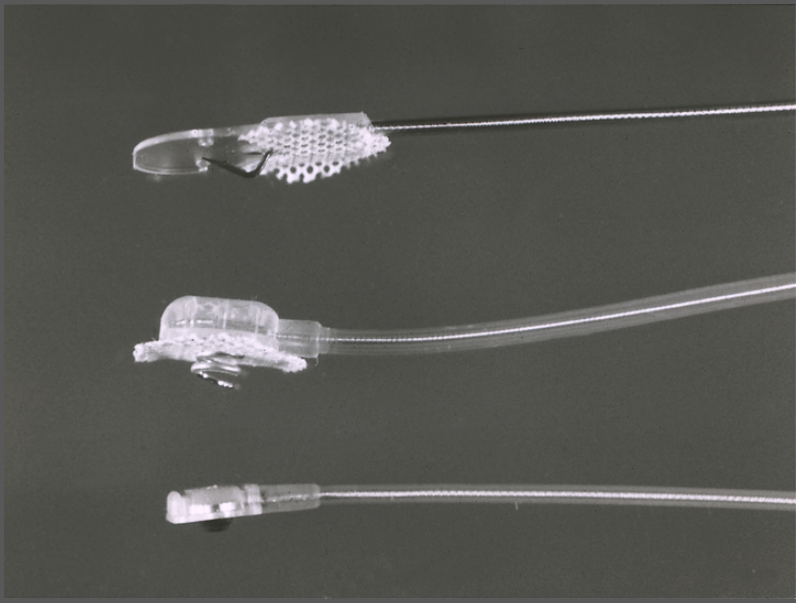
Myocardial and Epicardial Leads

- Leads applied directly to the heart
  - Fixation mechanisms include:
    - Epicardial stab-in
    - Myocardial screw-in
    - Suture-on



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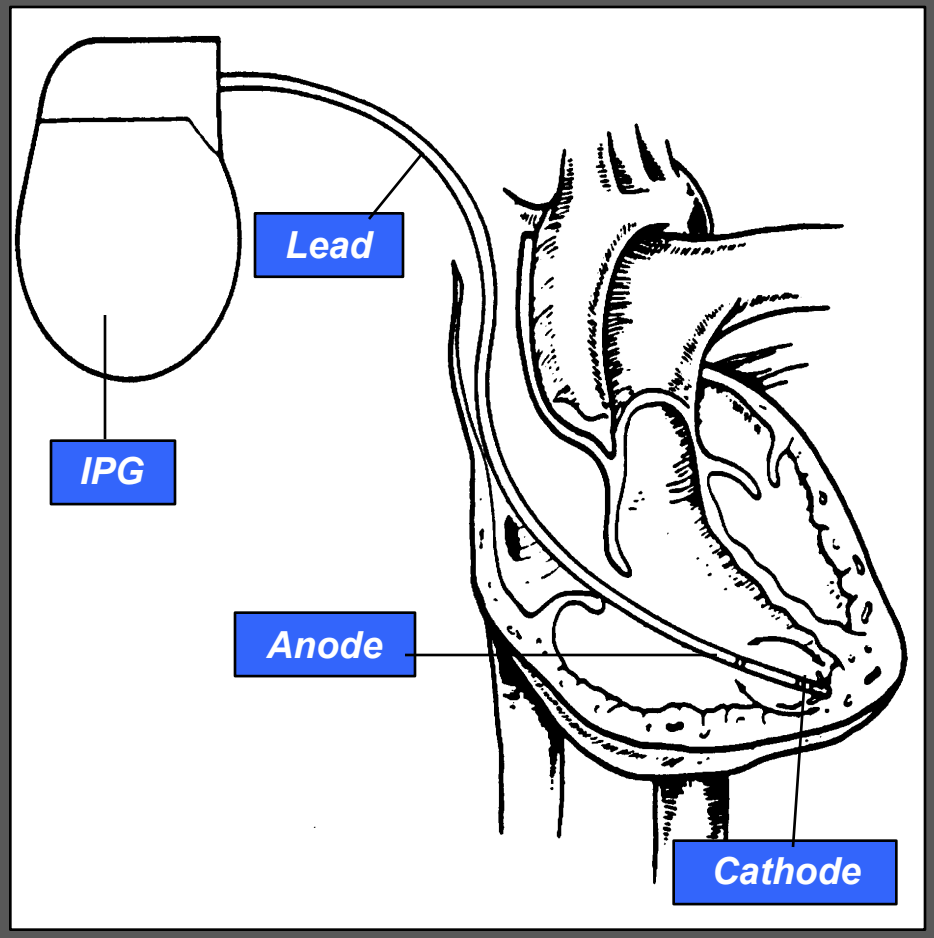
Pacemaker Components Combine with Body Tissue to Form a Complete Circuit

- Pulse generator: power source or battery
- Leads or wires
- Cathode (negative electrode)
- Anode (positive electrode)
- Body tissue



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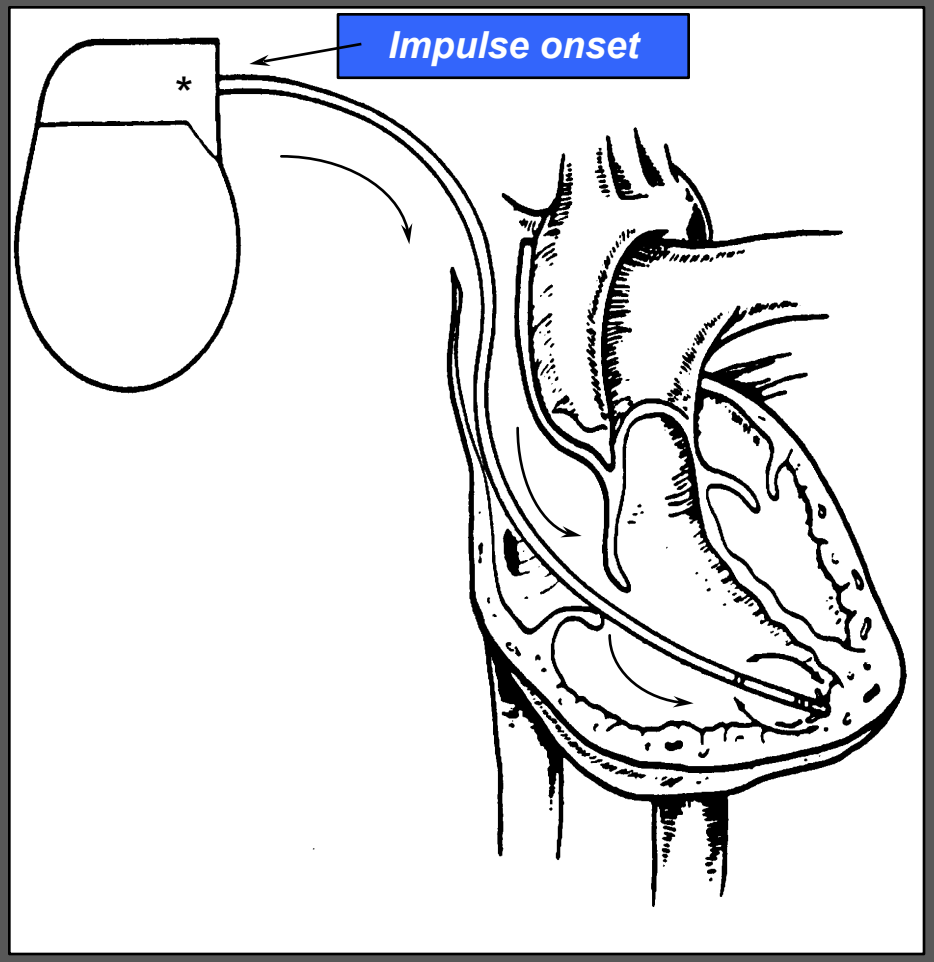
During Pacing, the Impulse:

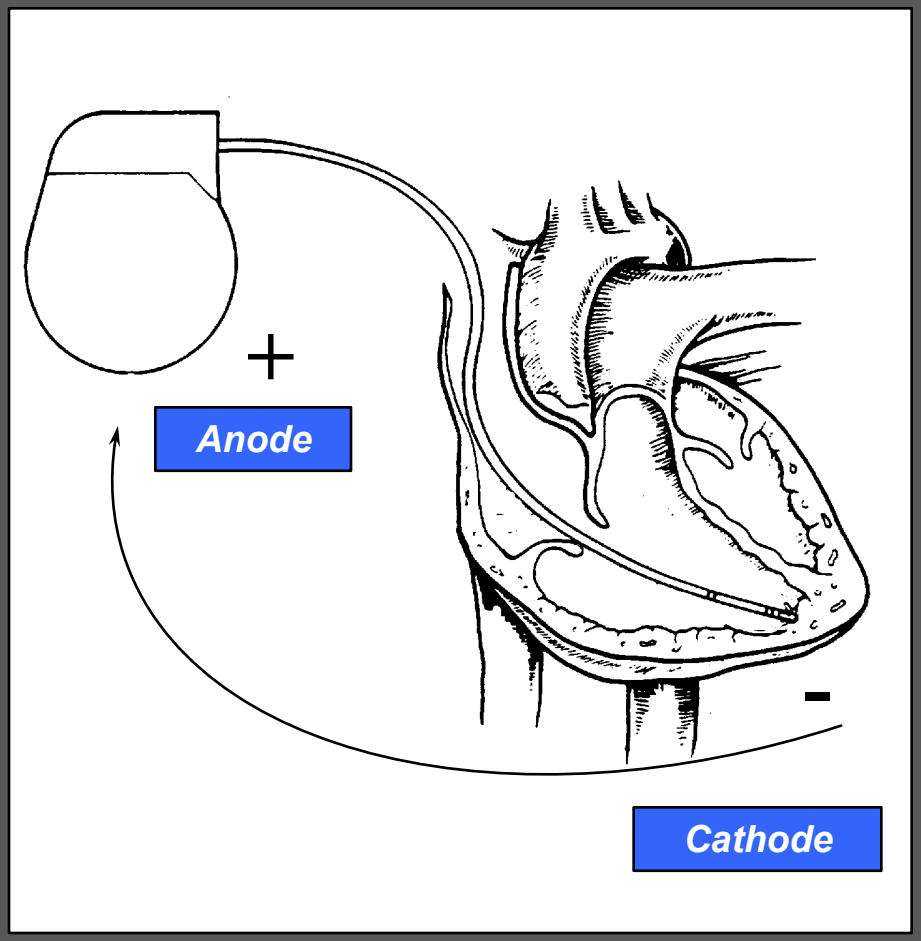
- Begins in the pulse generator
- Flows through the lead and the cathode (–)
- Stimulates the heart
- Returns to the anode (+)



Courtesy www.medtronicacademy.com

A Unipolar Pacing System Contains a Lead with Only One Electrode Within the Heart; In This System, the Impulse:

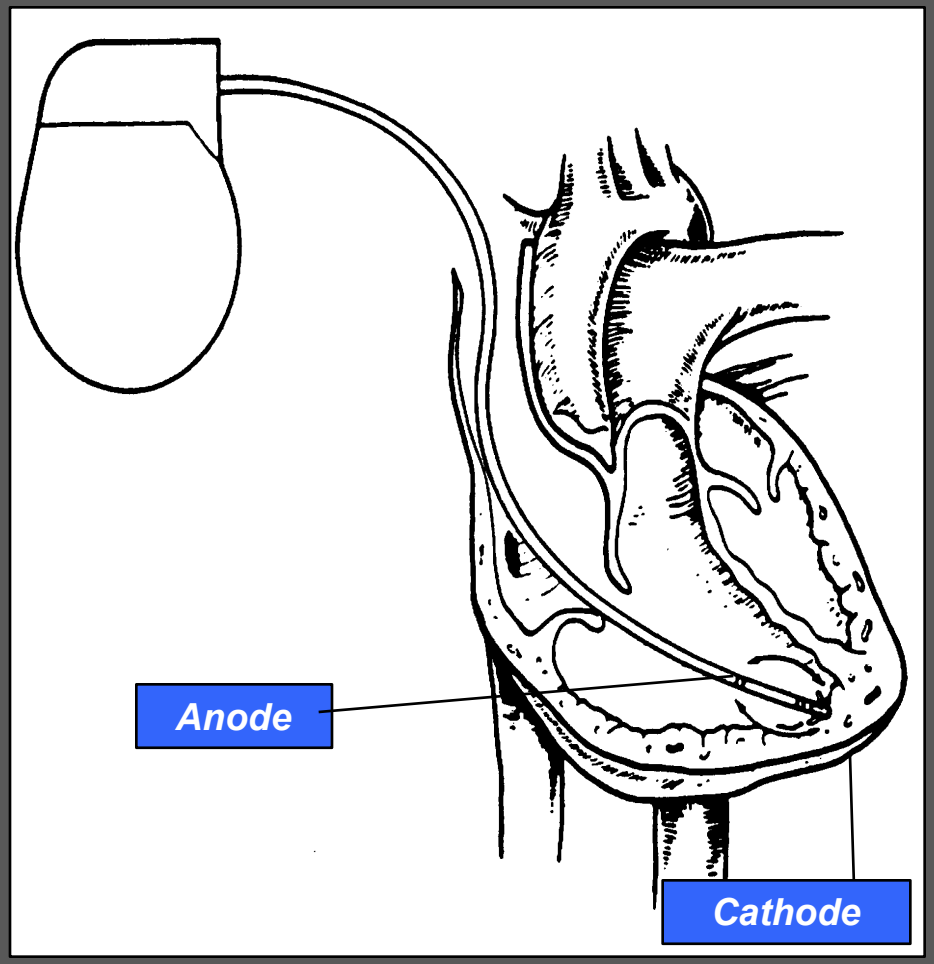
- Flows through the tip electrode (cathode)
- Stimulates the heart
- Returns through body fluid and tissue to the IPG (anode)



Courtesy www.medtronicacademy.com

A Bipolar Pacing System Contains a Lead with Two Electrodes Within the Heart. In This System, the Impulse:

- Flows through the tip electrode located at the end of the lead wire
- Stimulates the heart
- Returns to the ring electrode above the lead tip



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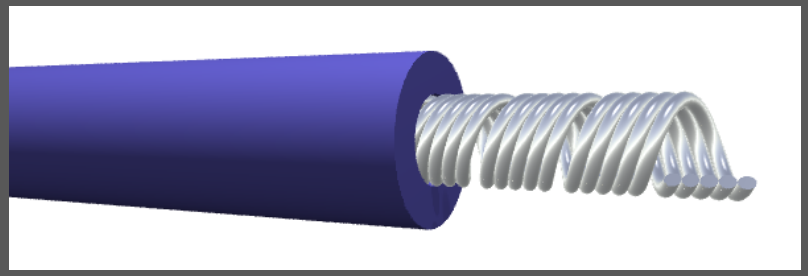
Unipolar leads

- Unipolar leads may have a smaller diameter lead body than bipolar leads
- Unipolar leads usually exhibit larger pacing artifacts on the surface ECG



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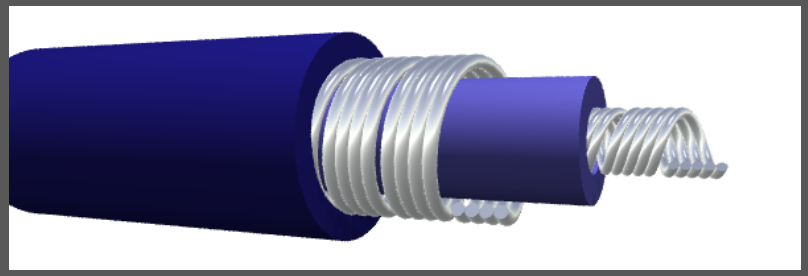
Bipolar leads

- Bipolar leads are less susceptible to oversensing noncardiac signals (myopotentials and EMI)

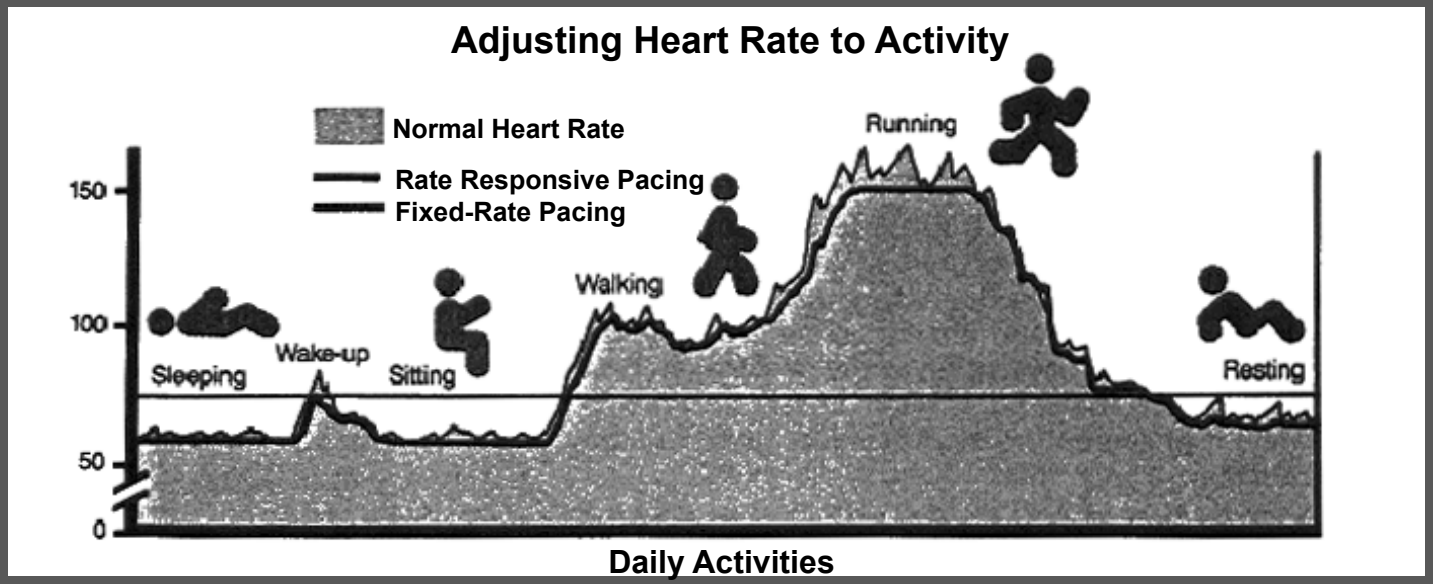


Coaxial Lead Design

Courtesy www.medtronicacademy.com

Rate Responsive Pacing

- When the need for oxygenated blood increases, the pacemaker ensures that the heart rate increases to provide additional cardiac output



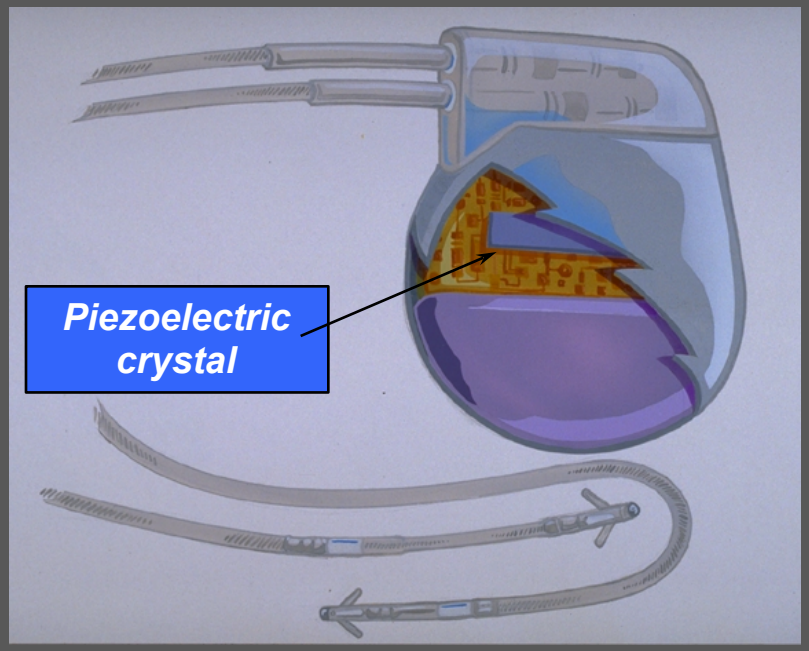
Courtesy www.medtronicacademy.com

A Variety of Rate Response Sensors Exist

- Those most accepted in the market place are:
  - Activity sensors that detect physical movement and increase the rate according to the level of activity
  - Minute ventilation sensors that measure the change in respiration rate and tidal volume via transthoracic impedance readings

Rate Responsive Pacing

- Activity sensors employ a *piezoelectric crystal* that detects mechanical signals produced by movement
- The crystal translates the mechanical signals into electrical signals that in turn increase the rate of the pacemaker



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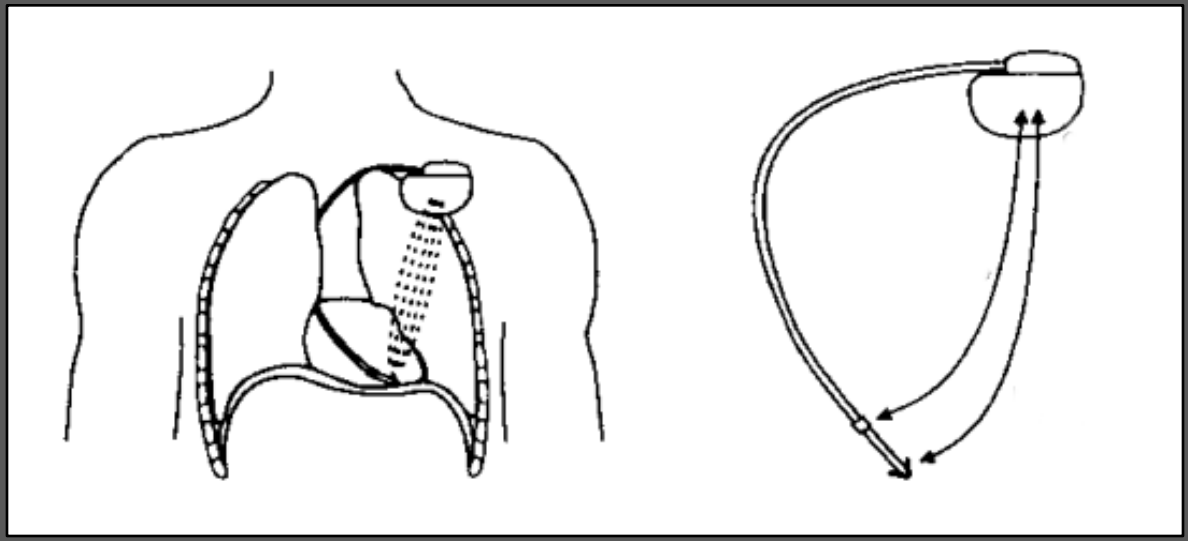
Rate Responsive Pacing

- Minute ventilation can be measured by measuring the changes in electrical impedance across the chest cavity to calculate changes in lung volume over time



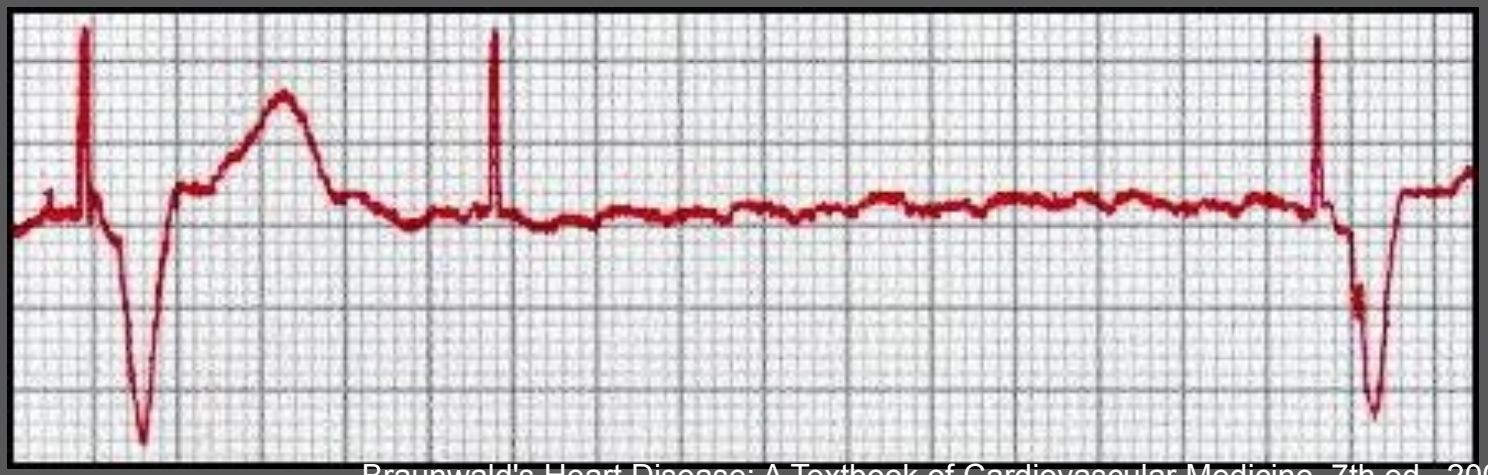
Pacemaker Codes

Position Function	1 Chambers Paced	2 Chambers Sensed	3 Response to Sensed Stimulus	4 Rate Modulation?
	O (none)	O	O	O (non-rate responsive)
	A (atrium)	A	T (triggered)	R (rate responsive)
	V (ventricle)	V	I (inhibited)	
	D (both atrium & ventricle)	D (both atrium & ventricle)	D (both atrium & ventricle)	

Pacemaker Complications:

- Pneumothorax
- Pericarditis
- Perforation of the atrium or ventricle
- Lead Dislodgement
- Venous thrombosis
- Infection

Problems with Pacemakers
Failure to Capture

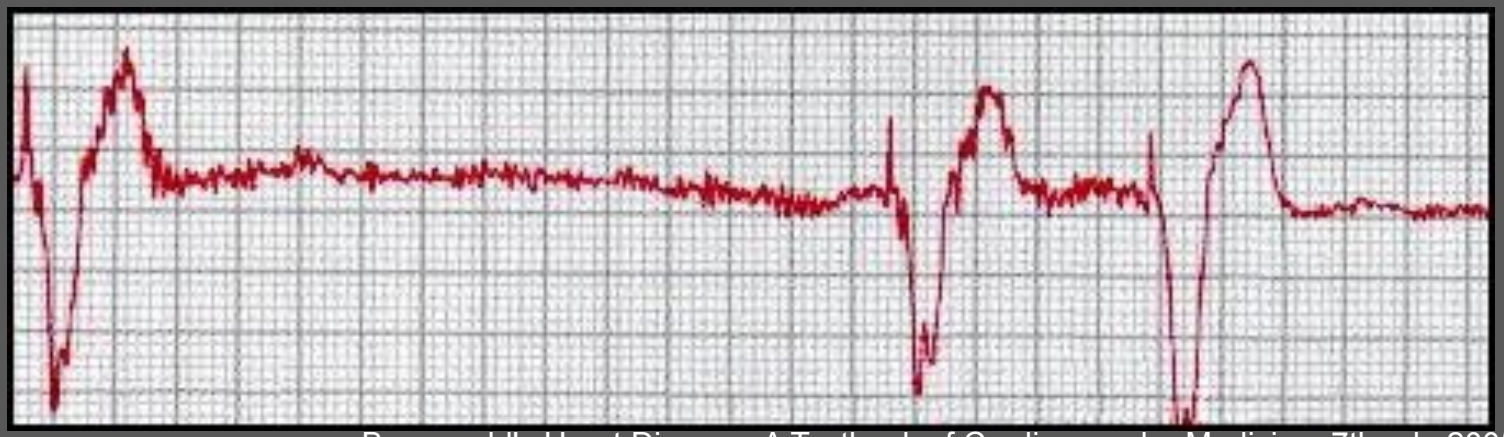


Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 7th ed., 2005.

Causes:

- Threshold rise (electrolytes, drugs)
- Lead dislodgement
- Lead fracture
- RV infarct

Problems with Pacemakers
Failure to Pace



Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 7th ed., 2005.

Causes:

- Oversensing
- Battery failure
- Internal insulation failure
- Conductor coil fracture

Problems with Pacemakers
Failure to Sense

Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 7th ed., 2005.

Causes:

- Undersensing
- Lead Fracture

What's next for pacemakers?

- Leadless Pacemakers
  - St. Jude Medical and Medtronic devices have concluded their clinical trials

Approval expected this year

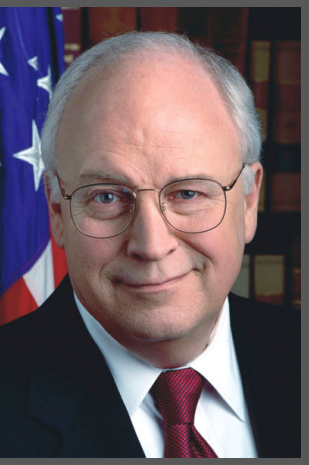
The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Percutaneous Implantation of an Entirely Intracardiac Leadless Pacemaker

Vivek Y. Reddy, M.D., Derek V. Exner, M.D., M.P.H., Daniel J. Cantillon, M.D., Rahul Doshi, M.D., T. Jared Bunch, M.D., Gery F. Tomassoni, M.D., Paul A. Friedman, M.D., N.A. Mark Estes III, M.D., John Ip, M.D., Imran Niazi, M.D., Kenneth Plunkitt, M.D., Rajesh Banker, M.D., James Porterfield, M.D., James E. Ip, M.D., and Srinivas R. Dukkipati, M.D., for the LEADLESS II Study Investigators*

Implantable Cardioverter Defibrillators

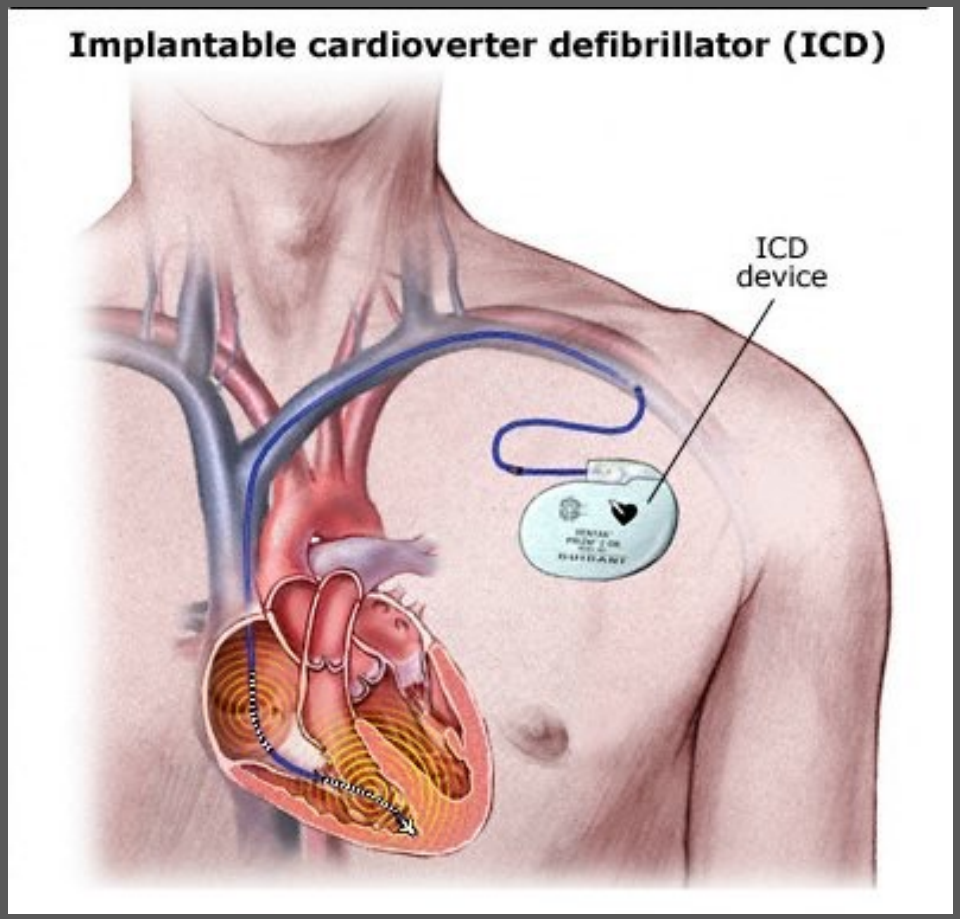


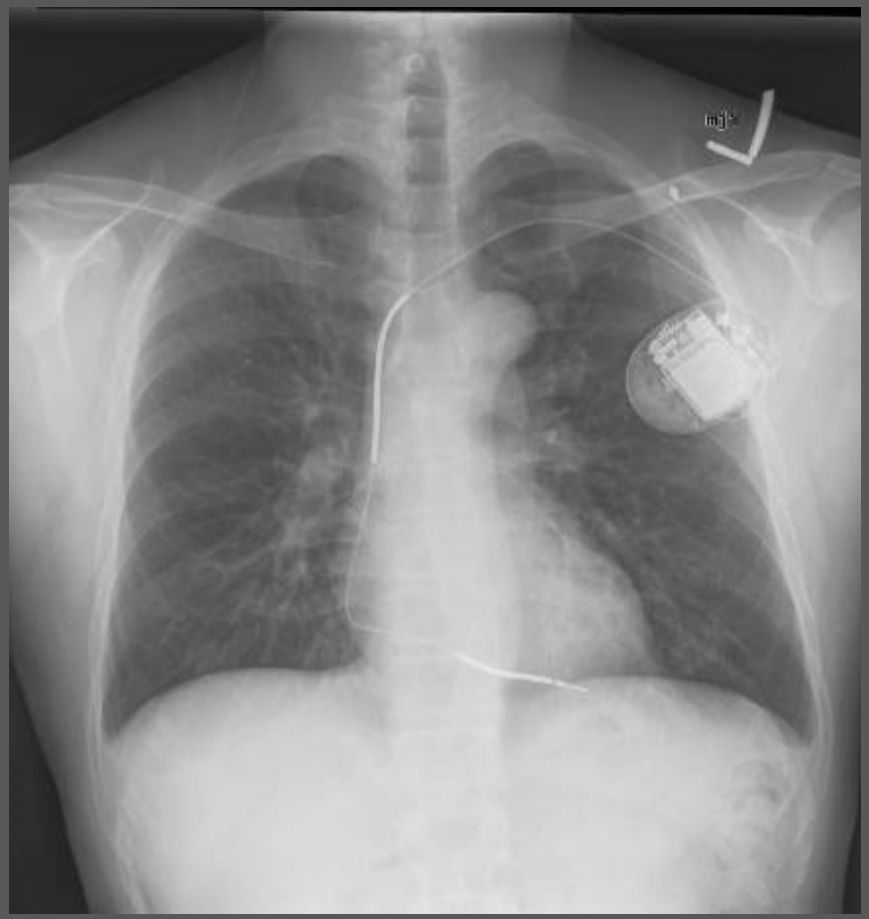
- All modern defibrillators have all the functions a pacemaker plus:
  - The ability to pace terminate or defibrillate ventricular tachyarrhythmias (VT/VF)
- System-wise, the only differences are:
  - The RV lead which has 1 or 2 defibrillator coils on it
  - The pulse generator is larger to accommodate a larger capacitor and battery

ICD Indications:

- Indications are primarily prophylactic (Primary Prevention):
  - High risk subgroups:
    - Low EF
    - Genetic syndromes
- Less commonly, ICDs are implanted for presumed or actual cardiac arrest
  - VT/VF without a reversible cause
  - Syncope with concerning history or findings at EP Study (presumed arrest)

How do ICDs work?





How do ICDs work?

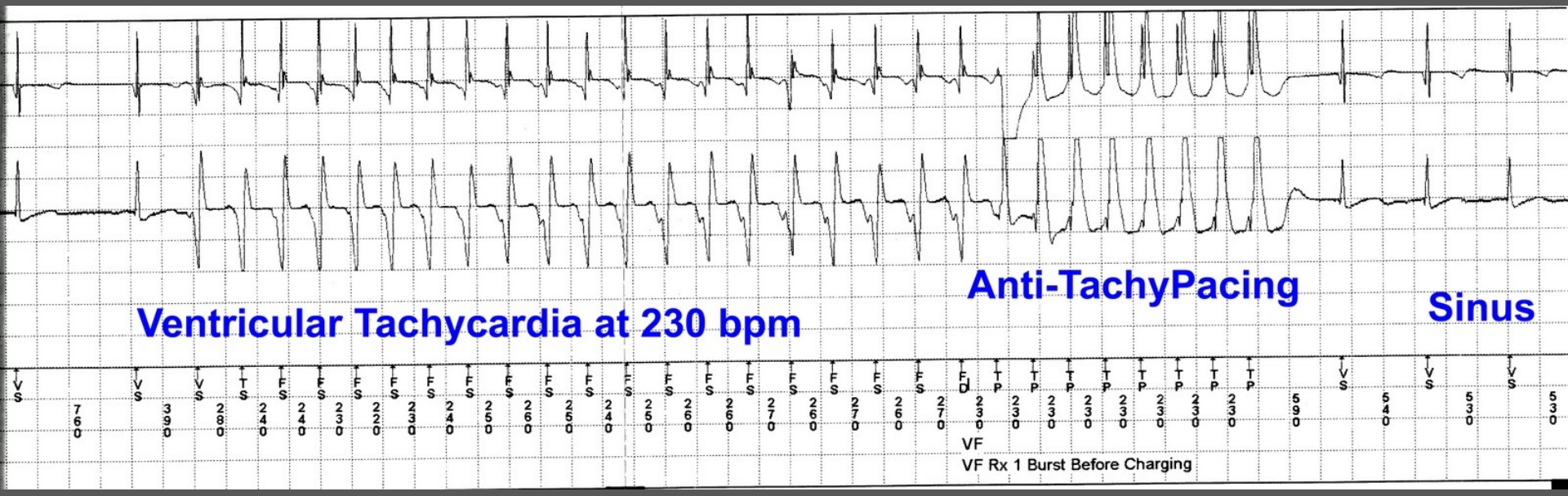
- Constant sensing by the RV lead for the presence of a fast rhythm
  - The threshold for detection is user definable
  - ICDs can discriminate between SVT and Ventricular based tachyarrhythmia (VT/VF)

How do ICDs work?

- Once VT/VF is detected, the device has a choice:
  - Pace termination
  - Defibrillation

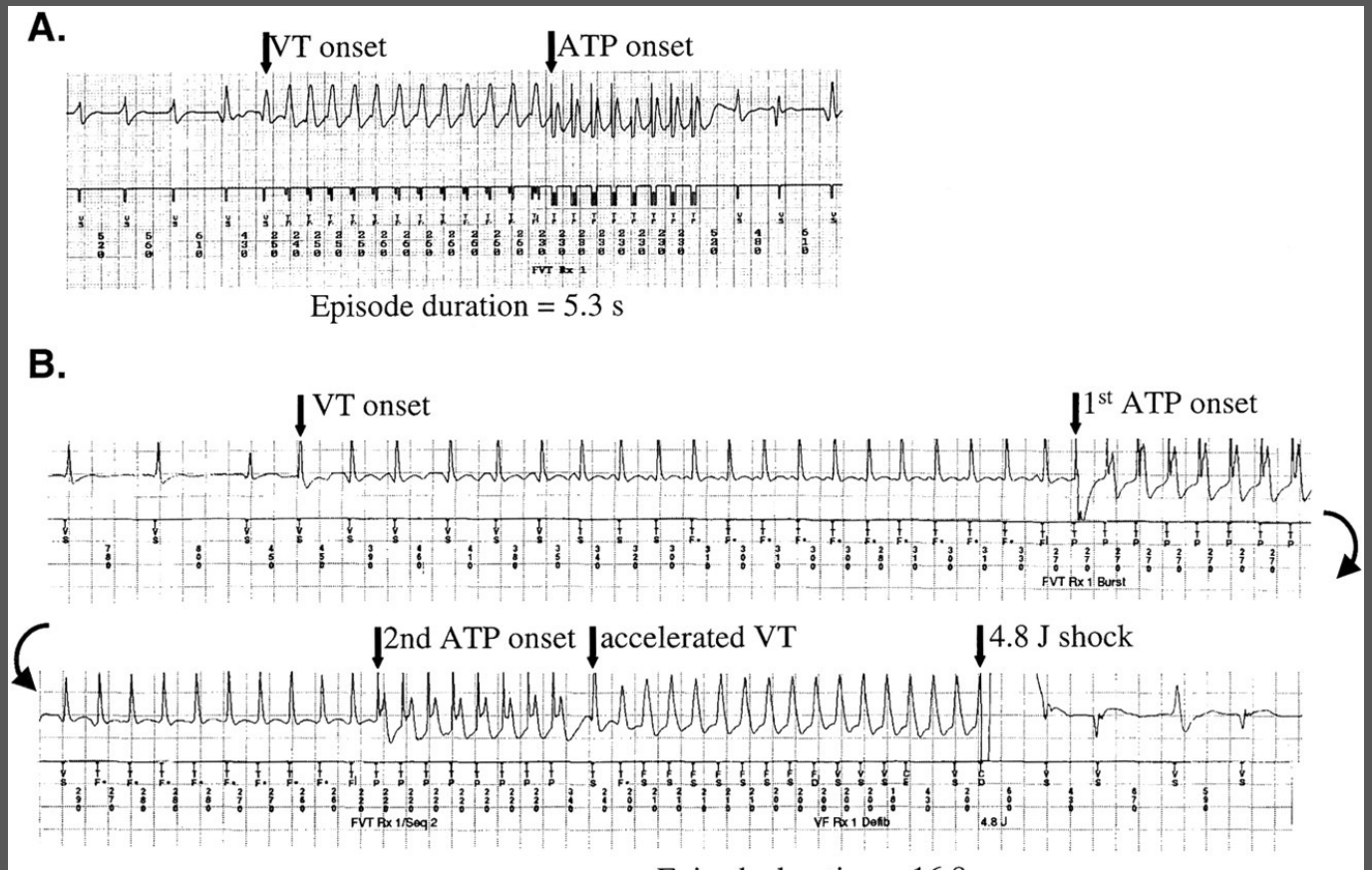
Pace Termination

- Pace Termination
  - More commonly known as Anti-tachy pacing (ATP)
  - Painless



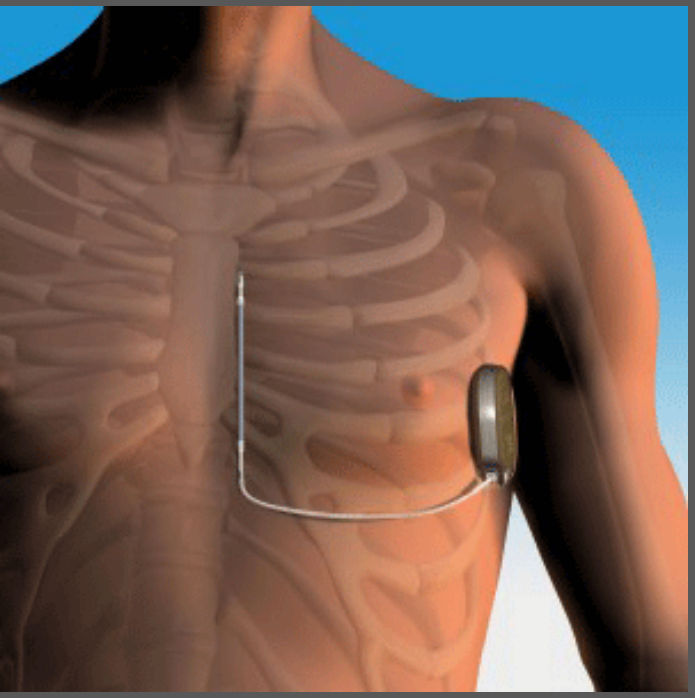
Defibrillation

- The ICD will charge its capacitor (3-6 seconds) and then deliver therapy



What's new?

- **Subcutaneous ICD:**



Courtesy Boston Scientific

- **Questions?**

References

- Open source slidesets on: https://www.medtronicacademy.com
- http://www.cardiachealth.org/heart-information/heart-arrhythmia/icd