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# **Cardiac Assist Devices**

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**Mohammad Shafiq, MD**

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# Types

**Pacemakers**

**AICDs**

**VADs**

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# History

- **First pacemaker implanted in 1958**
- **First ICD implanted in 1980**
- **Greater than 500,000 patients in the US population have pacemakers**
- **115,000 implanted each year**

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# Pacemakers Today

- **Single or dual chamber**
- **Multiple programmable features**
- **Adaptive rate pacing**
- **Programmable lead configuration**

# Internal Cardiac Defibrillators (ICD)

- **Transvenous leads**
- **Multiprogrammable**
- **Incorporate all capabilities of contemporary pacemakers**
- **Storage capacity**

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# Temporary Pacing Indications

- **Routes = Transvenous, transcutaneous, esophageal**
- **Unstable bradydysrhythmias**
- **Atrioventricular heart block**
- **Unstable tachydysrhythmias**
- **\*Endpoint reached after resolution of the problem or permanent pacemaker implantation**

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# Permanent Pacing Indications

- **Chronic AVHB**
- **Chronic Bifascicular and Trifascicular Block**
- **AVHB after Acute MI**
- **Sinus Node Dysfunction**
- **Hypersensitive Carotid Sinus and Neurally Mediated Syndromes**
- **Miscellaneous Pacing Indications**

# Chronic AVHB

- Especially if symptomatic

**Pacemaker most commonly indicated for:**

- Type 2 2°
  - Block occurs within or below the Bundle of His
- 3° Heart Block
  - No communication between atria and ventricles



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# Chronic Bifascicular and Trifascicular Block

- **Differentiation between uni, bi, and trifascicular block**
- **Syncope common in patients with bifascicular block**
- **Intermittent 3° heart block common**

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## AVHB after Acute MI

- Incidence of high grade AVHB higher
- Indications for pacemaker related to intraventricular conduction defects rather than symptoms
- Prognosis related to extent of heart damage

# Sinus Node Dysfunction

- Sinus bradycardia, sinus pause or arrest, or sinoatrial block, chronotropic incompetence
- Often associated with paroxysmal SVTs (bradycardia-tachycardia syndrome)
- May result from drug therapy
- Symptomatic?
- Often the primary indication for a pacemaker

# Hypersensitive Carotid Sinus Syndrome

- **Syncope or presyncope due to an exaggerated response to carotid sinus stimulation**
- **Defined as asystole greater than 3 sec due to sinus arrest or AVHB, an abrupt reduction of BP, or both**

# Neurally Mediated Syncope

- **10-40% of patients with syncope**
- **Triggering of a neural reflex**
- **Use of pacemakers is controversial since often bradycardia occurs after hypotension**

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## Miscellaneous

- **Hypertrophic Obstructive Cardiomyopathy**
- **Dilated cardiomyopathy**
- **Cardiac transplantation**
- **Termination and prevention of tachydysrhythmias**
- **Pacing in children and adolescents**

# Indications for ICDs

- **Cardiac arrest due to VT/VF not due to a transient or reversible cause**
- **Spontaneous sustained VT**
- **Syncope with hemodynamically significant sustained VT or VF**
- **NSVT with CAD, previous MI, LV dysfunction and inducible VF or VT not suppressed by a class 1 antidysrhythmic**

# Device Selection

- **Temporary pacing (invasive vs. noninvasive)**
- **Permanent pacemaker**
- **ICD**



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# Pacemaker Characteristics

- **Adaptive-rate pacemakers**
- **Single-pass lead Systems**
- **Programmable lead configuration**
- **Automatic Mode-Switching**
- **Unipolar vs. Bipolar electrode configuration**

# ICD selection

- **Antibradycardia pacing**
- **Antitachycardia pacing**
- **Synchronized or nonsynchronized shocks for dysrhythmias**
- **Many of the other options incorporated into pacemakers**

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# Approaches to Insertion

- a. IV approach (endocardial lead)**
- b. Subcostal approach (epicardial or myocardial lead)**
- c. Noninvasive transcutaneous pacing**  
**Alternative to emergency transvenous pacing**

# Mechanics

- ⊙ Provide the rhythm heart cannot produce
- ⊙ Either temporary or permanent
- ⊙ Consists of external or internal power source and a lead to carry the current to the heart muscle
- ⊙ Batteries provide the power source
- ⊙ Pacing lead is a coiled wire spring encased in silicone to insulate it from body fluids

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# Unipolar Pacemaker

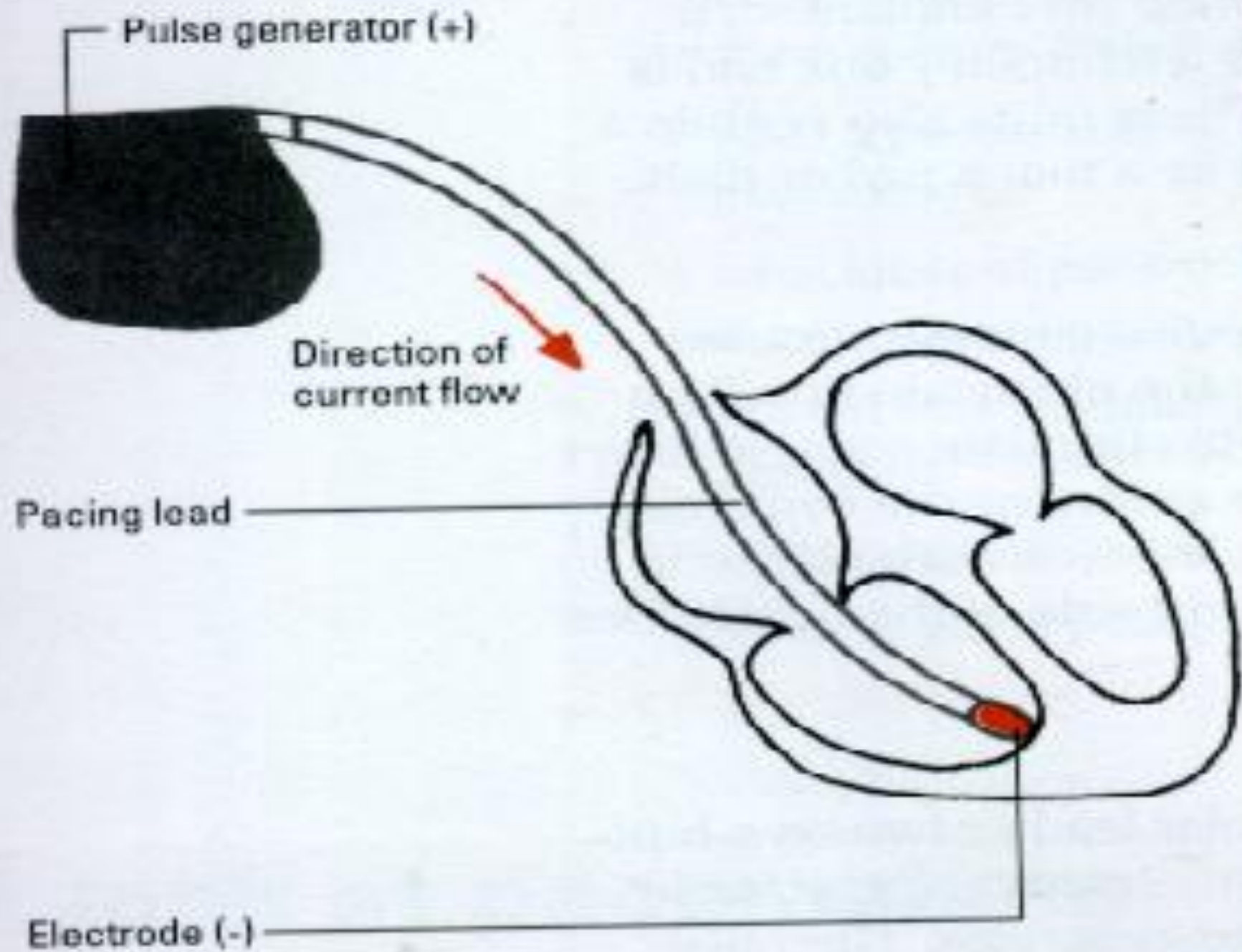
**Lead has only one electrode that contacts the heart at its tip (+) pole**

**The power source is the (-) pole**

**Patient serves as the grounding source**

**Patient's body fluids provide the return pathway for the electrical signal**

**Electromagnetic interference occurs more often in unipolar leads**



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# Bipolar Pacemaker

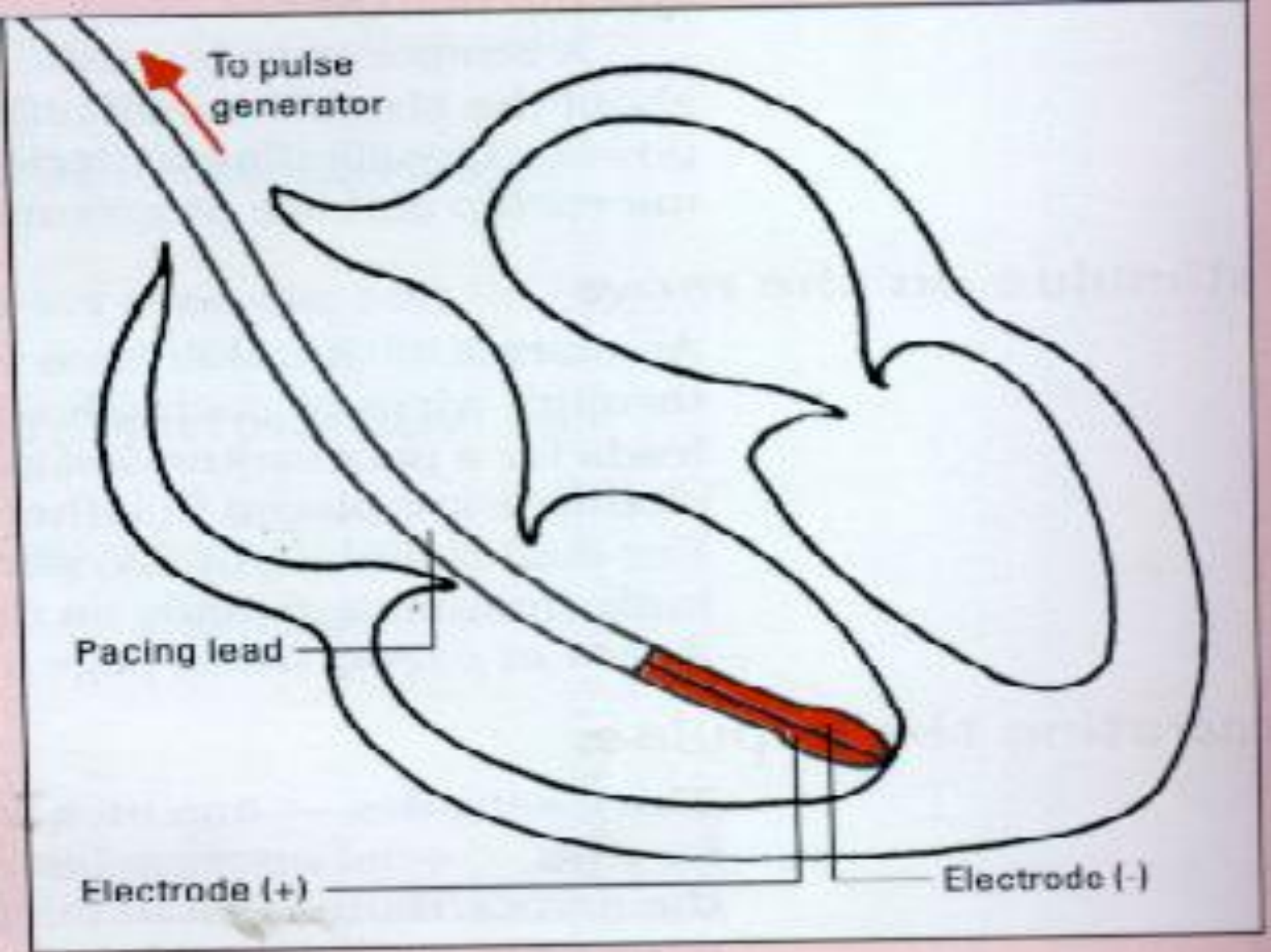
**If bipolar, there are two wires to the heart or one wire with two electrodes at its tip**

**Provides a built-in ground lead**

**Circuit is completed within the heart**

**Provides more contact with the endocardium; needs lower current to pace**

**Less chance for cautery interference**





# Indications

1. **Sick sinus syndrome (Tachy-brady syndrome)**
2. **Symptomatic bradycardia**
3. **Atrial fibrillation**
4. **Hypersensitive carotid sinus syndrome**
5. **Second-degree heart block/Mobitz II**

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# Indications

**6. Complete heart block**

**7. Sinus arrest/block**

**8. Tachyarrhythmias**

**Supraventricular, ventricular**

**To overdrive the arrhythmia**

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# Atrial Fibrillation

- \* A fibrillating atrium cannot be paced**
- \* Place a VVI**
- \* Patient has no atrial kick**

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# Types

1. **Asynchronous/Fixed Rate**
  2. **Synchronous/Demand**
  3. **Single/Dual Chamber**  
Sequential (A & V)
  4. **Programmable/nonprogrammable**
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# Asynchronous/Fixed Rate

- ⊙ Does not synchronize with intrinsic HR
- ⊙ Used safely in pts with no intrinsic ventricular activity
- ⊙ If pt has vent. activity, it may compete with pt's own conduction system
- ⊙ VT may result (R-on-T phenomenon)
- ⊙ EX: VOO, AOO, DOO

# **Synchronous/Demand**

**Contains two circuits**

- \* One forms impulses**
- \* One acts as a sensor**

**When activated by an R wave, sensing circuit either triggers or inhibits the pacing circuit**

**Called “Triggered” or “Inhibited” pacers**

**Most frequently used pacer**

**Eliminates competition;**

**Energy sparing**

# Examples of Demand Pacemakers

**DDI**

**VVI/VVT**

**AAI/AAT**

**Disadvantage: Pacemaker may be fooled by interference and may not fire**

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# **Dual Chamber: A-V Sequential**

**Facilitates a normal sequence between  
atrial and ventricular contraction**

**Provides atrial kick + ventricular pacing**

**Atrial contraction assures more complete  
ventricular filling than the ventricular  
demand pacing unit**

**Increase CO 25-35% over ventricular pacing  
alone**



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# A-V Sequential

**Disadvantage: More difficult to place**

**More expensive**

**Contraindication: Atrial fibrillation, SVT**

**Developed due to inadequacy of “pure atrial  
pacing”**

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# Single Chamber

**Atrial**

**Ventricular**

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# **“Pure Atrial Pacing”**

**Used when SA node is diseased or  
damaged but AV conduction system  
remains intact**

**Provides atrial kick**

**Atrial kick can add 15-30% to CO over a  
ventricular pacemaker**

**Electrode in atrium: stimulus produces a  
P wave**

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# Problems with Atrial Pacing

**Electrode difficult to secure in atrium**

**Tends to float**

**Inability to achieve consistent atrial  
“demand” function**

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# Ventricular Pacemakers

**If electrode is placed in right ventricle,  
stimulus produces a left BBB pattern**

**If electrode is placed in left ventricle,  
stimulus produces a right BBB pattern**

# **Programmability**

**Capacity to noninvasively alter one of several aspects of the function of a pacer**

**Desirable since pacer requirements for a person change over time**

**Most common programmed areas**

**Rate**

**Output**

**AV delay in dual chamber pacers**

**R wave sensitivity**

**Advantage: can overcome interference caused by electrocautery**

# 3-Letter or 5-Letter Code

- ◎ **Devised to simplify the naming of pacemaker generators**

# **First letter**

**Indicates the chamber being paced**

**A: Atrium**

**V: Ventricle**

**D: Dual (Both A and V)**

**O: None**



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# **Second Letter**

**Indicates the chamber being sensed**

**A: Atrium**

**V: Ventricle**

**D: Dual (Both A and V)**

**O: Asynchronous or does not apply**

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# Third Letter

**Indicates the generator's response to a sensed signal/R wave**

**I: Inhibited**

**T: Triggered**

**D: Dual (T & I)**

**O: Asynchronous/ does not apply**

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# Fourth Letter

## Indicates programming information

**O:** No programming

**P:** Programming only for output and/or rate

**M:** Multiprogrammable

**C:** Communicating

**R:** Rate modulation

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# **Fifth Letter**

**This letter indicates tachyarrhythmia functions**

**B: Bursts**

**N: Normal rate competition**

**S: Scanning**

**E: External**

**O: None**

**Table 4-4. Generic Code for Identification and Description of Pacemaker Function**

<b>First Letter</b>	<b>Second Letter</b>	<b>Third Letter</b>	<b>Fourth Letter</b>	<b>Fifth Letter</b>
Cardiac chamber paced	Cardiac chamber in which electrical activity is sensed	Response of generator to sensed R wave and P wave	Programmable functions of the generator	Antitachy- cardia functions of the generator
V—Ventricle	V—Ventricle	T—Triggering	P—Program- mable (rate and/or output only)	B—Bursts
A—Atrium	A—Atrium	I—Inhibited	M—Multipro- grammable	N—Normal rate com- petition <sup>a</sup>
D—Dual (atrium and ventricle)	D—Dual	D—Dual	C—Communi- cating <sup>b</sup>	S—Scanning
	O—None (asynchro- nous)	O—None (asynchro- nous)	O—None (fixed function)	E—External

<sup>a</sup> Stimuli delivered at normal rate

# Letter Number <sup>a</sup> Types of Pulse Generators

I	II	III	Description
A	O	O	Asynchronous (fixed rate) atrial pacing
V	O	O	Asynchronous (fixed rate) ventricular pacing
A	A	I	Noncompetitive (demand) atrial pacing, electrical output inhibited by intrinsic atrial depolarization (P wave)
V	V	I	Noncompetitive (demand) ventricular pacing, electrical output inhibited by intrinsic ventricular depolarization (R wave)
A	A	T	Triggered atrial pacing, electrical output triggered by intrinsic atrial depolarization (P wave)
V	V	T	Triggered ventricular pacing, electrical output triggered by intrinsic ventricular depolarization (R wave)
D	V	I	Paces (sequential) in atrium and ventricle, does not sense P waves, does sense R waves
D	D	D	Paces and senses in atrium and ventricle
V	D	D	Paces in ventricle, senses in atrium and ventricle, synchronized with atrial activity and paces ventricle after a preset atrioventricular interval

# Examples

## **AOO**

**A: Atrium is paced**

**O: No chamber is sensed**

**O: Asynchronous/does not apply**

## **VOO**

**V: Ventricle is paced**

**O: No chamber is sensed**

**O: Asynchronous/does not apply**

# Examples

## VVI

**V: Ventricle is the paced chamber**

**V: Ventricle is the sensed chamber**

**I: Inhibited response to a sensed signal**

**Thus, a synchronous generator that paces  
and senses in the ventricle**

**Inhibited if a sinus or escape beat occurs**

**Called a “demand” pacer**



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# Examples

## DVI

**D: Both atrium and ventricle are paced**

**V: Ventricle is sensed**

**I: Response is inhibited to a sensed ventricular signal**

**For A-V sequential pacing in which atria and ventricles are paced. If a ventricular signal, generator won't fire**

**Overridden by intrinsic HR if faster**

# Examples

## **DDD**

**Greatest flexibility in programming**

**Best approximates normal cardiac response to exercise**

## **DOO**

**Most apparent potential for serious ventricular arrhythmias**

## **VAT**

**Ventricular paced, atrial sensed**

**Should have an atrial refractory period programmed in to prevent risk of arrhythmias induced by PACs from ectopic or retrograde conduction**

**AV interval is usually 150-250 milliseconds**

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# Other Information

**Demand pacer can be momentarily converted to asynchronous mode by placing magnet externally over pulse generator in some pacers**

**Dual chamber pacers preferable for almost all patients except those with chronic atrial fibrillation (need a working conduction system)**

**Asynchronous pacer modes not generally used outside the OR**

**OR has multiple potential sources of electrical interference which may prevent normal function of demand pacers**

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# Other Information

**VVI: Standard ventricular demand pacemaker**

**DVI: AV pacemaker with two pacing electrodes**

**Demand pacer may be overridden by intrinsic HR if more rapid**

**Demand pacer can be momentarily converted to asynchronous mode by placing magnet externally over pulse generator**

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# Sensing

**Ability of device to detect intrinsic cardiac activity**

**Undersensing: failure to sense**

**Oversensing: too sensitive to activity**

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# **Undersensing: Failure to sense**

**Pacer fails to detect an intrinsic rhythm**

**Paces unnecessarily**

**Patient may feel “extra beats”**

**If an unneeded pacer spike falls in the latter portion of T wave, dangerous tachyarrhythmias or V fib may occur (R on T)**

**TX: Increase sensitivity of pacer**

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# Oversensing

**Pacer interprets noncardiac electrical signals as originating in the heart**

**Detects extraneous signals such as those produced by electrical equipment or the activity of skeletal muscles (tensing, flexing of chest muscles, SUX)**

**Inhibits itself from pacing as it would a true heart beat**

# Oversensing

**On ECG: pauses longer than the normal pacing interval are present**

**Often, electrical artifact is seen**

**Deprived of pacing, the patient suffers ↓  
CO, feels dizzy/light-headed**

**Most often due to sensitivity being  
programmed too high**

**TX: Reduce sensitivity**



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# Capture

**Depolarization of atria and/or ventricles in response to a pacing stimulus**

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# **Noncapture/Failure to Capture**

**Pacer's electrical stimulus (pacing) fails to depolarize (capture) the heart**

**There is no “failure to pace”**

**Pacing is simply unsuccessful at stimulating a contraction**

**ECG shows pacer spikes but no cardiac response**

**↓ CO occurs**

**TX: ↑ threshold/output strength or duration**

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# Pacer Failure

## A. Early

electrode displacement/breakage

## B. Failure > 6 months

Premature battery depletion

Faulty pulse generator

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# Pacer Malfunctions per ECG

- ◎ Failure to capture
- ◎ Failure to sense
- ◎ Runaway pacemaker

# Pacer Malfunction SX

1. Vertigo/Syncope
  - \*Worsens with exercise
2. Unusual fatigue
3. Low B/P/ ↓ peripheral pulses
4. Cyanosis
5. Jugular vein distention
6. Oliguria
7. Dyspnea/Orthopnea
8. Altered mental status

# EKG Evaluation

**Capture: Should be 1:1**

**(spike:EKG complex/pulse)**

**\*Not helpful if patient's HR is >  
pacer rate if synchronous type**

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# EKG Evaluation

## **Proper function of demand pacer**

**Confirmed by seeing captured beats on EKG  
when pacer is converted to asynchronous  
mode**

**Place external converter magnet over generator**

**Do not use magnet unless recommended**

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# CAPTURE

**Output: amt of current (mAmps) needed to get an impulse**

**Sensitivity: (millivolts); the lower the setting, the more sensitive**



# **Anesthesia for Insertion**

## **MAC**

**To provide comfort**

**To control dysrhythmias**

**To check for proper function/capture**

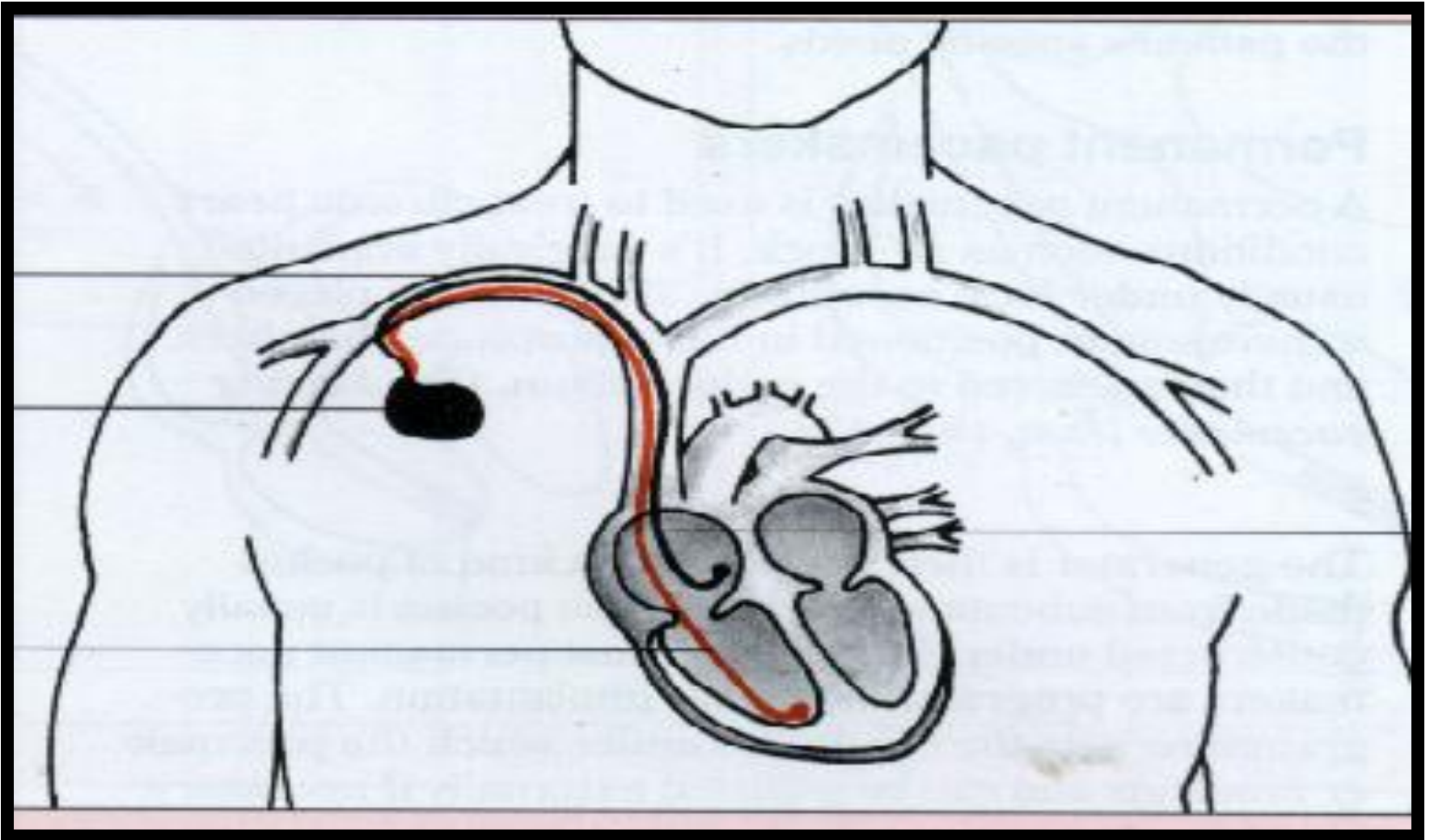
**Have external pacer/Isuprel/Atropine  
ready**

**Continuous ECG and peripheral pulse**

**Pulse ox with plethysmography to see  
perfusion of each complex**

**(EKG may become unreadable)**

# Pacemaker Insertion



# Interference

## **Things which may modify pacer function:**

**Sympathomimetic amines may increase myocardial irritability**

**Quinidine/Procainamide toxicity may cause failure of cardiac capture**

**↑ K<sup>+</sup>, advanced ht disease, or fibrosis around electrode may cause failure of cardiac capture**

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# **Anesthesia for Pt with Pacemaker**

- a. Continuous ECG and peripheral pulse**
- b. Pulse ox with plethysmography to see perfusion of each complex  
(EKG may become unreadable)**
- c. Defibrillator/crash cart available**
- d. External pacer available**
- e. External converter magnet available**

# **Anesthesia for Pt with Pacemaker**

**If using Succinylcholine, consider defasciculating dose of MR**

**Fasciculations may inhibit firing due to the skeletal muscle contractions picked up by generator as intrinsic R waves**

**Place ground pad far from generator but close to cautery tip**

**Cover pad well with conductive gel**

**Minimizes detection of cautery current by pulse generator**

**If patient has a transvenous pacemaker, increased risk of V. fib from microshock levels of electrical current**

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# **Anesthesia for Pt with Pacemaker**

**Cautery may interfere with pacer:**

**May inhibit triggering (pacer may sense electrical activity and not fire)**

**May inadvertently reprogram**

**May induce arrhythmias secondary to current**

**May cause fixed-rate pacing**

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# **Automatic Implantable Cardiac Defibrillators**

**Figure 1 The Ventak P AICD**

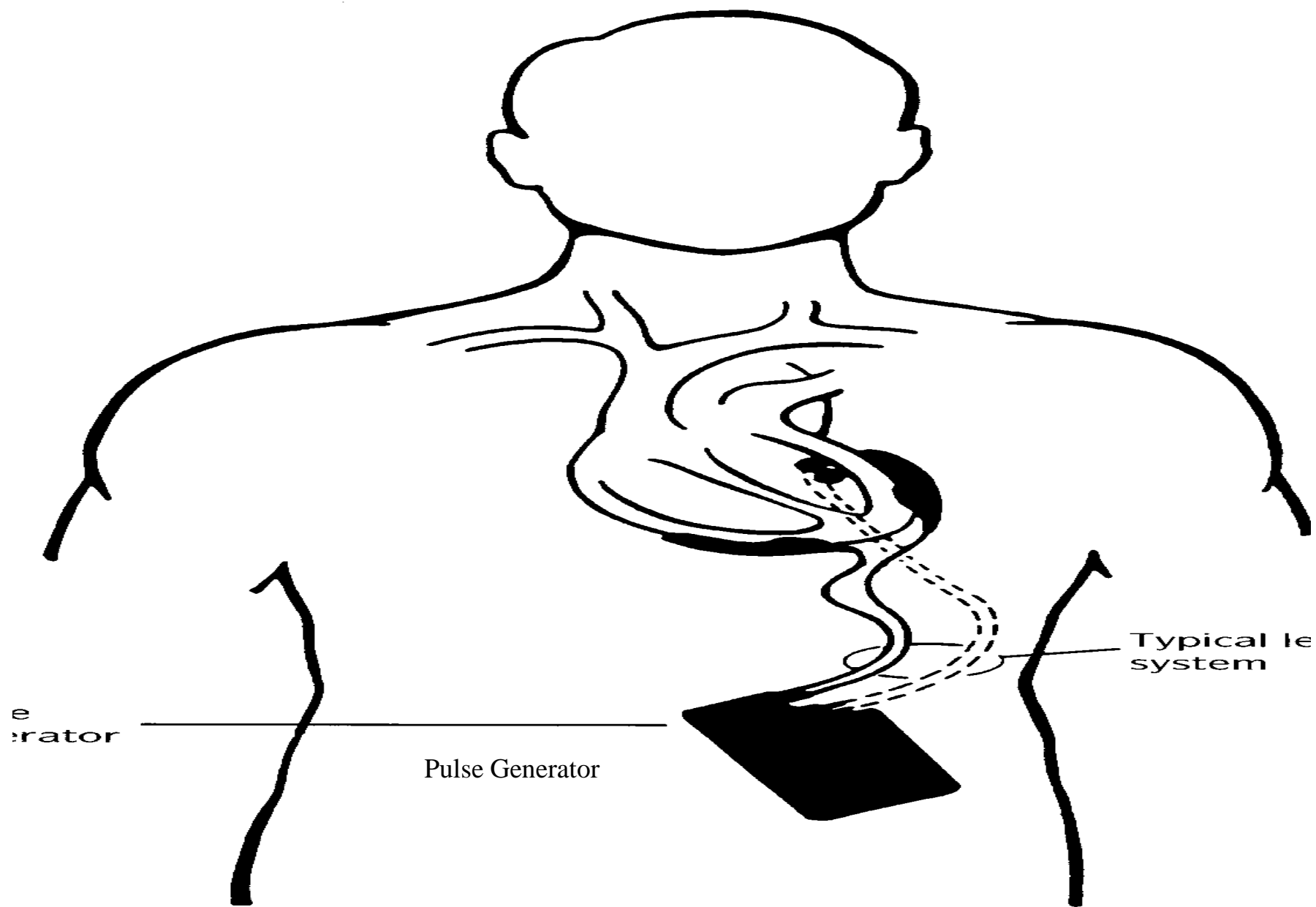




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# Parts of AICD

- **Pulse generator with batteries and capacitors**
- **Electrode or lead system**  
Surgically placed in or on pericardium/myocardium
- **Monitors HR and rhythm**
- **Delivers shock if VT or Vfib**



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# AICD Indications

- Risk for sudden cardiac death caused by tachyarrhythmias (VT, Vfib)
- Reduces death from 40% to 2% per year

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# Defibrillator Codes

## First letter: Shock Chamber

**A:** atrium

**V:** ventricle

**D:** dual

**O:** none

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# Defibrillator Codes

## **Second letter: Antitachycardia Chamber**

**A: atrium**

**V: ventricle**

**D: dual**

**O: none**

## **Third letter: Tachycardia Detection**

**E: EKG**

**H: Hemodynamics**

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# Defibrillator Codes

## **Fourth letter: Antibradycardia Pacing Chamber**

**A: atrium**

**V: ventricle**

**D: dual**

**O: none**

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# Settings

**Gives a shock at 0.1-30 joules**

**Usually 25 joules**

**Takes 5-20 seconds to sense VT/VF**

**Takes 5-15 seconds more to charge**

**2.5-10 second delay before next shock is administered**

**Total of 5 shocks, then pauses**

**If patient is touched, may feel a buzz or tingle**

**If CPR is needed, wear rubber gloves for insulation**

# Tiered Therapy

**Ability of an implanted cardioverter  
defibrillator to deliver different types of  
therapies in an attempt to terminate  
ventricular tachyarrhythmias**

**EX of therapies:**

**Anticardiac pacing**

**Cardioversion**

**Defibrillation**

**Antibradycardia pacing**



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# **Anesthesia**

## **MAC vs General**

**Usually general due to induction of VT/VF so  
AICD can be checked for performance**

**Lead is placed in heart**

**Generator is placed in hip area or in upper  
chest**

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# VADs

**Ventricular assist devices**

**Implantable pumps used for circulatory support in pts with CHF**

**Blood fills device through a cannulation site in V or A**

**Diaphragm pumps blood into aorta or PA**

**Set at predetermined rate (fixed) or automatic (rate changes in response to venous return)**

# **Electromagnetic Interference on Pacers and AICDs**

## **Electrocautery**

**May inhibit or trigger output**

**May revert it to asynchronous mode**

**May reprogram inappropriately**

**May induce Afib or Vfib**

**May burn at lead-tissue interface**

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# **Electromagnetic Interference on Pacers and AICDs**

## **Defibrillation**

**May cause permanent damage to pulse generator**

**May burn at lead-tissue interface**

## **Radiation Therapy**

**May damage metal oxide silicon circuitry**

**May reprogram inappropriately**

# **Electromagnetic Interference on Pacers and AICDs**

## **PET/CT (Contraindicated)**

**May damage metal oxide silicon circuitry**

**May reprogram inappropriately**

## **MRI (Contraindicated)**

**May physically move pulse generator**

**May reprogram inappropriately**

**May give inappropriate shock to pt with AICD**

## **PNSs**

**May cause inappropriate shock or inhibition**

**Test at highest output setting**

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# Deactivating a Pacemaker

**Deactivate to prevent inappropriate firing or inhibition**

**Can be deactivated by a special programmer/wand or by a magnet placed over generator for 30 seconds**

**Put in asynchronous mode or place external pacer on patient**

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# If Pt has a Pacemaker/AICD

**Not all models from a certain company  
behave the same way with magnet  
placement !**

***For all generators, call manufacturer  
Most reliable method for determining magnet  
response !!***

# **Coding Patient**

**If patient codes, do not wait for AICD to work**

**Start CPR & defibrillate immediately**

**Person giving CPR may feel slight buzz**

**A 30-joule shock is  $< 2$  j on pt's skin**

**External defibrillation will not harm AICD**

**Change paddle placement if unsuccessful attempt**

**Try A-P paddle placement if A-Lat unsuccessful**



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# **Pts with Pacemakers/AICDs/VADs**

**Obtain information from patient regarding device**

**Ask how often patient is shocked/day**

**High or low K<sup>+</sup> may render endothelial cells more or less refractory to pacing**

**A properly capturing pacemaker should also be confirmed by watching the EKG and palpating the patient's pulse**

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# Anesthetic Considerations

**Avoid Succinylcholine**

**Keep PNS as far from generator as possible**

**Have backup plan for device failure**

**Have method other than EKG for assessing  
circulation**

**Have magnet available in OR**

# **Electrocautery Use**

**Place grounding pad as far from generator as possible**

**Place grounding pad as near to surgical field as possible**

**Use bipolar electrocautery if possible**

**Have surgeon use short bursts of electrocautery**

**(<1 sec, 5-10 seconds apart)**

**Maintain lowest possible current**

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# Electrocautery Use

**If cautery causes asystole, place magnet  
over control unit & change from  
inhibited to fixed mode**

**Change back afterwards**

**Be alert for R on T phenomenon**

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# Postoperative Considerations

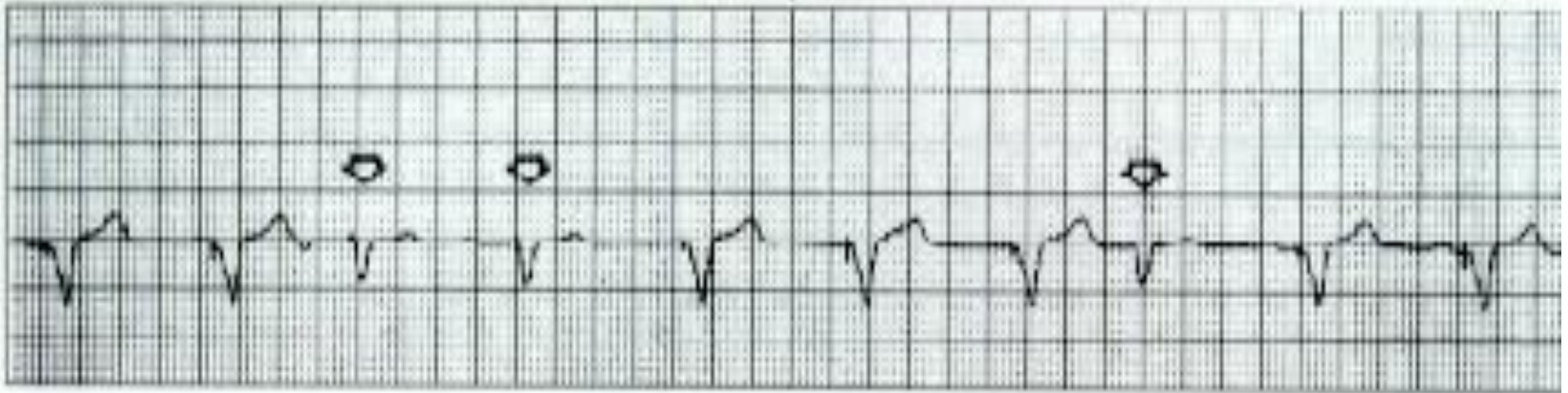
**Avoid shivering**

**Have device checked and reprogrammed if  
questions arise about its function**

# Examples of Rhythms

## Sensing

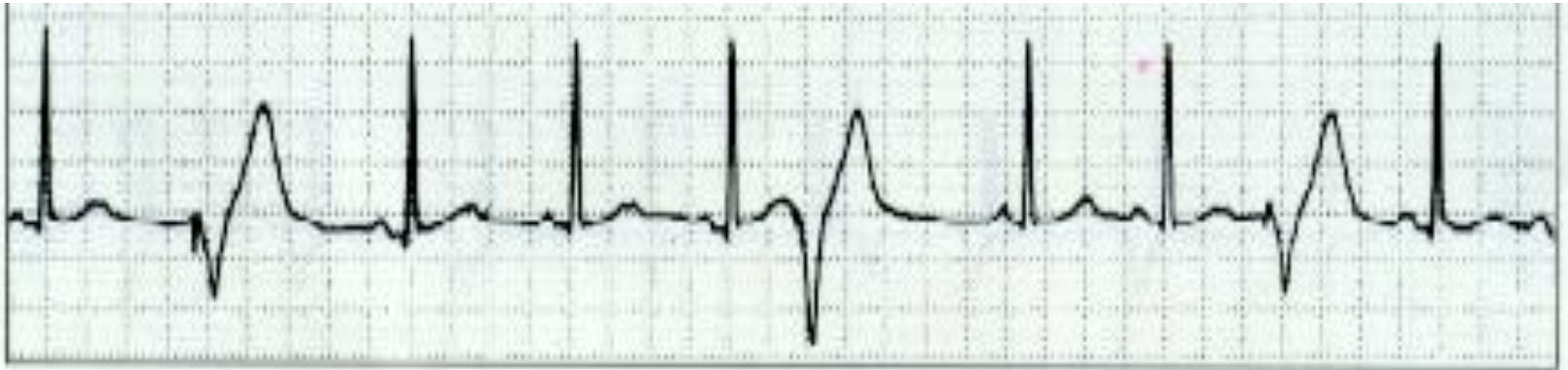
Patient's own beat is sensed by pacemaker so does not fire



# Examples of Rhythms

## Undersensing

**Pacemaker doesn't sense patient's own beat and fires (second last beat)**



# Examples of Rhythms

## Oversensing

**Pacemaker senses heart beat even though it isn't beating.  
Note the long pauses.**

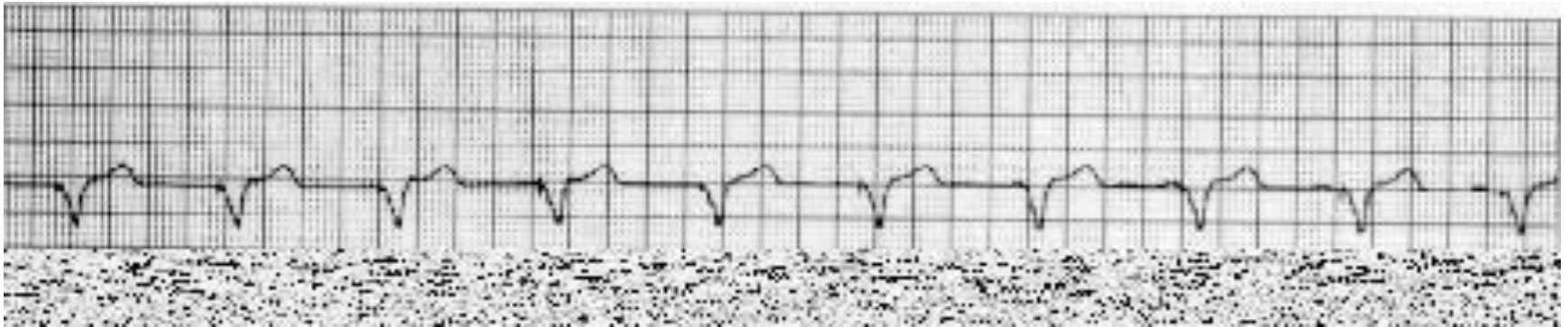




# Examples of Rhythms

## Capture

**Pacemaker output (spike) is followed by ventricular polarization (wide QRS).**

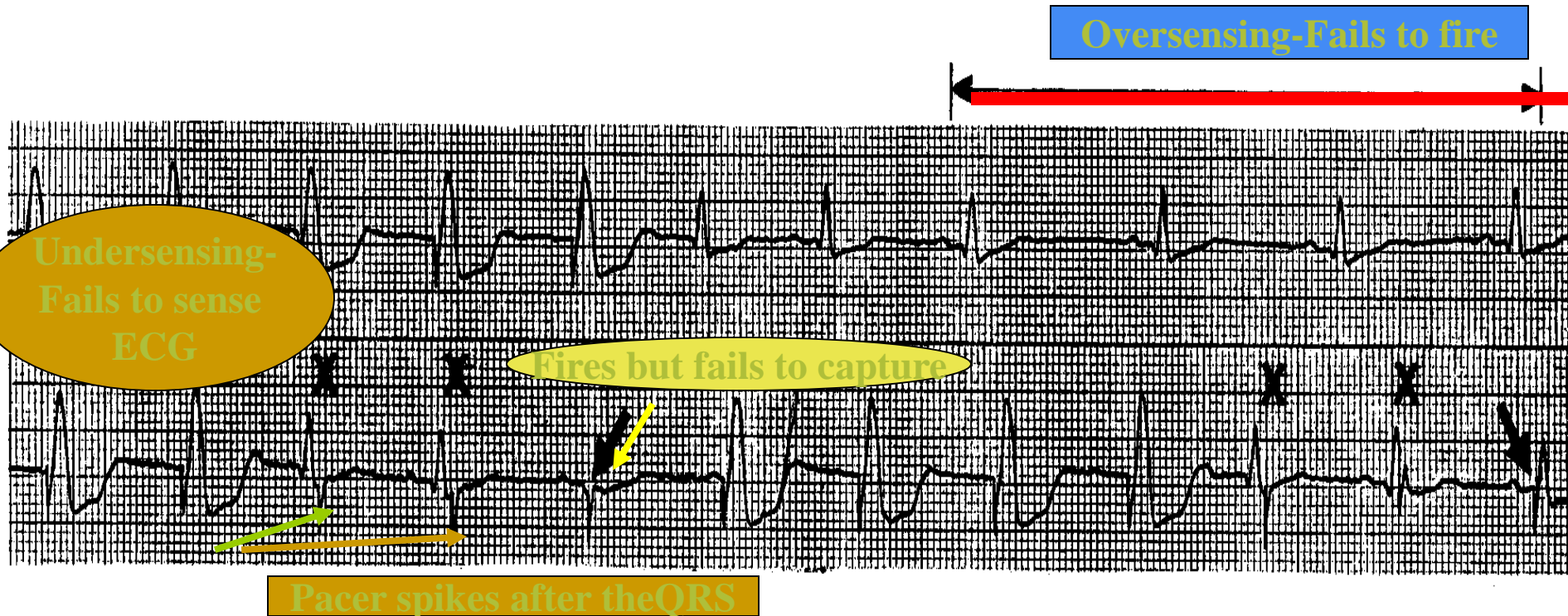


# Examples of Rhythms

## Noncapture

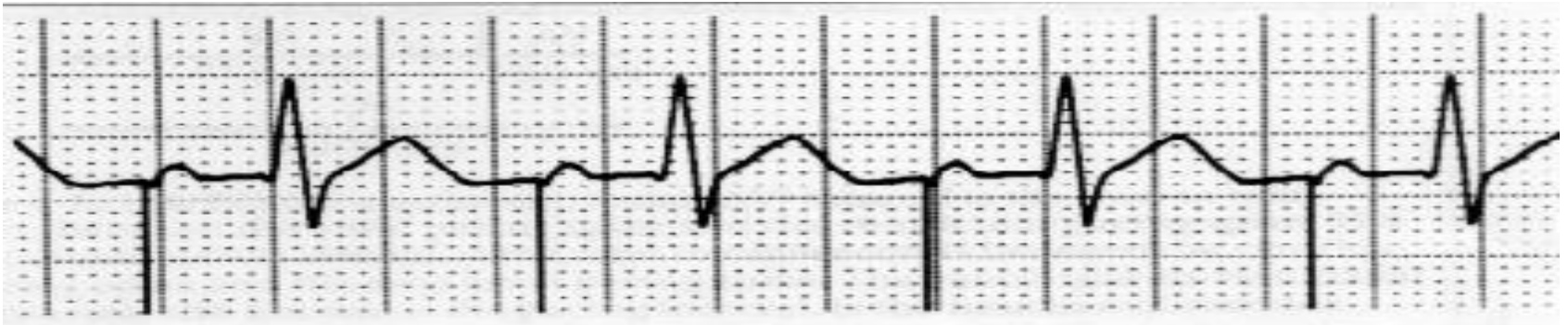
Pacer stimulus fails to cause myocardial depolarization

Pacer spike is present but no ECG waveform



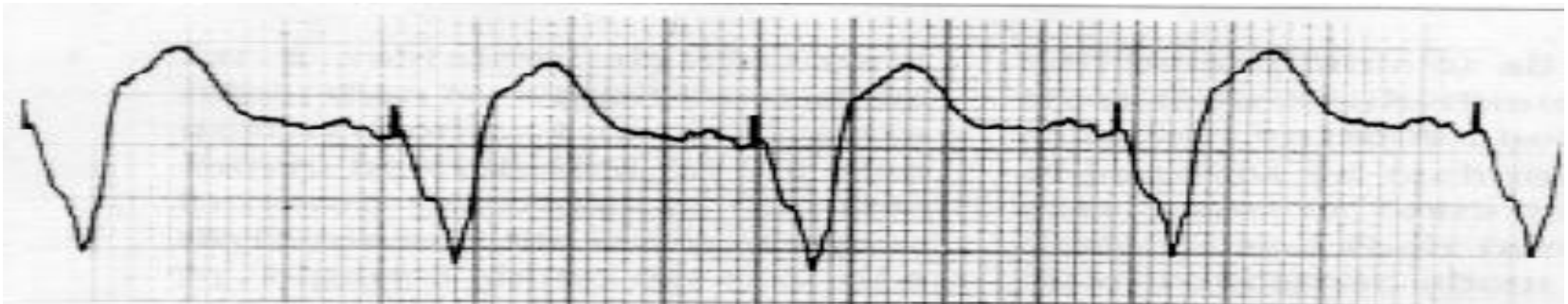
# Examples of Rhythms

**100 % Atrial Paced Rhythm with 100% Capture**



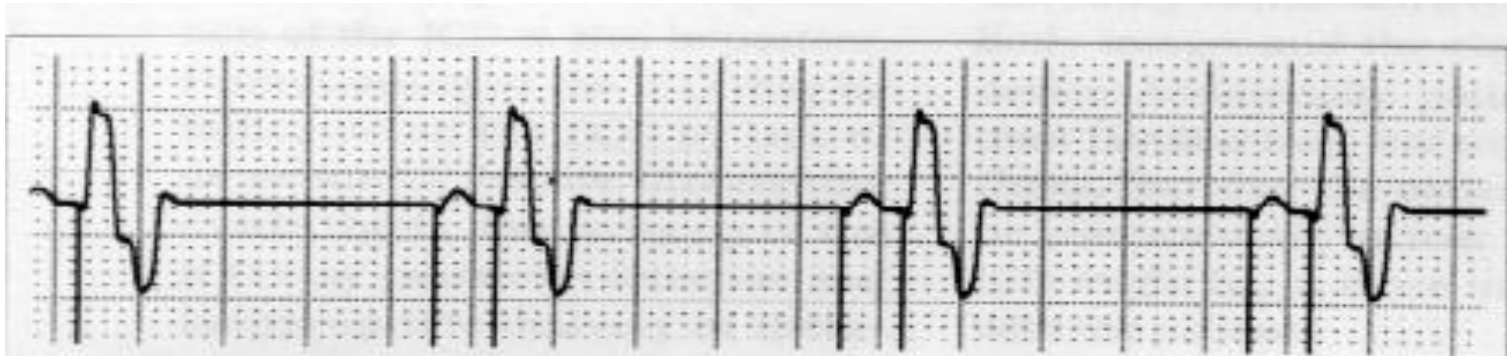
# Examples of Rhythms

## 100% Ventricular Paced Rhythm with 100% Capture



# Examples of Rhythms

**100% Atrial and 100% Ventricular Paced Rhythm  
with 100% Capture**



# Examples of Rhythms

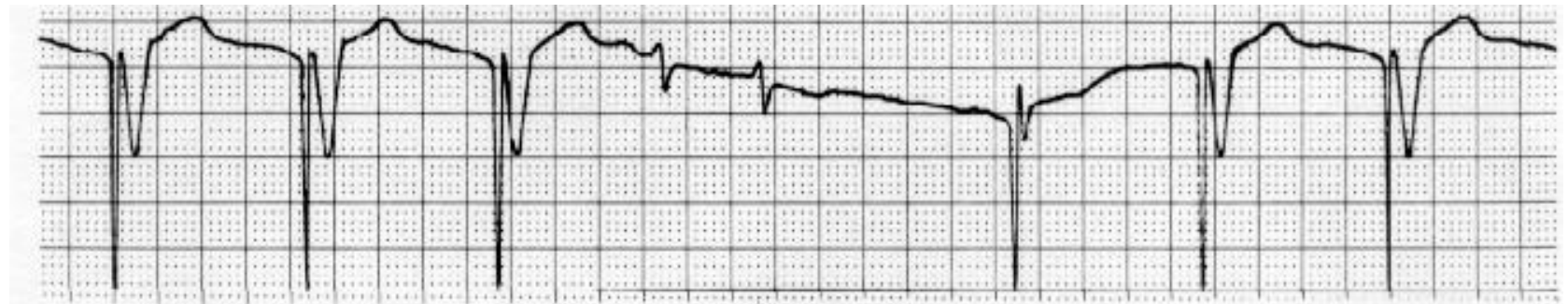
## 50% Ventricular Paced Rhythm with 100% Capture





# Examples of Rhythms

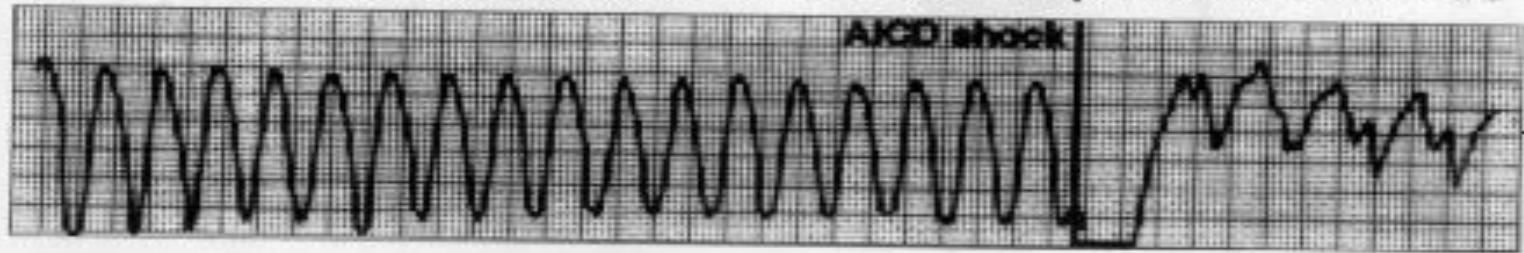
**25% Ventricular Paced Rhythm with 100% Capture  
(Note the sensing that occurs. Pacer senses  
intrinsic HR and doesn't fire).**



# Examples of Rhythms

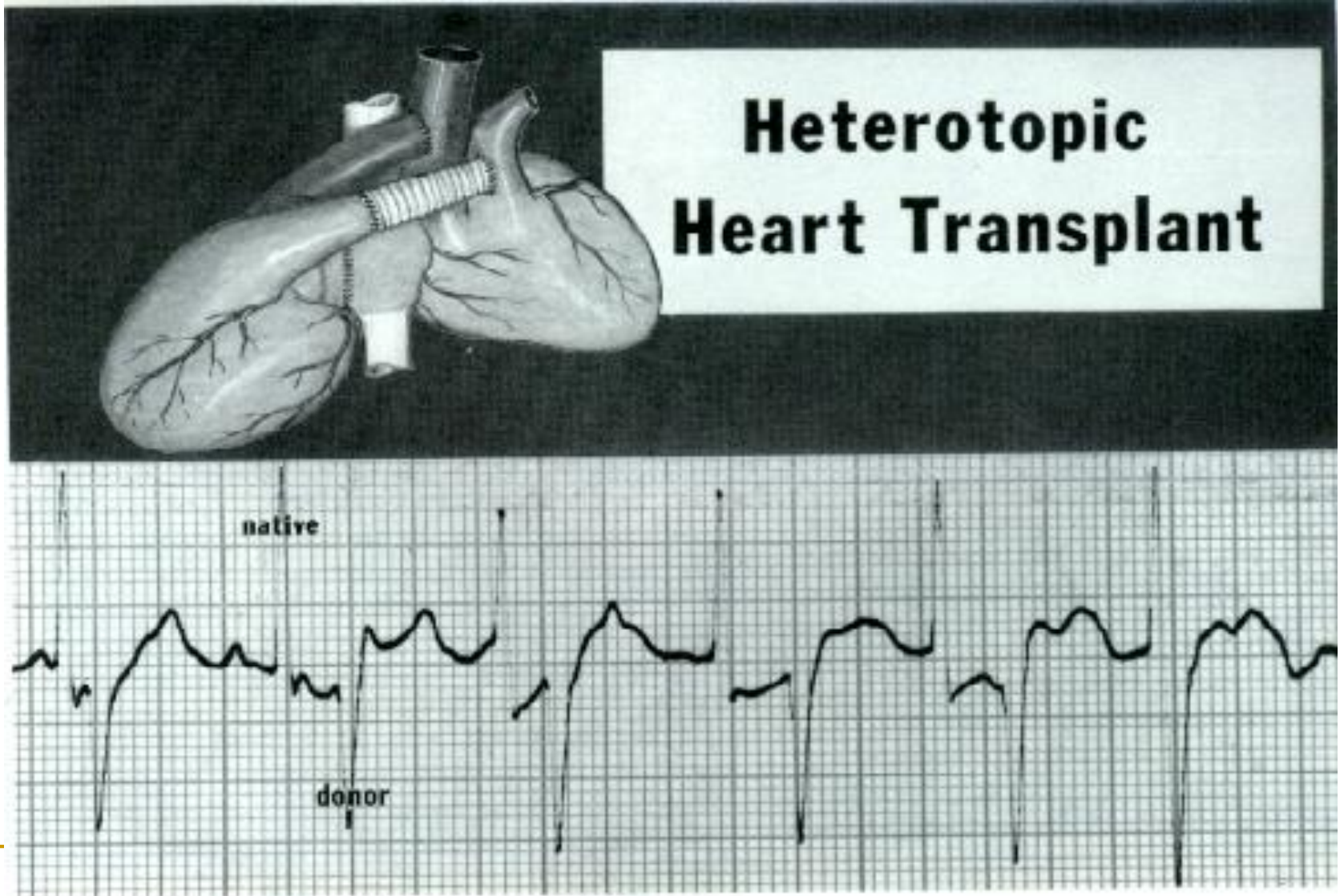
## AICD Shock of VT Converted to NSR

**Figure 2** Example of AICD conversion of ventricular tachycardia on surface ECG





# Examples of Rhythms



# Examples of Rhythms



## Heart Transplant

$P_n$  - native P wave

$P_d$  - donor P wave



# Examples of Rhythms

## DDD Pacemaker





# References

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