

Keeping the Beat: Pacemaker Essentials

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1

Objectives



List three types of emergent/temporary pacing options.



Discuss principles of pacemaker function, including common modes, indications, and key components.



Analyze normal and abnormal pacemaker rhythms on cardiac monitoring.



Identify and troubleshoot common pacemaker malfunctions.

2

Conduction Pathways

1) Sinoatrial (SA) Node:
"The Pacemaker"
~ 60 - 100 bpm. Influenced by the sympathetic and parasympathetic nervous system.

2) Atrioventricular (AV) Junction:
~ 40 - 60 bpm. The AV node receives an impulse from the SA node and slows it down creating a delay before the impulse is carried to the ventricles. If the SA node is not functioning properly, the AV node takes over.

3) Bundle of His:
Receives impulse from AV node and accelerates the impulse from the atria to the bundle branches in the ventricles.

4) Left and Right Bundle Branches:
Receives impulse from Bundle of His. Carries electrical impulses at high speeds to the ventricles simultaneously

5) Purkinje Fibers:
~ 20 - 40 bpm. Rapidly transmits impulse through the endocardial surface of the left and right ventricle.

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3

Conduction Pathways

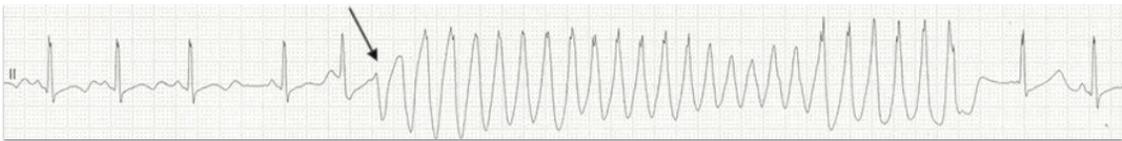
ECG	Normal measurements and
P wave	• Represents atrial depolarization
PR Interval	• Represents the time it takes for an electrical impulse to be conducted from the atria through the AV node
QRS Complex	• Represents ventricular depolarization
QT Interval	• Represents the time between ventricular depolarization & repolarization
T Wave	• Represents ventricular repolarization
ST Segment	• Normally flat relative to the isoelectrical baseline

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The Cardiac Cycle

- **Electrical impulse** → **mechanical response** → **pressure waveform**
- **Depolarization:** Cardiac tissue activation
- **Repolarization:** Cardiac tissue recovery
- **Refractory period:**
 - **Absolute:** No amount of stimulus will result in a response
 - **Relative:** A Strong impulse will result in a response
 - Risk of R on T!



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Pacemaker Indications

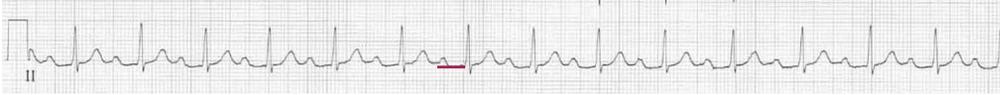
- **Symptomatic bradycardia**
 - **Sinus node dysfunction**
 - Sinus bradycardia
 - Sinus arrest/pause
 - Chronotropic incompetence
 - **Alternating BBB**
 - **Anti-tachycardia pacing**
 - **AV blocks**
 - 2nd & 3rd Degree
 - **Acute phase of MI**
 - **Neurocardiogenic syncope**
 - **Post-Cardiac Surgery / Ablation**
 - **Cardiac resynchronization therapy (CRT)**
- **Failure of SA node to generate impulses**
 - **Failure to transmit impulse**
 - **Failure to maintain CO resulting in symptoms**
 - Dizziness
 - Presyncope / syncope
 - Shock
 - Hypotension
 - Altered LOC
 - Chest pain

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Atrioventricular Blocks

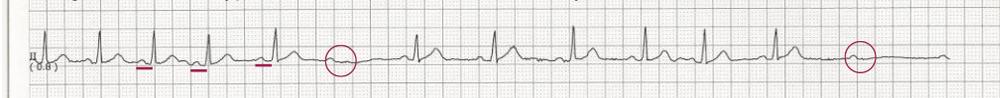
1st degree AV block: PR interval > 0.20



2nd degree AV block Type 1 (Wenckebach) : Progressively longer PR interval until a “dropped” QRS complex



2nd degree AV block Type 2: Some P waves not followed by a QRS



3rd degree AV Block: No consistent relationship between P waves and QRS complex



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Atrioventricular Blocks

- **Causes:** Acute MI, injury to the conduction system (cardiac surgery, ablation, tumors), electrolyte disturbances (K^+ , Mg^{++}), cardioactive drugs (CCB, BB, Digoxin, antiarrhythmics)
- **Management:**
 - **1st Degree:** Monitor for asymptomatic
 - **2nd Degree Type 1:** Symptomatic → Atropine, pacing
 - **2nd Degree Type 2:** Emergent pacing (TCP→TVP), *dopamine, epinephrine*
 - **3rd Degree:** Emergent pacing(TCP→TVP), *dopamine, epinephrine*

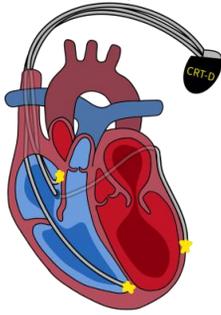
- If the **Qs** are far from **P**, then you have a **First Degree**.
- **Longer, longer, longer drop**, then you have a **Wenckebach**.
- If **some Ps** don't get through, prepare to **pace that Type 2**.
- If the **Ps** and **Qs** don't agree, prepare to **pace that Third Degree**.

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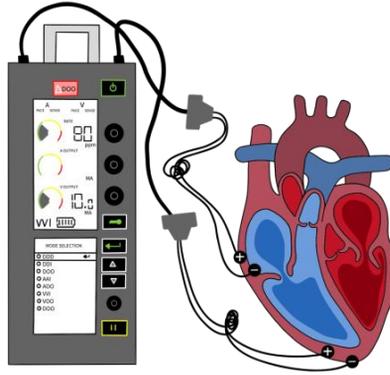
8

Pacemaker Components

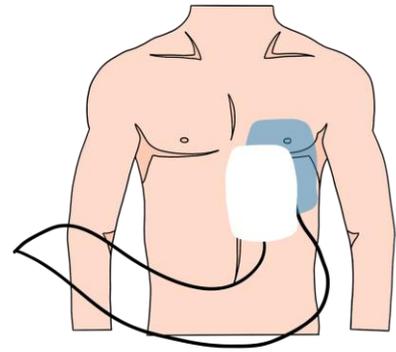
- Pulse generator, battery, leads/wires, electrodes



Implantable pulse generator



Pulse generator

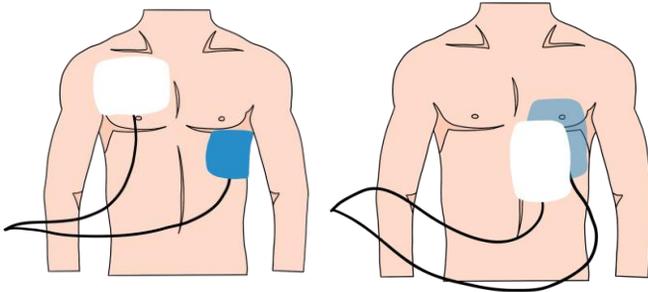


Defibrillator - monitor with pacing

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Types of Pacing: Transcutaneous



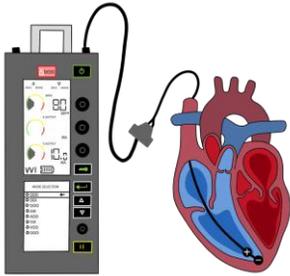
- Increase mA 10 over the initial "capture"
- Ventricular demand pacing
- Assess for mechanical capture

- Prep skin well before applying: clean, dry, and clipped of hair.
- Consider sedation/analgesia.
- Very temporary - be thinking: What is next?

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Types of Pacing: Transvenous



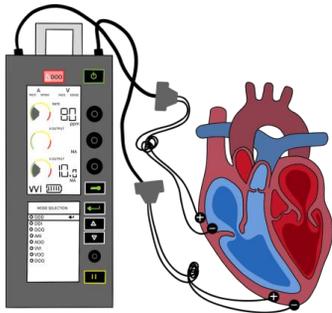
- Invasive method of *temporary* pacing.
- Ventricular demand pacing
- Inserted either at bedside, Cath lab/ Operating room

- Know the CM marking!!!
- When in doubt → transcutaneous & obtain an XRAY
- Ventricular demand pacing
- Assess for mechanical capture

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Types of Pacing: Epicardial



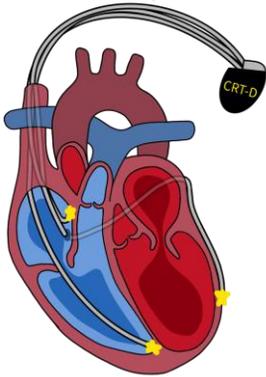
- Insulate wires when not in use
- Be aware of dislodgement and risk of cardiac tamponade!
- Site care

- Cardiac surgery
- Ventricular exist on the left, atria exist on the right
- DDD, AAI, VVI

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Types of Pacing: Permanent



- **Single chamber, dual chamber**
- **Cardiac resynchronization therapy (CRT)**

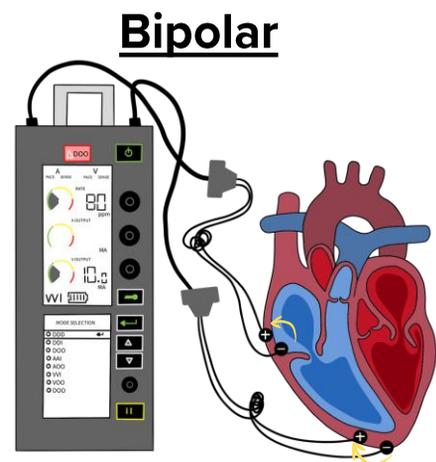
- Know the company
- Interrogation of the pacer if there issues
- Transcutaneous pads away from PPM

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Bipolar vs Unipolar

- **Cathode (-) & anode (+)**
 - Pulse generator → down cathode
→ myocardium → anode
- **Bipolar:** Two electrodes located within the heart
 - 2 Ventricular, 2 Atrial
- **Unipolar:** One electrode with direct contact
 - Ground lead in SQ tissue
 - ex. 1 Ventricular wire, 1 ground



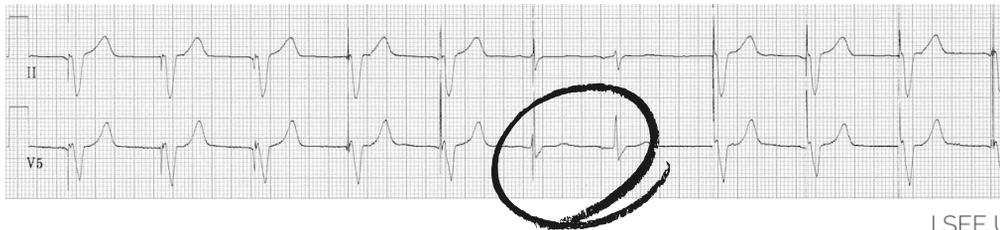
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VVI

I	II	III
Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing
V = Ventricle	V = Ventricle	I = Inhibits

- **AKA ventricular demand**
- **Pace & sense ventricles**
- **Inhibit pacing if the intrinsic activity above setting is sensed**
- Atrial arrhythmias



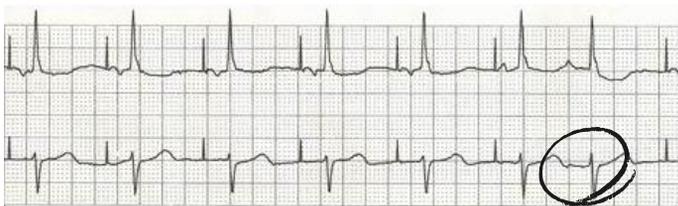
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AAI

I	II	III
Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing
A = Atria	A = Atria	I = Inhibits

- **AKA atrial demand**
- **Pace & sense atria**
- **Inhibit pacing if the intrinsic activity above setting is sensed**
- Sinus node dysfunction
 - Conduction pathway intact



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18

Asynchronous Pacing: AOO, VOO, DOO

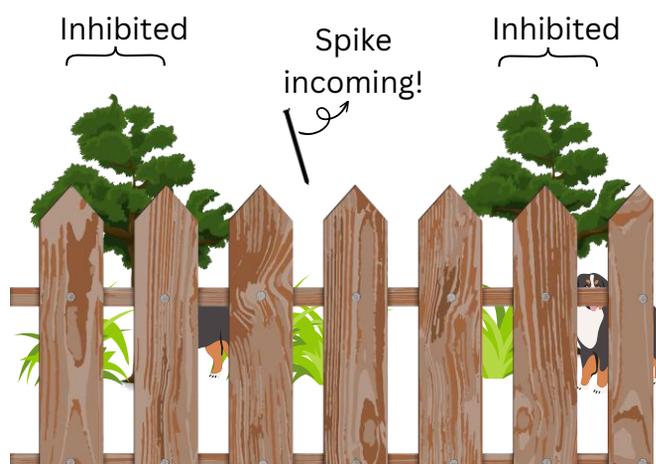
I	II	III
Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing
<ul style="list-style-type: none"> • A = Atrium • V = Ventricle • D = Dual 	O = Off "asynchronous"	O = Off "asynchronous"

- **DOO: Emergencies or immediate off-pump**
- **R-on-T phenomenon!**
- **Magnet placed over PPM → switches pacemaker to asynchronous pacing**

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Sensitivity



VVI setting. Trees = QRS, Bush = P wave, Dog = T wave

Expected "normal" sensitivity

Just right for VVI - can see intrinsic QRS complexes. Stimulus will be inhibited (not attempt to pace) if it SEEs an intrinsic beat. Will throw a spike (deliver a stimulus) if a tree is missing.

- **0.4-10mV** for the atria
- **0.8-20mV** for the ventricle

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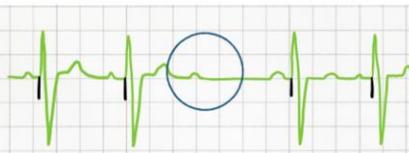
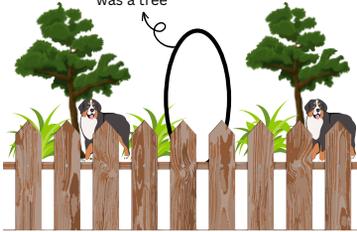
20

Sensitivity

Oversensing = under-pacing

Fence too low. Seeing inappropriate things (artifact, T wave, or P wave) and thus not attempting to pace if a tree is missing!

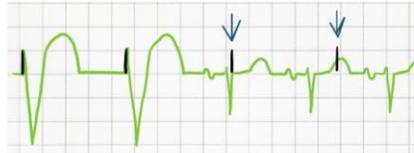
Tree missing, but no spike because it thought the bush was a tree



Undersensing = over-pacing

Fence too high. Not seeing an intrinsic/native beat. Throwing spikes randomly because it isn't sensing anything.

Spikes regardless of what is there

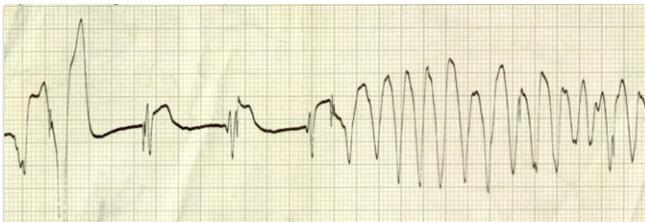


- Improper position of the lead
- Incorrect sensitivity settings

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21

Sensitivity Threshold



- DO NOT TEST if patient is pacer dependent

1. Set the heart rate 10 beats/min below the patient's intrinsic rate.
2. Reduce the output to 0.1 mA to prevent competitive pacing.
3. Increase the millivoltage (decrease sensitivity) until the sense indicator stops flashing and the pace indicator starts flashing.
4. Slowly decrease the millivoltage (increase sensitivity) until the sense indicator flashes continuously. This value is the sensing threshold.
5. Set the millivoltage at half the sensitivity threshold value.
6. Reset pacer to prescribed rate

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22

Capture

Failure to Capture



Troubleshooting: ↑ mA, check connections, assess pH, address electrolytes, assess for ischemia or drug toxicity.

Possible Causes:

- Electrode lead/wire dislodgement or misplacement
- Improper position of pacing pads
- Output set too low (mA)
- Electrolyte imbalances
- Battery failure
- Increased pacing threshold due to medications
- Loose connections
- Fibrosis at the catheter tip (TVP & epicardial)

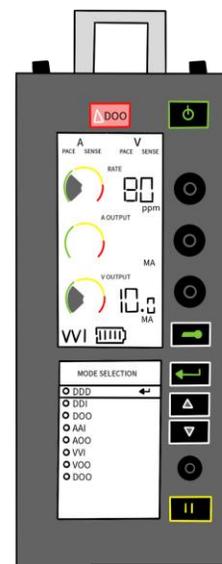
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Capture Threshold

- **DO NOT TEST** if patient is pacer dependent

1. Turn the pacemaker rate up 10 beats/min higher the patient's intrinsic rate.
2. Decrease the milliamperage until loss of capture occurs, and then slowly increase it until depolarization occurs after every pacer spike. The milliamperage setting at which depolarization occurs with every spike is the threshold for capture.
3. Set the milliamperage to 2 to 3 times the determined threshold.
4. Reset the pacer to the prescribed rate.



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24

Failure to Pace

Possible Causes:

- Electrode lead/wire dislodgement or misplacement
- Battery failure
- Sensing malfunction
- Lead failure

- Always check the battery and have an extra close by!
- Double check connections



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25

Resources

Kurapati R, Heaton J, Lowery DR. Atrial Kick. [Updated 2025 Sep 15]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK48242/>

Medtronic. (2020). Title of the manual (Document No. M811268A001A). https://www.medtronic.com/content/dam/emanuals/crdm/M811268A001A_view.pdf

Moayedi, S., Patel, P., Brady, N., Witting, M., & Dickfeld, T. M. L. (2022). Anteroposterior pacer pad position is more likely to capture than anterolateral for transcutaneous cardiac pacing. *Circulation*, 146(14), 1103-1104.

Self M, Tainter CR. Overdrive Pacing. [Updated 2023 Apr 24]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK549874/>

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26