Invasive Cardiac Pacing (Pacemaker)

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Outline

■ Definition.
■ Indications for invasive cardiac pacing.
■ Types of pacemakers.
■ Components of Pacing.
■ Pacemaker concepts:
  1) Connection
  2) Output (rate, amount, chamber)
  3) Capture
  4) Sensetivity
Pacemaker

- Is an artificial electronic device that provide electrical stimuli to cause cardiac contraction during periods when intrinsic cardiac electrical activity is inappropriately slow or absent.
- Used to initiate **myocardial contractions** when
  1) Intrinsic stimulation is insufficient,
  2) The native impulses are not being conducted,
  3) The **heart rate** is too slow to maintain an adequate cardiac output.
- Care of Patients With Pacemakers
- Complications Related to Pacemakers.
- Patient education regarding permanent pacemaker insertion procedure.
Indications for temporary invasive cardiac pacing

1) **Sick sinus syndrome:**
   - Symptomatic sinus arrest.
   - Suppression of ventricular ectopy resulting from bradycardia
   - Atrial fibrillation
   - Bradycardia/tachycardia syndrome
   - Symptomatic sinus bradycardia

2) **Heart blocks:**
   - Type I (occasionally) and type II second-degree atrioventricular block
   - Acute bifascicular or trifascicular block
   - Complete atrioventricular block
   - Cardiac arrest with ventricular asystole
3) Drug-refractory dysrhythmia:
- Overdrive ventricular pacing to suppress or prevent ventricular ectopic activity
- Overdrive atrial pacing to “break” supraventricular tachycardia or atrial flutter

4) Cardiovascular surgery:
- Prophylactic use during anesthesia and surgery in patients with a history of acute coronary syndrome or cardiac dysrhythmias
- Treatment for complete heart block developed during or after surgery
- Cardiac output augmentation postoperatively
5) Recent myocardial infarction:
- Treatment with β-blocking agents
- Serious bradydysrhythmias often occur even without drug therapy.
- Temporary pacing after myocardial infarction can be a lifesaving intervention, allowing patients to enjoy the benefits of β-blocker therapy while simultaneously maintaining an adequate heart rate and cardiac output.
Types of pacemakers

- **Permanent/long-term pacemaker:**
  - An incision (cut) is made in the neck or chest. The leads are guided through a vein into the heart, and attached to the generator.
  - The generator is placed in a pocket under the skin.

- **Transvenous/temporary pacemaker:**
  - The leads for the pacemaker are guided into the heart through an incision in neck, chest, or leg.
  - The generator is worn outside the body in a small pouch.
Components of Pacing

1) The **battery-powered generator** that initiates electrical stimulation.

- Three basic **types of pulse generators** are available:
  1. **single-chamber atrial pacers**, are adequate for enhancing heart rate in patients with an intact cardiac conduction system.
  2. Single-chamber **ventricular pacers**, designed for patients with normal contractility who require an increase in heart rate.
  3. **Atrioventricular sequential pacers**, pace both atrial and ventricular chambers.

Provide **synchronization** between the atria and the ventricles for optimal **cardiac output**.
- Permanent pacemaker pulse generators are usually powered by lithium batteries that function for five to eight years before they need to be replaced.

- Replacing the generator usually requires a simple procedure in which a repeat incision is made, the old generator is removed, and a new generator is implanted and joined with the existing leads.
2) The pacing generator is connected to **pacing wires/leads** and may or may not require a **connecting cable**.

3) **The patient’s own cardiac tissue:**

- Failure to pace may be due to a malfunction or disruption of **mechanical** components.
- May also be due to poor **myocardial** function associated with **electrolyte** disturbances, myocardial scarring, or any factors that affect impulse conduction or cardiac contractility.
Pacemaker Functioning Concepts
(Connection, output, capture, sensitivity)

1) The **Connection** between the pacemaker generator and the heart:

A) **Unipolar electrode wire**, only the **negative** electrode is in direct contact with the heart.

B) **Bipolar electrode wires**, **both** negative and positive electrodes lie within the heart.

- Pacemakers can be either unipolar or bipolar.
- Distinguishing between the negative and positive electrodes is important so that the wires are connected appropriately to the pulse generator.
Connection

- Types of invasive temporary pacing:

1) The **Transvenous** category, involves a pulse generator externally connected to 2 electrode wires, threaded through a **large vein** into either the right atrium or the right ventricle. These wires directly contact the **endocardium** within the heart.
Connection

2) Directly stimulating the epicardium:
- Initiated after cardiac surgery. Electrodes are lightly sutured to the epicardium before the thorax is closed.
- These pacing wires are pulled through the skin and secured to the external chest wall, ready for attachment to a temporary pacing generator as needed.
- A patient may have a single set or a double set of electrodes, but each set of electrodes includes 2 wires that protrude from a stab incision in the chest wall.
- Ventricular pacing wires exit through the left side of the sternum; atrial pairs are placed on the right side.
- Having identifying labels on the wires is helpful. If no labels are present, ascertaining which wire is which (and marking the wires accordingly) can save precious time later in emergency situations.
Temporary pulse generator for a dual-chamber pacemaker

On the top of the generator of each temporary atrioventricular sequential pacemaker are connectors labeled Atrial +/-, and Ventricular +/-.

Single-chamber pacemakers have only 2 connector ports, positive and negative; the wires must be connected and secured to the correct port.
2) Output (rate, amount, and chamber)

- The sole function of the generator is to supply sufficient energy to the heart muscle to stimulate a contraction.

A) The Rate: determines the number of stimulations to be delivered per minute.

- The original rate setting depends on both the patient’s condition and the reason for pacing.

- Rates for a surgical patient can start as high as 90 to 110 beats/min.

- In medical patients, therapy is generally started at 70 to 90 beats/min.

- In patients who have had cardiac arrest, the initial rate is 80 beats/min.

- The heart rate on a patient’s rhythm strip should never be lower than the patient’s set pacemaker rate.
B) The Output Amount:

- Is the **level of energy** delivered by the pulse generator to the heart to initiate **depolarization**.
- Output is measured in **milliamperes (mA)**.
- The usual starting point is **10 mA** in **nonurgent** situations.
- Output is then **slowly increased** until **capture** is obtained and the “**pacing threshold**” is defined.
- This level is not constant; it fluctuates over time as an **endothelial sheath** forms around the tips of the electrodes. Therefore, to prevent loss of capture, the output is set **1.5 to 3 times higher** than the identified pacing threshold.
- In **emergent** circumstances, starting with a **high output (15-20 mA)** is recommended.
C) The chamber:

- The **location** in the heart to which the energy is delivered.
- The **atrial, ventricular, or both** chambers can be paced.
- Pulse generators for dual-chamber pacemakers have separate atrial and ventricular output controls.
- The settings for the 2 chambers may be different or identical.
3) Electrical Capture

- The ability of the electrical impulse to initiate a **cardiac response**, is detected by examining an **electrocardiogram**.
- Capture is both an **electrical & a mechanical** event.
- Electrical capture is indicated by a **pacer spike** followed by a corresponding **P wave or QRS complex**, depending on which chamber is being paced (F).
- If the **atrium** is paced, the spike appears **before the P wave**.
- If the **ventricle** is paced, the spike occurs **before the QRS complex**.
- Because the pacemaker causes the heart to **depolarize in an artificial fashion**, the path of depolarization is abnormal, resulting in **widened** P waves and QRS complexes.
Normal electrical capture, atrial pacer. Normal atrial electrical capture is demonstrated by a pacer spike (Ap) followed by a corresponding P wave.

Abbreviations: Ap, atrial pacing; As, atrial stimulation (intrinsic).
Normal electrical capture, ventricular pacer. Normal ventricular electrical capture is demonstrated by a pacer spike (Vp) followed by a corresponding, widened QRS complex.

Abbreviations: Vp, ventricular pacing; Vs, ventricular stimulation (intrinsic).
A pacer spike without a corresponding P wave or QRS complex indicates failure to capture (F).

If loss of capture occurs, the patient is assessed first and then connections and settings are checked to detect disconnections, broken wires, or other mechanical issues.

If the patient’s condition is stable, threshold testing is done.

If hemodynamic compromise exists, the milliamperae/amount is quickly increased until capture occurs.
- **Turning** the patient onto his/her **left** side may also improve capture by increasing contact between the electrode and myocardial tissue.

- Electrical capture alone is inadequate. **Adequacy** of mechanical capture is assessed by feeling for a **pulse** or checking **blood pressure**.

- **Mechanical capture** exists when the **pacer spike** and its corresponding **QRS complex** are followed by a **cardiac contraction**.
Failure to capture, dual-chamber pacemaker. Failure to capture occurs when a **pacer spike is present** but is not followed by a corresponding **waveform** (P wave or QRS complex). Arrow indicates **electrical stimulus without ventricular capture**.
4) Sensitivity

- The ability of the generator to detect & recognize the impulses the myocardial tissue is generating on its own (Intrinsic cardiac activity).

- Intrinsic activity stimulates better contractions, & more effective forward blood flow, from the chambers of the heart, especially when the atria and ventricles are intrinsically beating synchronously.

- 30% of normal C.O. is due to the atrial “kick” or atrial systole, that occurs during ventricular filling when the 2 chambers perform in sync.
When atrial beats are unsynchronized or absent, as in atrial fibrillation, ativoventricular block, or sinus arrest, cardiac output decreases because less blood than usual is ejected from the atria during ventricular diastole.

- Intrinsic beats must be supplemented when the rate is insufficient or conduction of the beats does not generate ventricular contractions.

- For maximum effectiveness, paced beats and intrinsic beats must be synchronized.

- To synchronize the beats, the generator first analyzes the intrinsic rhythm and then stimulates the heart only as needed.
- Adjusting the sensing level sets the pacer to “look” for intrinsic beats, & provide pacing on demand.
- Pacemaker generators can be programmed to deliver an impulse to the ventricle each time an **atrial beat is sensed**, or they can be set to stimulate only when **no intrinsic beat has been detected during a predetermined interval**.
- The sensitivity setting is measured in **millivolts (mV)** and is initially set at about **2 to 5 mV**.
- **Failure to sense** occurs when the generator does not recognize the heart’s intrinsic impulses.
Failure to sense, single-chamber atrial pacemaker. Failure to sense occurs when the generator does not detect intrinsic beats and initiates an inappropriate impulse that may or may not capture. Arrow indicates an atrial beat not sensed by the pulse generator, which is followed by a pacer spike.
## Factors that influence capture and sensing

<table>
<thead>
<tr>
<th>Factor</th>
<th>Capture</th>
<th>Sensing</th>
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</thead>
<tbody>
<tr>
<td>Fluid status changes</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Pericardial effusion</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Electrolyte or metabolic abnormalities</td>
<td>X</td>
<td></td>
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<tr>
<td>Medications</td>
<td>X</td>
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<tr>
<td>Tissue inflammation, fibrosis, or necrosis</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Generator battery failure</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Low pulse generator voltage</td>
<td>X</td>
<td></td>
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<tr>
<td>High pulse generator amperage</td>
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<td>X</td>
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<tr>
<td>Development of endothelial sheaths</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Disconnection, dislodgment, or fracture of leads</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*X denotes an influence; no entry indicates no influence.*
The most common cause of failure to sense is displacement of the electrode.

Repositioning the patient on his or her left side may improve contact between the electrode and the myocardium.

If the response is still inadequate, then the sensitivity must be increased by turning down the millivoltage, allowing the generator to detect beats that occur at lower millivolt levels.

If the pacemaker is detecting beats that are not actually occurring (inappropriate sensing), then the sensitivity threshold must be increased to block out artifact by turning up the millivoltage.
Care of Patients With Pacemakers

1) **Electrical** safety practices, to prevent **microshocks** which are associated with **ventricular dysrhythmias**.
   - Always wear **gloves** when handling electrodes
   - Cover unused transthoracic wires

2) The pulse generator must be placed in a location where it will not be dropped on the floor.

3) Lengthy cables attached to the pacemaker need careful attention so that wires are not inadvertently dislodged.
4) Routine nursing care of regular cardiovascular assessment to evaluate pulses, level of consciousness, heart rhythm, pacer activity, and hemodynamic response.

5) The wires must be secure and not at risk for dislodgement.
   - check to see if the wires are intact and note the number & location.

6) Care for a transvenous wire site:
   - Daily assessment of the insertion site.
   - dressing are changed as prescribed
   - cleaned with povidone-iodine/another antimicrobial agent
   - A sterile occlusive dressing is applied, with changes every 48 to 72 hours.
7) **After cardiac surgery** & once dressings are removed, care of the **epicardial site** should be performed **daily** whether the site is left open to air or covered with a light dressing.

- The area is cleaned with **isotonic sodium chloride solution** and assessed for **redness or drainage**.
- The wires must be **taped securely to the skin** to prevent accidental dislodgement.
8) **Capture and sensitivity threshold** testing should be performed every 12 to 24 hours to determine the best settings for the generator.

- As time passes, both transvenous and epicardial wires acquire **endothelial sheaths around their tips** and thus require **more milliamperes to capture and fewer millivolts to sense**.

- Threshold testing is generally **contraindicated** when patients are being **paced more than 90% of the time** because of the **risk of losing capture** while the patients are **dependent** on generator-initiated beats.
# Complications Related to Pacemakers

<table>
<thead>
<tr>
<th>Early complications, related to implant</th>
<th>0.5–1.9%</th>
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<tbody>
<tr>
<td>Pneumothorax</td>
<td>0.5–1.7%</td>
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<tr>
<td>Large hematoma</td>
<td>0.2–1.2%</td>
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<tr>
<td>Cardiac perforation</td>
<td>1.6–3.8%</td>
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<tr>
<td>Lead dislodgment, atrial</td>
<td>0.5–1.4%</td>
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<tr>
<td>Lead dislodgment, ventricular</td>
<td>2–5%</td>
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<table>
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<tr>
<th>Other complications</th>
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<tbody>
<tr>
<td>Wound dehiscence</td>
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<tr>
<td>Infection</td>
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<td>Pain</td>
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<tr>
<td>High thresholds</td>
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<td>Loose setscrew</td>
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<td>Lead failure</td>
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<td>Pacemaker failure</td>
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<tr>
<td>Diaphragmatic stimulation</td>
<td></td>
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<tr>
<td>Skin erosion</td>
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<td>Pacemaker syndrome</td>
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</table>
Complication treatment depends on the etiology

- **Pneumothorax**, being dependent on size, may require **chest thoracostomy**.
- **Erosion** of the pacer through the **skin**, while rare, requires **pacer replacement and systemic antibiotics**.
- **Hematomas** may require **drainage**.
- **Lead dislodgment** usually occurs within 2 days following implantation of a permanent pacer and may be **seen on chest radiography**. If the lead is floating freely in the ventricle, malignant arrhythmias may develop.
- Thrombosis is rare and usually presents as unilateral arm edema. Treatment includes arm elevation and anticoagulation.

- Advanced life support protocols, including defibrillation, may safely be executed in patients with pacemakers in place. Sternal paddles are placed at a safe distance (10 cm) from the pulse generator.
Patient education regarding permanent pacemaker insertion procedure
Before the Procedure

- You will be asked to sign a consent form.
- If you are pregnant or suspect that you are pregnant, you should notify your physician.
- Notify your physician if you have a history of bleeding disorders or if you are taking any anticoagulant (blood-thinning) medications. It may be necessary for you to stop some of these medications prior to the procedure.
- Your physician may request a blood test prior to the procedure.
- Remove any jewelry or other objects that may interfere with the procedure.
- **Not eat or drink after midnight the night before the procedure.**
- **Tell your doctor and nurses if you are allergic to any medicines or Iodine.**
- **Empty your bladder before the procedure.**
- **Your chest area may be shaved, and will be prepared for the procedure.**
- **You may be given medicine to help you relax.**
- **An intravenous line (IV line) will be inserted into your arm.**
During the Procedure

- You will be placed on a thin, hard table.
- A large drape will be placed on the chest area where the pacemaker will be inserted.
- You will be given an antibiotic in your IV.
- The doctor will insert the pacing leads (wires) into the heart, and then attach the leads to the pacemaker or generator.
- You may be awake during the procedure, and you may be asked to take deep breaths.
There will be a large camera that rotates and takes pictures of your heart as the leads are being positioned by the doctor.

It is very important to tell the doctor or nurse if you have any discomfort or chest pain.

A large bandage that applies pressure will have been placed on the incision site (the area where your stitches are).
After the Procedure:

- **Not raise the arm on the same side as the incision site above your shoulder for three weeks.**
- **Arrange to have someone drive you home from the hospital following the procedure.**
■ Notify your physician &/or nurse to report any of the following:

- Fever and/or chills
- Pain, redness, swelling, or bleeding or other drainage from the insertion site.
- Chest pain/pressure, nausea and/or vomiting, profuse sweating, dizziness and/or fainting.
- Swelling at the pacemaker site.
- Shortness of breath
- Palpitations (a feeling of irregular heartbeat).
At Home

- Not do any lifting or pulling on anything for a few weeks.

- Keep the insertion site clean and dry.
Pacemaker Precautions/ Follow-up care

- Always carry an **ID card** that states you are wearing a pacemaker.

- Tell your **surgeon or dentist** that you have a pacemaker; so that **electrocautery** will not be used to control bleeding (the electrocautery device can change the pacemaker settings).

- Always **consult your physician** if you have any questions concerning the use of certain **equipment** near your pacemaker.

- Always consult your physician when you **feel ill after an activity**, or when you have questions about beginning a new activity.
A follow-up visit at the physician’s office is usually scheduled every six to 12 months, to ensure that the pacemaker is working properly by programming testing and if needed battery replacement is necessary.
Permanent Pacemaker programming

- Can be performed noninvasively by an electrophysiologist or cardiologist.
- Patients should carry a card with them providing information about their particular model. This information is crucial when communicating with the cardiologist about a pacer problem.
- Most pacemaker generators have an x-ray code that can be seen on a standard chest x-ray.
AVOIDING POSSIBLE ELECTROMAGNETIC INTERFERENCE
Patients with artificial pacemakers should be aware of the following:

- **Household appliances** — microwave energy.

- **Cellular phones** — Avoid placing a cell phone over the pacemaker (especially the antenna of the phone), and should not carry it in a pocket close to or over the pacemaker while the phone is on.

- **Electromagnetic Security Systems** — found in or near the workplace, at airports, in shopping malls, at courthouses, or in other high-security areas.

  - Be aware of the location of security systems and move through them at a normal pace.

  - Avoid sitting or standing close to a security system.
■ **External electrical equipment** — In places that contain welding equipment or motor-generator systems.

- Remain **at least two feet** from external electrical equipment,
- Verify that the **equipment is properly grounded**,
- Wear **insulated gloves** when using electrical devices,
- Leave the work area immediately if they experience **lightheadedness** or other concerning symptoms.
Diagnostic or therapeutic procedures:

Certain diagnostic or treatment procedures may interfere with pacemakers. Thus, clinician recommend avoiding these procedures or using special precautions, such as reprogramming of the pacemaker. Such procedures include:

- **Magnetic resonance imaging (MRI)**, a noninvasive diagnostic imaging procedure that uses a strong magnetic field that is pulsed on and off at a rapid rate.
- Transcutaneous electrical nerve/muscle stimulators, a method of pain control involving the application of electrical impulses to muscle or nerve via electrodes placed on the skin
- Diathermy, the production of heat in body tissues for therapeutic purposes through high-frequency electromagnetic radiation or microwaves
- Extracorporeal shock wave lithotripsy, the use of sound waves to break up stones (calculi) in the urinary tract or gallbladder
- Therapeutic radiation for cancer or tumors, which can cause permanent pacemaker damage from the radiation
The End

Thank You