Pacemakers and Pacing

Keith Martin, RN, BSN, BSc.
Clinical Nurse Educator, ER/ICU
MD10
nursekeithmartin@yahoo.ca

Disclaimer: this handout contains a lot of information that is protocol oriented. Protocols are not examinable in the first year MD/DMD curriculum. Further, a lot of information contained is handout is beyond the scope of the first year CV block. Please refer to the weekly objectives and the weekly quizzes to help you determine what is included in the curriculum of the block. Questions relating to the content of this handout should be emailed to the author. The author is responsible for accuracy. J Waechter
Pacemakers and Pacing

What is pacing?
- An electrical stimulus is given to the heart which results in depolarization of the myocardial tissue.
- This depolarization results in contraction of the heart muscle tissue.

What is a pacemaker?
- A pacemaker is an electronic device that provides an electrical signal to make the heart beat when its own, built-in pacemakers fail. The anatomical, built-in pacemakers provide what's called the "intrinsic" rhythm, and they can be disrupted by various conditions (e.g. ischemia or an MI.)
  - **Intrinsic rhythm**: coming from the patient's own built-in, natural pacemakers (the SA or AV nodes; or sometimes from lower down in the ventricles).

Why would you pace?
- There are 5 reasons why you would pace someone
  1. **Symptomatic Bradycardia** (low BP, CP, SOB, decreased LOC) associated with the following rhythms:
     - **2nd degree heart block type 2**: this HB is characterized by an atrial rate that is usually two or three times the ventricular rate. The atrial rhythm is regular, but the ventricular rate is variable depending upon the degree of the block. The PR interval in this rhythm stays the same, only QRS complexes are dropped at usually predictable intervals. The problem with this rhythm is that it frequently degenerates into 3rd degree HB.

     ![Heart Activity](image)

     **3rd degree heart block**: this rhythm is characterized by the atria and ventricles being completely independent or out of sync with each other. There is no PR interval. The atria are controlled by the SA node and the ventricles are usually controlled by a ventricular pacemaker (hence the usually widened QRS complex).
2. **Asystole:**
   - Probably the most difficult rhythm strip to identify. It is characterized by its definitive straight line across the screen.

3. **Permanent Pacemaker Failure**
   - **Failure to Capture:** This rhythm is characterized by the failure of a QRS complex being generated following the pacer spike.
   - **Failure to Sense:** This rhythm is characterized by a pacer spike after or near a QRS complex. The danger of this is that the pacer may fire during the "vulnerable" period of the T-wave, leading to the "R-on-T" phenomenon.

4. **Overdrive Pacing:**
   - Rarely used (I’ve never seen it done). It involves cranking up the rate faster then the current atrial rate and then slowly decreasing the rate until it returns to normal. This breaks the malfunctioning conduction pathway.
5. **Pulseless Electrical Activity (Only in the following cases)**
   - Drug overdose
   - Acidosis
   - Correctable electrolyte abnormality

**How do they Work?**
- The pacemaker essentially does two things:
  - **senses** the patient’s own rhythm using a “sensing circuit”, and
  - **sends** electrical signals using an “output circuit”.
- If the patient’s intrinsic rhythm becomes too slow or goes away completely, the electronic pacemaker senses that, and starts sending out signals along the wires leading from the control box to the heart muscle. The signals, if they’re “capturing” properly, provide a regular electrical stimulus, making the heart contract at a rate fast enough to maintain the patient’s blood pressure.

**Where do you pace?**
- There are three different areas of the heart that you can pace
  1. **Atrial**: pacer wire stimulates the atria to contract. This rhythm is characterized by the presence of a small peak before the P wave.

   ![Pacer Spike](image)

  2. **Ventricular**: the pacer stimulates the ventricles to contract. This rhythm is characterized by a large peak before a widened QRS complex. One downside is that you lose the atrial kick in this method.
    - **Atrial kick**: the contraction of the atria prior to the contraction of the ventricle accounts for more volume (1/3 more) to the ventricle and more muscle stretch. With Starling’s Law at play, atrial kick accounts for 15-30% of blood ejected. Note that the older one becomes, the higher the percentage owed to atrial kick. For example, an elderly person with only quivering atria (atrial fibrillation) is often more affected because as much as a third of their blood supply to ALL of their cells has been eliminated.

   ![Pacer Spike](image)
3. **AV sequential pacing** (i.e. sequential pacing): this rhythm is characterized by the dual pacer spike. One before the P wave and one before the widen QRS complex.

- **Dual-site pacing**: newer pacing systems have 2 atrial leads, one in the right atrial appendage and the other either in the coronary sinus or at the os of the coronary sinus. The ventricular lead is in the right ventricle, either at the apex or at the outflow tract. This system is used to prevent or reduce episodes of atrial fibrillation.

**Combined pacemaker with Internal Defibrillator**
- specialized device designed to directly treat a cardiac tachyarrhythmia. If a patient has a ventricular defibrillator and the device senses a ventricular rate that exceeds the programmed cut-off rate of the defibrillator, the device performs cardioversion/defibrillation. Alternatively, the device, if so programmed, may attempt to pace rapidly for a number of pulses, usually around 10, to attempt pace-termination of the ventricular tachycardia.

**Types of Pacing**:
- **Transvenous**
  - In this type of pacing, the pacing wire is threaded down the jugular vein through an introducer.
- The introducer is put in first, like any central neck IV line, and the wire is passed through it, until it makes contact with the inner wall of the RV. Then the wire is attached to a generator box, and the heart is paced using the wire. We hardly ever do this at the bedside anymore, other than in the ICU.

- **Transcutaneous**
  - Involves using external pacing pads connected to a device like the Lifepak 12 or 20, or one of the defibrillators that has external pacing ability.

- **Transthoracic**
  - In this case the wires are inserted either during cardiac surgery – small wires that sit on the outer wall of the heart – “epicardial” wires, then lead out of the chest, to a control box.
    - Right wires are atrial, left wires are ventricular.

- **Permanent**
  - The one we all know and love is implanted under the skin, usually below the left clavicle.
# What are the parts?

<table>
<thead>
<tr>
<th>Transvenous</th>
<th>Transcutaneous</th>
<th>Permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulse Generator:</strong></td>
<td><strong>LIFEPAK® 12, 20 defibrillator/pacer/monitor</strong></td>
<td><strong>Medtronic Kappa Permanent Pacemaker</strong></td>
</tr>
<tr>
<td>Single-Chamber Medtronic Model 5348 Specifications</td>
<td></td>
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<tr>
<td><strong>Wires/Cables:</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Pacer function located here</td>
</tr>
<tr>
<td><strong>Battery:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard 9 V, Alkaline or Lithium</td>
<td>BC Hydro or Rechargeable nickel-cadmium battery with 1.2 amp hours capacity</td>
<td>Internal Battery Based on general conditions, the battery lasts an estimated 6 to 7 years</td>
</tr>
<tr>
<td><strong>Lasts:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkaline: 300 hours</td>
<td>Lithium: 650 hours</td>
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</table>
Dials on the Pacemaker

Rate
- How fast do you want the heart rate to be?
  - Depends
    - upon the patients condition
    - what the patient needs
  - e.g. MI or poor perfusion

Output
- Amount of energy (current) that the pacer sends out to the heart
  - Measured in milliamps (mA)
    - Transvenous typically is anywhere from 5-20 mA
    - Transcutaneous can be anywhere from 1-200 mA

Sensitivity
- This is the pacemaker's ability to sense the intrinsic rhythm of the heart.
- This setting make sure that the pacemaker only fires when it is suppose to fire. (i.e. why fire when the heart is already beating?)
- Asynchronous pacing
  - This is a fixed mode, the pacemaker will fire regardless of the intrinsic rhythm.
  - Only ever used in asystole and overdrive pacing
- Demand mode
  - In this mode the pacemaker will only fire if the heart rate falls below certain rate.

Low Sensitivity
- AKA Undersensing
  - The pacemaker does NOT sense the underlying intrinsic beat
  - It fires continuously
  - HAZARD: R on T V. Fib.
  - A high number on the dial = low sensing
    - (i.e. the fence is too high, can't see what the neighbours are doing)

High Sensitivity
- AKA Oversensing
  - The pacemaker senses everything (e.g. breathing, movement) and thinks it is an intrinsic beat.
  - It never fires
  - HAZARD: Asystole
  - Low number on the dial = High sensing
    - (i.e. there is no fence, you can see everything the neighbours are doing)
Capture
- Heart response to electrical stimuli and depolarizes
  - You should see a pacer spike followed by whatever you are trying to pace
  - Check for a pulse with every QRS
    - Don’t want PEA
- **Stimulation Threshold**: the minimum amount of energy to stimulate depolarization
  - Start with the lowest mA, and increase it until you get capture, and then add 2 - for transvenous pacing or 10% - for transcutaneous

Loss of Capture
- **Causes:**
  - Intrinsic:
    - MI,
    - hypertrophy,
    - acidosis,
    - hypoxia,
    - electrolyte imbalance
  - Mechanical:
    - machine malfunction
    - low battery
    - wire disconnected (from heart or pulse generator)
    - damaged cable or wire
- **Solutions:**
  - Check all of the above!
  - Turn up mA
  - Change the patient’s position
  - Slap the pacer pads on them and externally pace the patient
  - Start CPR/Call for help

Pause
- Used to see what the underlying rhythm is

Battery/Low battery
- Pretty obvious

Lock
- Stops the patient from changing/playing with the settings of the pacemaker
Procedure for using a Transcutaneous Pacemaker:

1. Explain the procedure to the patient
2. Administer analgesic or sedation (this procedure hurts!)
3. The patient should be connected to monitor and a rhythm strip obtained in order to verify the dysrhythmia the patient has and to confirm is not mistaken for an artifact.
4. Apply pacer pads as per package.
   - Posterior electrode on back, to the left of the thoracic spinal column (directly opposite the anterior electrode).
   - Anterior electrode to the left of sternum, centered close to the point of maximal cardiac impulse.
5. Connect the pacer pads to the device (if not already done so)
6. Turn on the device, and select synchronous (demand) or asynchronous (fixed-rate or non-demand) mode.
7. Set the pacing rate (usually 80 beats/minute).
8. Set the pacing current output. This is in milliamps.
9. Start with the minimal setting and slowly increase output until the pacer spike appears on the monitor.
   - An external pacer's spike is wider and shorter than that of a transvenous pacer.
10. Slowly increasing output until the ECC tracing indicates electrical “capture”
    - usually characterized by a widened QRS complex and broad T wave after each pacer spike
11. Set the output 10% higher than the threshold of initial electrical capture as a safety margin.
    - Threshold is the minimum current needed to achieve consistent electrical capture
12. Document the pacing in a clinical record.

Things to monitor once the pacemaker is set:

1. Monitor heart rate and rhythm to assess ventricular response to pacing.
2. Make sure that the device is appropriately pacing and sensing intrinsic beats.
3. Assess his hemodynamic response to pacing by assessing his central pulses.
4. Taking blood pressure (BP) on both arms.
5. Also assess your patient's pain and administer analgesia/sedation.
6. Maintain electrical safety
Transvenous Pacing:

CONFIRMING POSITION:
The following EKG findings indicate electrode position:

<table>
<thead>
<tr>
<th>Location</th>
<th>Lead V1</th>
<th>Lead II, III, AVF</th>
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</thead>
<tbody>
<tr>
<td>Vena Cava</td>
<td>Small inverted p</td>
<td>Same</td>
</tr>
<tr>
<td>Right Atrium</td>
<td>Tall biphasic p</td>
<td>Same</td>
</tr>
<tr>
<td>Coronary Sinus</td>
<td>Positive QRS</td>
<td>Positive or neg QRS</td>
</tr>
<tr>
<td>Right Ventricular</td>
<td>with rabbit ears</td>
<td>Left Axis/ pattern of injury</td>
</tr>
<tr>
<td>(Out flow tract)</td>
<td>Negative QRS</td>
<td>(elevated ST)</td>
</tr>
<tr>
<td>Right Ventricular Apex</td>
<td>LBBB, Negative QRS</td>
<td></td>
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- Should get a PCXR to confirm placement
- Can also insert under fluoroscopy to ensure correct placement

POST INSERTION PROCEDURE:

<table>
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<tr>
<th>ACTION</th>
<th>RATIONALE</th>
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<tbody>
<tr>
<td>1. After contact between pacing electrode and the right ventricular endocardium is established, assist the physician in connecting to pacemaker generator. Set according to physician’s orders.</td>
<td>1. The physician sets the parameters; must generate a written order for its use. Establish a baseline. The output dial regulates the amount of electric current (mA) that is delivered to the myocardium to initiate depolarization. Ventricular pacing (stimulation threshold) should be established at less than 1 mA output whenever possible. The maintenance threshold is set at 1.5 to 2 times above the stimulation threshold to allow for increases in stimulation threshold without loss of ventricular capture. Sensitivity threshold is the level at which intrinsic ventricular activity is recognized by sensing electrodes. For demand pacing, the sensitivity must be measured and set. Sensitivity threshold is set at maximum and is lowered only if pacer is sensing inappropriately. If set too high, it will result</td>
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For all Methods of Temporary Pacing
A. Determine the stimulation threshold:
   a. Set pacing rate above patient’s intrinsic rate.
   b. Gradually decrease output (mA) from 20 mA until capture is lost.
   c. Gradually increase output (mA) until capture is established. This is the stimulation threshold.
   d. Set output (mA) at least 1.5 to 2 times higher than the stimulation threshold. This output setting is sometimes referred to as the maintenance threshold.
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<tr>
<td><strong>B. Determine the sensitivity threshold:</strong></td>
<td><strong>in sensing P or T as an R wave; if set too low, it results in asynchronous pacing (nonsensing).</strong> Determined by patient’s response. A-V interval (similar to intrinsic PR interval) should be set for optimal ventricular filling, usually between 150 to 250 ms. ECG tracing should reflect appropriate response to pacemaker settings if pacemaker is functioning properly.</td>
</tr>
<tr>
<td>a. Set rate at least 10 beats per minute below patient’s intrinsic heart rate.</td>
<td></td>
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<tr>
<td>b. Set sensitivity control to most sensitive setting (fully demand or lowest numerical setting). Sensing indicator light should flash with each intrinsic R wave.</td>
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<tr>
<td><strong>C. Set the pacemaker rate, output (mA), and sensitivity (demand or asynchronous), as prescribed or as determined by threshold testing.</strong></td>
<td></td>
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<tr>
<td><strong>D. Assess rhythm for appropriate pacemaker function:</strong></td>
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<tr>
<td>a. Capture: is there a QRS complex for every ventricular pacing artifact?</td>
<td></td>
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<tr>
<td>b. Rate: is the rate at or above the pacemaker rate if in the demand mode?</td>
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<tr>
<td>c. Sensing: does the sensitivity light indicate that every QRS complex is sensed?</td>
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<tr>
<td><strong>2. Ensure the pacing wire is secured as it exists the introducer; check all connections as well as battery and control settings at least q.4 hrs and document.</strong></td>
<td><strong>2. Prevent migration of wires; these connects are easily disconnected and may result in cardiac arrest. Protects setting from being inadvertently being altered.</strong></td>
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<tr>
<td><strong>3. Maintain site care per Infection Control Manual SOP on central lines.</strong></td>
<td><strong>3. This is a central line with potential for sepsis.</strong></td>
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<td><strong>4. Keep the pulse generator dry and the controls protected from mishandling.</strong></td>
<td><strong>4. Moisture will cause pacemaker malfunction; improperly set controls can cause cardiac irritability resulting in dysrhythmias and cardiac arrest.</strong></td>
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<tr>
<td><strong>5. Protect the patient from electromicroshock and electromagnetic interference (EMI):</strong></td>
<td><strong>5. Electromicroshock and EMI can cause the pulse generator to fail.</strong></td>
</tr>
<tr>
<td>a. Cover exposed wires with gloves or tape.</td>
<td></td>
</tr>
<tr>
<td>b. Enclose pulse generator in rubber</td>
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glove.
c. Wear rubber gloves when handling exposed wires.
d. Avoid any nurse-patient contact with electrical apparatus.
e. Check for ungrounded electrical equipment.
f. Keep dressing over wires dry and intact when not in use.

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<td>6. All invasive procedures have a percentage of complications that can be prevented by an astute nurse.</td>
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<tr>
<th>7. Document location, type of pacing, pacing mode, stimulus threshold, sensitivity setting, pacing rate and intervals, intrinsic rhythm, and percent of pacing. Post sample tracings.</th>
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</table>

Chart from: [http://rnbob.tripod.com/transven.htm](http://rnbob.tripod.com/transven.htm)

**Now the Great Mystery of the letters demystified**
- **Letter 1**: chamber that is paced (A=atria, V=ventricles, D=dual chamber).
- **Letter 2**: chamber that is sensed (A=atria, V=ventricles, D=dual chamber, 0=none).
- **Letter 3**: response to a sensed event (T=triggered, I=inhibited, D=dual - T and I, R=reverse).
- **Letter 4**: rate responsive features (R=rate responsive pacemaker).
- **Letter 5**: Anti-tachycardia facilities.