Introduction to Pacemakers

• March 3, 2009
• David Stultz, MD
• Southwest Cardiology, Inc.
Topics to be covered

- Indications
- Pacemaker nomenclature
- Insertion Technique
- Complications
- Orientation to “the box” (Pacemaker)
- Troubleshooting
- Questions?
General indications for a temporary pacemaker

- Heart rate is slow, causing hemodynamic compromise
- Sick sinus syndrome
  - Sinus bradycardia or atrial fibrillation with slow heart rate response (generally <40 bpm)
- Heart block
  - 3rd degree
  - 2nd degree type 2 (Mobitz)
- Malignant Tachyarrhythmia caused by bradycardia
  - Torsades de Pointes
Clinical settings for temporary pacemaker

- Syncope
- Myocardial infarction
  - Especially inferior
- Shock due to bradycardia
- Myocarditis
- Lyme disease
2nd Degree AV block type 1

Wenkebach – not a reason for pacemaker
2nd Degree AV block type 2
(Mobitz)
Inferior/Lateral/Posterior Infarct with 2:1 block
3rd degree heart block
Another 3\textsuperscript{rd} degree heart block
Atrial fibrillation → Asystole
NSR $\rightarrow$ 20 second asystole
Pacemaker Nomenclature

- **Common Modes**
  - VVI – Single chamber (ventricle)
  - DDD – Dual chamber
  - AAI (uncommon) – Single chamber (atrium)

- **1\(^{st}\) Letter is chamber PACED**

- **2\(^{nd}\) Letter is chamber SENSED**

- **3\(^{rd}\) Letter is response**
  - I = Inhibit
  - T = Triggered (Unusual)
  - D = Dual (Inhibit or Pace)

- **4\(^{th}\) Letter – R = Rate responsive (permanent pacers)**
Components of a pacemaker system

- **Lead**
  - **Wire connects to heart**
    - Percutaneous
      - Ventricular wire sits in RV apex
    - Epicardial (post surgery)

http://www.oscor.com/images/lead%20pics/RU-STR-Polaris%20lead2%20copy.jpg
The Can
AKA “Pulse Generator,” “Battery”

Temporary

Single chamber

Dual chamber

Permanent single chamber


http://upload.wikimedia.org/wikipedia/commons/thumb/b/b1/Pacemaker_GuidantMeridianSR.jpg/549px-Pacemaker_GuidantMeridianSR.jpg
Schematic of pacemaker system.
Sites of insertion for a temporary pacemaker

- Right internal jugular
- Left subclavian vein
- Right subclavian vein
- Either femoral vein (Fluoroscopy required)
- Left IJ is possible but very difficult
Seldinger technique for percutaneous vascular access

General steps
• Trendelenberg position or leg elevation can facilitate access to IJ and subclavian veins
• Sterile Field
• Anesthetize skin with lidocaine
• Access vein with Cook needle
• Insert guidewire
• Remove needle
• Consider making a skin nick with scalpel
• Insert 6-8F introducer sheath with dilator over guidewire
• Remove dilator and guidewire
• Flush sheath using side port
• Advance temporary pacemaker to right ventricle
Complications of temporary pacemaker insertion

- Blood loss/hematoma
- Infection
- Arrhythmia (especially during insertion)
  - PVC’s are common
  - Heart block
    - Especially in patients with underlying LBBB
  - Bundle branch block
- Pneumothorax (about 1+% when subclavian access used)
- Cardiac perforation \(\rightarrow\) Tamponade
Pneumothorax of Left Lung
Functions of a pacemaker

- Sensing
  - The device ‘sees’ a native heart beat

- Pacing
  - The device delivers a shock to stimulate a heart beat
VVI Explained

- A VVI pacemaker
  - Paces the ventricle
  - Senses the ventricle
  - In response to a sensed event it INHIBITS the pacing response
    - So if it doesn’t SENSE a native heart beat in a specified period, it will deliver a pace.
Timing cycles

VVI pacemaker
LR = lower rate limit
VRP = ventricular refractory period
Note that a sensed QRS starts the VRP and resets the LR
The dials on the Temporary pacemaker

- **Rate**
  - Determines the lower rate limit of the device
  - Heart rate should not go lower than the set rate

- **Output**
  - In milliamps, the amount of ‘juice’ the device outputs with each pacer spike
Sensitivity

- Sensitivity → asynchronous
  - In millivolts, the amount of energy that has to be detected in order for the device to ‘sense’ a beat
  - Higher millivolts = less sensitive
    - More likely for the pacemaker to pace at the lower rate regardless of what the heart does on its own
  - Lower millivolts = more sensitive
    - More likely to pick up noise, and ‘sense’ a ventricular beat even though nothing actually happened
Sensitivity low – Everything (QRS, T, U) can be sensed by the pacemaker as a QRS
Sensitivity

Sensitivity low – QRS and some T waves will be sensed by pacemaker as a QRS

http://www.univie.ac.at/cga/courses/BE513/EKG/qrs.gif
Sensitivity

Sensitivity just right
QRS will be sensed,
T waves will not

PR interval

QRS interval

QT interval

0 mV

http://www.univie.ac.at/cga/courses/BE513/EKG/qrs.gif
Sensitivity

Sensitivity too high
Nothing will be sensed

PR interval  QRS interval

http://www.univie.ac.at/cga/courses/BE513/EKG/qrs.gif
Testing thresholds

- **Output Threshold**
  - Set Sensitivity to ‘asynchronous’
  - Set Rate just above the native heart rate
    - 60-80 bpm
  - Start output at 5-10 mA, and gradually turn down until ventricular capture is lost
  - The last point before losing capture is the threshold
  - Pacemaker output should be set at 2-3x the threshold
Testing Thresholds

- **Sensitivity Threshold**
  - Not always necessary
  - Testing the amplitude of native QRS complexes as seen by the can
  - Set Rate just below native heart rate
  - Set Output at 2-3x the Pacing threshold
  - Start asynchronous, then slowly turn dial down. Pacemaker spikes will disappear when the sensitivity threshold is reached. The pacemaker can now ‘see’ the native QRS complexes.
  - The pacemaker should be set at a sensitivity 1/3 to 1/2 the sensitivity threshold
Troubleshooting Pacemakers

- Normal behavior that looks strange
- Failure to Capture
- Undersensing
- Oversensing
- Cross Talk (Dual Chamber only)
Normal behavior of VVI pacemaker
Normal behavior of VVI pacemaker

Paced beat with capture
Normal behavior of VVI pacemaker

Fusion beat – combination of native QRS and paced beat
Normal behavior of VVI pacemaker

Pseudofusion – pacing spike, normal QRS
Failure to Capture

Atrial pacing with intermittent ventricular capture

Braunwald, 7th ed.
Failure of output (oversensing)

VVI pacemaker sensing artifact as ventricular contractions (oversensing)
As a result, the pacemaker does not output
VVI pacemaker
3\textsuperscript{rd} ventricular beat is a PVC, but it is followed by a pacemaker spike
4\textsuperscript{th} beat is a probably a normal ventricular beat, but it is also followed by a pacer spike
Cross Talk

Dual chamber pacemaker in DDD mode
3rd atrial pacing spike is not followed by ventricular spike
Ventricular lead detects the atrial spike as a ventricular depolarization,
So the pacemaker fails to deliver a ventricular spike

Braunwald, 7th ed.
Pacemaker Interrogation

Patient Data File

Patient Name
Pulse Generator Data
Model S603
Serial 122305
PG Implant Date 11 FEB 2009
Last Interrogation Date 11-FEB-2009

Indications
Atrial N.R.
AV Nodal 2nd Degree HB Mobitz II
Ventricular N.R.

Lead Data
Atrium
Lead Implant Date FEB 2009
Lead Manufacturer Guidant
Lead Model 4136
Connector Type IS-1 Bipolar
Lead Serial Number 28372183
Impedance at PG Implant 700 Ω
Threshold at PG Implant 0.75 V
Wave Amplitude at PG Implant 3 mV
Slew Rate at PG Implant N.R.

Ventricle
FEB 2009
Guidant
4137
IS-1 Bipolar
28337873
600 Ω
1.50 V
7 mV
N.R.

Physician
STULTZ, DAVE
Kettering Hospital EP Lab
Phone 937-312-9890

Notes
# Lead data and settings

<table>
<thead>
<tr>
<th>Institution</th>
<th>Kettering Hospital - 3rd Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>S603</td>
</tr>
<tr>
<td>Serial</td>
<td>122305</td>
</tr>
<tr>
<td>Programmer</td>
<td>065046</td>
</tr>
<tr>
<td>Date</td>
<td>12-FEB-2009 10:00</td>
</tr>
</tbody>
</table>

## Measured Data - Lead Impedance

<table>
<thead>
<tr>
<th>Date of last test</th>
<th>Atrial Impedance</th>
<th>Ventricular Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Present</td>
<td>Previous Present</td>
<td>Present</td>
</tr>
</tbody>
</table>

- Impedance
  - 11-FEB-2009
  - 590 530 700 660 Ω
- Amplitude
  - 3.5 3.5 3.5 0.9 V
- Pulse Width
  - 0.50 0.50 0.40 0.80 ms
- Current
  - 6 7 5 1 mA
- Energy
  - 10.4 11.6 7.0 0.5 μJ

## Measured Data - Intrinsic Amplitude

<table>
<thead>
<tr>
<th>Date of last test</th>
<th>Chamber Tested</th>
<th>Measured Amplitude</th>
<th>Lead Configuration (sensed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Present</td>
<td>Atrium</td>
<td>2.1 2.3 mV</td>
<td>Bipolar Bipolar</td>
</tr>
</tbody>
</table>

## Measured Data - Intrinsic Amplitude

<table>
<thead>
<tr>
<th>Date of last test</th>
<th>Chamber Tested</th>
<th>Measured Amplitude</th>
<th>Lead Configuration (sensed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Present</td>
<td>Ventricle</td>
<td>5.6 5.7 mV</td>
<td>Bipolar Bipolar</td>
</tr>
</tbody>
</table>

## Threshold Test Report

### Chamber Tested: Atrium

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Mode</th>
<th>Rate</th>
<th>AV Delay</th>
<th>Ampl</th>
<th>PW</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-Ampl</td>
<td>AAI</td>
<td>90</td>
<td>--</td>
<td>1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>A-Ampl</td>
<td>AAI</td>
<td>90</td>
<td>--</td>
<td>1.6</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>A-Ampl</td>
<td>AAI</td>
<td>75</td>
<td>--</td>
<td>0.7</td>
<td>0.50</td>
</tr>
</tbody>
</table>

### Chamber Tested: Ventricle

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Mode</th>
<th>Rate</th>
<th>AV Delay</th>
<th>Ampl</th>
<th>PW</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V-Auto</td>
<td>VVI</td>
<td>90</td>
<td>--</td>
<td>0.4</td>
<td>0.40</td>
</tr>
</tbody>
</table>

End of Report
Bradycardia settings

| Institution:  
Kettering Hospital - 3rd Floor  
Patient:  
Model: S603  
Serial: 122305  
Software: 2992 |  
Date: 12-FEB-2009  
Time: 10:00  
Programmer: 065046 |
|---|---|

**Brady Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>DDRR</td>
<td>DDDR</td>
</tr>
<tr>
<td>Lower Rate Limit</td>
<td>55 ppm</td>
<td>55 ppm</td>
</tr>
<tr>
<td>Max Tracking Rate</td>
<td>120 ppm</td>
<td>120 ppm</td>
</tr>
<tr>
<td>Max Sensor Rate</td>
<td>120 ppm</td>
<td>120 ppm</td>
</tr>
<tr>
<td>AV Delay (paced)</td>
<td>DYN</td>
<td>DYN</td>
</tr>
<tr>
<td>Atrial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.50</td>
<td>0.50 ms</td>
</tr>
<tr>
<td>Amplitude</td>
<td>3.5 V</td>
<td>3.5 V</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.50</td>
<td>0.50 mV</td>
</tr>
<tr>
<td>Refractory (PVARP)</td>
<td>DYN</td>
<td>DYN</td>
</tr>
<tr>
<td>Ventricular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse Width</td>
<td>0.40</td>
<td>0.40 ms</td>
</tr>
<tr>
<td>Amplitude</td>
<td>AUTO</td>
<td>AUTO</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>2.5</td>
<td>2.5 mV</td>
</tr>
<tr>
<td>Refractory</td>
<td>250 ms</td>
<td>250 ms</td>
</tr>
</tbody>
</table>

**AV Delay**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic AV Delay</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Maximum Delay</td>
<td>350 ms</td>
<td>350 ms</td>
</tr>
<tr>
<td>Minimum Delay</td>
<td>200 ms</td>
<td>200 ms</td>
</tr>
<tr>
<td>Sensed AV Offset</td>
<td>-30</td>
<td>-30 ms</td>
</tr>
<tr>
<td>AV Search Hysteresis</td>
<td>Off</td>
<td>64 cycles</td>
</tr>
<tr>
<td>AV Increase</td>
<td>--</td>
<td>30 %</td>
</tr>
</tbody>
</table>

**Sensor Settings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Activity Threshold</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>30 sec</td>
<td>30 sec</td>
</tr>
<tr>
<td>Response Factor</td>
<td>8</td>
<td>Passive</td>
</tr>
<tr>
<td>Recovery Time</td>
<td>2</td>
<td>2 min</td>
</tr>
<tr>
<td>Minute Ventilation</td>
<td>Off</td>
<td>0</td>
</tr>
<tr>
<td>MV Lead</td>
<td>--</td>
<td>Ventricle</td>
</tr>
<tr>
<td>Response Factor</td>
<td>--</td>
<td>3</td>
</tr>
<tr>
<td>High Rate Response Factor</td>
<td>--</td>
<td>70 %</td>
</tr>
<tr>
<td>High Rate Break Point</td>
<td>--</td>
<td>110 ppm</td>
</tr>
<tr>
<td>Age</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>AutoLifestyle with Exercise</td>
<td>--</td>
<td>Off</td>
</tr>
<tr>
<td>Time Dependent Blend</td>
<td>--</td>
<td>0</td>
</tr>
</tbody>
</table>

**Refractory**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic PVARP</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum PVARP</td>
<td>250 ms</td>
<td>250 ms</td>
</tr>
<tr>
<td>Minimum PVARP</td>
<td>240 ms</td>
<td>240 ms</td>
</tr>
<tr>
<td>PVARP after PVC/PAC</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>V-Blanking after A-Pace</td>
<td>40</td>
<td>40 ms</td>
</tr>
<tr>
<td>A-Blanking after V-Pace</td>
<td>120</td>
<td>120 ms</td>
</tr>
</tbody>
</table>

**A-Tachy Response**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Tachy Response</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Trigger Rate</td>
<td>170</td>
<td>170 bpm</td>
</tr>
<tr>
<td>Duration</td>
<td>8</td>
<td>8 cycles</td>
</tr>
<tr>
<td>Entry Count</td>
<td>8</td>
<td>8 cycles</td>
</tr>
<tr>
<td>Exit Count</td>
<td>8</td>
<td>8 cycles</td>
</tr>
<tr>
<td>Fallback Mode</td>
<td>DDDR</td>
<td>DDI</td>
</tr>
<tr>
<td>Fallback Time</td>
<td>30</td>
<td>30 sec</td>
</tr>
<tr>
<td>Lower Rate Limit</td>
<td>70</td>
<td>70 ppm</td>
</tr>
<tr>
<td>Atrial Flutter Response</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>PMT Termination</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventricular Rate Regulation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Max Pacing Rate</td>
<td>110</td>
<td>110 ppm</td>
</tr>
</tbody>
</table>
# Lead Configuration

<table>
<thead>
<tr>
<th>Lead Configuration</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial Pace</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Atrial Sense</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Atrial Safety Switch</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Ventricular Pace</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ventricular Sense</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ventricular Safety Switch</td>
<td>On</td>
<td>On</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Magnet Response</th>
<th>Initial Value</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet Response</td>
<td>ASYNC</td>
<td>ASYNC</td>
</tr>
</tbody>
</table>

End of Report