Interpreting Pacemaker ECGs: Pearls & Pitfalls

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Disclosures

None
Objectives

• Understand pacing vectors on standard ECGs

• Appreciate some pacemaker “enhancements”

• Review common findings on pacemaker ECGs
Where is the ventricular lead?
Where is the ventricular lead?
Pacemaker Operation (Dual)

• $A_{\text{SENSE}} - V_{\text{SENSE}}$ (Intrinsic rhythm)

• $A_{\text{SENSE}} - V_{\text{PACE}}$ (p-synchronous pacing)

• $A_{\text{PACE}} - V_{\text{SENSE}}$ (Intrinsic conduction)

• $A_{\text{PACE}} - V_{\text{PACE}}$ (AV sequential pacing)
<table>
<thead>
<tr>
<th>Position:</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category:</td>
<td>Chamber(s) Paced</td>
<td>Chamber(s) Sensed</td>
<td>Response to Sensing</td>
<td>Rate Modulation</td>
<td>Multisite Pacing</td>
</tr>
<tr>
<td>O = None</td>
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</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>T = Triggered</td>
<td>R = Rate modulation</td>
<td>A = Atrium</td>
<td>V = Ventricle</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td>I = Inhibited</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>D = Dual (A + V)</td>
<td>D = Dual (A + V)</td>
<td>D = Dual (T + I)</td>
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</tr>
<tr>
<td>Manufacturers’ designation only:</td>
<td>S = Single (A or V)</td>
<td>S = Single (A or V)</td>
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</tbody>
</table>
Pacemaker Modes

• VVI
• DDD
• VOO
• DDI
Pacing mode?

DDD or VDD
Pacing mode?

VOO or VVI
Programmed Settings

- Lower rate limit
- Upper rate limit
- A-V Interval
- Output Voltage
- Output Pulse Width
- Input sensitivity
- Refractory Periods
Programming Outputs

• Conserving energy

• Preserving safety margin

• Managing acute threshold rise (usually for first 4-6 weeks)

• Chronic thresholds
  2-3 X energy
  2-3 X pulse width
Factors in Programming Outputs

- Pacemaker dependency
- Greater safety margin on RV channel
- History of high thresholds
- History of fluctuating thresholds
- Lower safety margin for LV channel
Strength-Duration Curve

- **V amplitude (V)**
- **V pulse width (ms)**

- **Threshold**
- **Programmed values**

- **Chronaxie**
- **Rheobase**

- 2X amp
Threshold (V, μJ, μC)

Chronaxie estimated as threshold pulse duration at 2X rheobase V

Energy

Charge

Rheobase estimated by decreasing the V amplitude at a PW of 1.5 to 2.0 ms

Potential

Rheobase

Chronaxie

Pulse width (ms)
Pacer Spike Rejection

700 mV

2 mV
Simplified ECG Front-end

ECG Leads \rightarrow Amp \rightarrow BPF \rightarrow Slew Limiter \rightarrow dV/dT \rightarrow Amp \rightarrow \mu P
Pacemaker Timing

- Ventricle Based
- Atrial Based
Ventricle Based Timing I

- LRL = 60 BPM = 1000 msec $C_L$

- AV delay = 200 msec

- Calculated VA interval (Atrial Escape Interval) = $1000 - 200 = 800$ msec
Ventricle Based Timing II

• For each Ventricular sensed or paced beat, the atrial escape escape timer will time out after 800 msec

75 BPM

Ventricular
Ventricle Based Timing III

- If the physiologic AV delay is only 150 msec ....

(AV: 600, 800, 150, 80 BPM)

(Ap: 63 BPM)

(Ap: 63 BPM)

(Ap: 63 BPM)
Atrial Based Timing

- The A-A interval tries to remain at the programmed LRL and the AEI is allowed to vary
Relationship of Refractory Periods & Blanking Periods

- AV delay
- PVAB
- Total Atrial Refractory Period
- P-wave alert period
- Ventricular refractory
- Ventricular blanking
- Crosstalk detection window (VSS)
- R-wave alert period
- Absolute portion of PVARP
- Absolute portion of ventricular refractory
AV Interval

Blanking period

Cross talk sensing window

AVI

msec

0 25 50 75 100 125 150 175
Managed Ventricular Pacing®
**AAI(R) Mode**
Atrial based pacing allowing intrinsic AV conduction

**Ventricular Backup**
Ventricular pacing only as needed in the presence of transient loss of conduction

**DDD(R) Switch**
Ventricular support if loss of AV conduction is persistent

**Switching from DDD(R) to AAI(R)**
If AV conduction check passes (1 beat)
DDDR 60-140, AV delay 220 msec
V-A interval (AEI): 780 msec
Pseudo-pseudofusion

Usually due to atrial undersensing

Occurs when intrinsic ventricular rate is ≈ calculated V-A interval { for ventricle-based timing }
Rhythm?
76 year old male with dyspnea and palpitations

19 AF
55 Lateral MI, acute
53 Anterior MI, acute
94 PM malfunction, not sensing
What is the mechanism of tachycardia during atrial threshold testing at setting of DDD 90?

Pacemaker Mediated Tachycardia
<table>
<thead>
<tr>
<th>Mode</th>
<th>Basic Timing</th>
<th>Sensor</th>
<th>Stimulation &amp; Refractory</th>
<th>Post-Shock Pacing</th>
<th>Special Sensing</th>
<th>Special Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A. Output</td>
<td>2.0 V, 0.5 ms</td>
<td>Automatic, Max 0.2 mV</td>
<td>3 months (830 V)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>V. Output</td>
<td>2.0 V, 0.5 ms</td>
<td>Automatic, Max 0.3 mV</td>
<td>Ventricular Blanking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pace Refractories</td>
<td>250 ms</td>
<td></td>
<td>45 ms</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Rate Responsive Refractory (V)</td>
<td>250 ms</td>
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<tr>
<td>Max Track Rate</td>
<td>110 ppm / 545 ms</td>
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<tr>
<td>AV/PV Delay</td>
<td>250 ms / 225 ms</td>
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<tr>
<td>Rate Responsive AV/PV Delay</td>
<td>Medium (&gt;= 50 ms)</td>
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<tr>
<td>Max Sensor Rate</td>
<td>120 ppm / 500 ms</td>
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<tr>
<td>Threshold</td>
<td>Auto (+0,0)</td>
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<tr>
<td>Measured Average Sensor</td>
<td>2.6</td>
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<tr>
<td>Reaction Time</td>
<td>Slow</td>
<td></td>
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<tr>
<td>Recovery Time</td>
<td>Very Slow</td>
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<tr>
<td>Slope</td>
<td>8</td>
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<tr>
<td>AMS</td>
<td>DDDR (Base Rate: 60 ppm)</td>
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</tr>
<tr>
<td>Atrial Tachycardia Detection Rate</td>
<td>170 bpm / 353 ms</td>
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<tr>
<td>PVC Options</td>
<td>Off</td>
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<tr>
<td>PMT Options</td>
<td>A Pace on PMT (Detect: 110 bpm)</td>
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<td>Ventricular Noise Reversion Mode</td>
<td>Pacer Off</td>
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<td>Ventricular Safety Standby</td>
<td>On</td>
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<tr>
<td>Episodal Pacing Mode</td>
<td>DDI</td>
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</tbody>
</table>
Bradycardia with Pacemaker

• Hysteresis

• Sleep Mode

• Ventricular Ectopy

• Malfunction
1. Atrial undersensing
2. Appropriate ventricular sensing

Kenny 2009. The nuts and bolts of paced ECG interpretation
Acknowledgments

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