Principles of Cardiac Pacing

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Pacemakers
Implantable Cardioverter-Defibrillators
## Advances in Device (ICD) Implantation

<table>
<thead>
<tr>
<th></th>
<th>1980 - 1999</th>
<th>2000 - date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implanting physician</td>
<td>Cardiac surgeon</td>
<td>EP or surgeon</td>
</tr>
<tr>
<td>Device size (volume)</td>
<td>120 - 140 mL</td>
<td>≤ 40 mL</td>
</tr>
<tr>
<td>Implant site</td>
<td>Abdominal</td>
<td>Pectoral</td>
</tr>
<tr>
<td>Procedure</td>
<td>Median sternotomy</td>
<td>Skin incision</td>
</tr>
<tr>
<td></td>
<td>Lateral thoracotomy</td>
<td></td>
</tr>
<tr>
<td>Procedure time</td>
<td>2 - 4 hours</td>
<td>1 hour</td>
</tr>
<tr>
<td>Perioperative mortality</td>
<td>2.5%</td>
<td>&lt; 0.5%</td>
</tr>
<tr>
<td>Post-implant hospitalization</td>
<td>3 - 5 days</td>
<td>1 day</td>
</tr>
<tr>
<td>Battery longevity</td>
<td>18 months</td>
<td>Up to 9 years</td>
</tr>
<tr>
<td># Implants</td>
<td>0-2,000/yr</td>
<td>80,000 / year</td>
</tr>
</tbody>
</table>

Evolution of ICD Therapy

1980
- First Human Implant

1985
- FDA Approval of ICDs

1988
- Tiered Therapy

1989
- Transvenous Leads
- Biphasic Waveform

1993
- Smaller Devices

1996
- Steroid Leads
- MADIT

1997/98
- DC ICDs
- AT Therapies
- AVID
- CASH
- CIDS

1999
- MUSTT

2000
- CRT-D

Number of Worldwide ICD Implants Per Year
External Defibrillator
Pacemaker ECG Strips

- Assessing Paced ECG Strips
  - Identify intrinsic rhythm and clinical condition
  - Identify pacer spikes
  - Identify activity following pacer spikes
  - Failure to capture
  - Failure to sense

- EVERY PACER SPIKE SHOULD HAVE A P-WAVE OR A QRS-COMPLEX FOLLOWING IT.
# Pacemaker Codes

<table>
<thead>
<tr>
<th>Position Function</th>
<th>1 Chambers Paced</th>
<th>2 Chambers Sensed</th>
<th>3 Response to Sensed Stimulus</th>
<th>4 Rate Modulation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chambers Paced</td>
<td>O (none)</td>
<td>O</td>
<td>O</td>
<td>O (non-rate responsive)</td>
</tr>
<tr>
<td>Chambers Sensed</td>
<td>A (atrium)</td>
<td>A</td>
<td>T (triggered)</td>
<td>R (rate responsive)</td>
</tr>
<tr>
<td>Response to Sensed Stimulus</td>
<td>V (ventricle)</td>
<td>V</td>
<td>I (inhibited)</td>
<td></td>
</tr>
<tr>
<td>Rate Modulation?</td>
<td>D (both atrium &amp; ventricle)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Principles of Pacing

• Commonly used modes:
  – AAI – atrial demand pacing
  – VVI – ventricular demand pacing
  – DDD – atrial/ventricular demand pacing, senses & paces both chambers; trigger or inhibit
  – AOO – atrial asynchronous pacing
  – VOO – ventricular asynchronous pacing
Normal Pacing

- Atrial pacing
  - Atrial pacing spikes followed by P-waves
Normal Pacing

- Ventricular pacing
  - Ventricular pacing spikes followed by wide, bizarre QRS-complexes
Normal Pacing

• Sequential AV pacing
  – Atrial & ventricular pacing spikes followed by atrial & ventricular complexes
Normal Pacing

- **P-wave synchronous mode of pacing**
  - Ventricle paced at sensed atrial rate
Abnormal Pacing

• Atrial non-capture
  – Atrial pacing spikes are not followed by P-waves
Abnormal Pacing

- Ventricular non-capture
  - Ventricular pacing spikes are not followed by QRS-complexes
Failure to Capture

• Causes
  – Insufficient energy delivered by pacer
  – Low battery voltage
  – Dislodged, loose, fibrotic, or fractured electrode
  – Electrolyte abnormalities
    • Acidosis
    • Hypoxemia
    • Hyperkalemia
Failure to Capture

• **Solutions**
  – View rhythm in different leads
  – Change electrodes
  – Check connections
  – **Increase pacer output**
  – Change battery, cables, pacer
  – Reverse polarity
Abnormal Pacing

- Atrial undersensing
  - Atrial pacing spikes occur irregardless of P-waves
  - Pacemaker is not “seeing” the intrinsic activity
Abnormal Pacing

- **Ventricular undersensing**
  - Ventricular pacing spikes occur regardless of QRS-complexes
  - Pacemaker is not “seeing” the intrinsic activity
Failure to Sense

**Causes**

- Pacemaker not sensitive enough to detect the patient’s intrinsic electrical activity (mV)
- Insufficient myocardial voltage
- Dislodged, loose, fibrotic, or fractured electrode
- Electrolyte abnormalities
- Low battery voltage
Failure to Sense

- Danger – potential (low) for paced ventricular beat to land on T wave (R-on-T phenomenon)
Failure to Sense

• Solutions
  – View rhythm in different leads
  – Change electrodes
  – Check connections
  – Increase pacemaker’s sensitivity
  – Replace cables and/or battery
  – Reverse polarity
  – Check electrolytes
  – Unipolar setting
Oversensing

- Pacing does not occur when intrinsic rhythm is inadequate
Oversensing

- **Causes**
  - Pacemaker inhibited due to sensing of “P” waves & “QRS” complexes that do not exist
  - Pacemaker too sensitive
  - Possible wire fracture, loose contact
  - Pacemaker failure

- **Risks:** heart block, asystole
Oversensing

• Solutions
  – View rhythm in different leads
  – Change electrodes
  – Check connections
  – Decrease pacemaker sensitivity
  – Change cables and/or battery
  – Reverse polarity
  – Check electrolytes
  – Unipolar pacing with subcutaneous “ground wire”
Competition

• Assessment
  – Pacemaker & patient’s intrinsic rates are similar
  – Pacer spikes unrelated to P-waves and/or QRS-complexes
  – Fusion/pseudo-fusion beats
Magnet mode

- Pacemakers: asynchronous pacing
- Defibrillators: suspended detection of arrhythmias
Assessing Underlying Rhythm

- Carefully assess underlying rhythm
  - Right way: slowly decrease pacemaker rate
Assessing Underlying Rhythm

- Wrong way: pause pacer or unplug cables
Pacemaker Wenckebach

- **Assessment**
  - Appears similar to 2\(^{nd}\) degree heart block
  - Occurs with intrinsic tachycardia
Pacemaker Wenckebach

• **Causes**
  - DDD mode safety feature
  - Prevents rapid ventricular pacing impulse in response to rapid atrial rate
    • Sinus tachycardia
    • Atrial fibrillation, flutter
    • Prevents pacemaker-mediated tachycardia
    • Upper rate limit may be inappropriate
• **Solution**
  
  – Treat cause of tachycardia
    
    • Fever: Cooling
    • Atrial tachycardia: Anti-arrhythmic
    • Pain: Analgesic
    • Hypovolemia: Fluid bolus

  – Adjust pacemaker upper rate limit as appropriate
Special scenarios – MVP (Managed Ventricular Pacing)

1. The device operates in DDD/R mode.
2. The device performs an AV conduction check. AV conduction is not detected.
3. The device continues to operate in DDD/R mode.
Practice Strip #1

AAI: normal atrial pacing
Sinus rhythm: no pacing; possible back-up settings are AAI, VVI or DDD
DDD: failure to sense ventricle; increase ventricular sensitivity
Practice Strip #4

VVI: ventricular pacing
Practice Strip #5

DDD: failure to capture atria or ventricle; increase atrial & ventricular output
Practice Strip #6

DDD: normal atrial & ventricular pacing
Practice Strip #7

DDD: normal atrial sensing, ventricular pacing
DDD: failure to sense P-waves; increase atrial sensitivity
Practice Strip #9

DDD: ventricular oversensing; decrease ventricular sensitivity
Thank you!

Questions?