Pacing the Heart

Ayo Ositelu
ECE 5030 Final Presentation
Tuesday, 15 December 2009 @ 1:00pm
Outline

• Background

• Main Features

• New Features
The Cardiac Action Potential

Natural Pacemakers of the Heart

Two Schools of Thought

• *Current density theory*
  • “The critical factor required to induce a regenerative wave front of depolarization is the magnitude of current flowing through a given mass of myocardium…”

• *Electric Field Theory*
  • “The critical factor affecting myocardial depolarization is the magnitude of the electric field that is induced in the myocardium…”
History

Hyman’s Pacemaker of 1932

Accompanying Flow Diagram

http://www.hrsonline.org/News/ep-history/topics-in-depth/hymanspacemaker2.cfm
Components

- Pacemaker Leads
- Pulse Generator
- Power Source (not discussed)
Pacemaker Leads

• “The leads are the only link between the sophisticated electronics in the pulse generator and the heart.”

• Relevant Issues: Polarization, electrode porosity, electrode composition, the electrode-tissue interface, etc.

http://www.hrsonline.org/News/ep...

Clinical Cardiac Pacing, pg 70.
Pacemaker Leads

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg. 74, 75.
Pacemaker Leads

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 86.
Pulse Generator

- Pacing therapy controller
- Output amplifiers
- Sense amplifiers
- Diagnostic subsystem
Pulse Generator

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 113, 114.
New Features

• Sensing
• Telemetry
• Improved SNR
Rate-Adaptive Sensors

- Activity-Sensing Rate-Adaptive Sensors
- Rate-Modulated Pacing Controlled by Mixed Venous Oxygen Saturation
- Temperature-Controlled Rate-Adaptive Pacing
- Rate-Adaptive Pacing Controlled by Dynamic Right Ventricular Pressure (dP/dtmax)
- Rate-Adaptive Pacing Based on Impedance-Derived Minute Ventilation, etc.
Rate-Adaptive Sensors

Kristensson, et al.
Activity-Sensing Sensors

Activity-Sensing Sensors

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 171.
Activity-Sensing Sensors

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 171.
Activity-Sensing Sensors

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 171.
Rate-Adaptive Venous Oxygen Sensor

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 188.
Rate-Adaptive Venous Oxygen Sensor

Rate-Adaptive Venous Oxygen Sensor

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 192.
Temperature-Controlled Sensor

Temperature-Controlled Sensor

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 203.
Temperature-Controlled Sensor

CYCLIC VARIATION DURING DEEP SLEEP

Ellenbogen, Kay, and Wilkoff. Clinical Cardiac Pacing, pg 203.
Temperature-Controlled Sensor

Temperature-Controlled Sensor

Fearnot, et al.
Manufacturer Overview

• Biotec, S.P.A., Bologna, Italy
• Biotronik, GmbH & Co., Berlin, Germany
• Cardiac Pacemakers Inc., St. Paul, MN
• Cook Pacemakers Corporation, Leechburg, PA
• Ela Medical, Rougermont, France
• Intermedics Inc., Angleton, TX
• Medtronic Inc., Minneapolis, MN
Manufacturer Overview

- Siemens Ltd., Solna, Sweden
- Sorin Biomedica, Saluggia, Italy
- St. Jude Medical, Inc, St. Paul, MN
- Teletronics Pacing Systems, Englewood, CO
- Vitatron Medical B.V., Dieren, The Netherlands.
### Manufacturer Overview

<table>
<thead>
<tr>
<th>METHODS</th>
<th>PHYSIOLOGIC PARAMETERS</th>
<th>EXAMPLES</th>
<th>MODELS</th>
<th>MANUFACTURERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impedance sensing</td>
<td>Respiratory rate</td>
<td>Biorate</td>
<td>Biotec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minute ventilation</td>
<td>Meta</td>
<td>Telectronics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stroke volume, prejection period, right ventricular ejection time</td>
<td>Chorus RM</td>
<td>Ela Medical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Legend plus</td>
<td>Medtronic Inc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Precept</td>
<td>CPI</td>
<td></td>
</tr>
<tr>
<td>Ventricular evoked response and</td>
<td>Evoked QT interval</td>
<td>TX, Quintech, Rhythmx</td>
<td>Viatron</td>
<td></td>
</tr>
<tr>
<td>output pulse parameter sensing</td>
<td>Evoked R-wave area (&quot;gradient&quot;)</td>
<td>Prism CL</td>
<td>Telelectronics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trailing edge of output pulse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration sensing</td>
<td>Body movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special sensors on pacing electrode</td>
<td><strong>Physical Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Central venous temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. $\Delta P/\Delta t$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Average atrial rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Right atrial pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Pulmonary arterial pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Chemical Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. $pH$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Mixed venous oxygen saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Catecholamine levels</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ellenbogen, Kay, and Wilkoff. *Clinical Cardiac Pacing*, pg 144.
Telemetry

• “Telemetry involves the transmission of information from the pulse generator to an external programmer.”

• Battery voltage and impedance, stimulus current, voltage, and energy, lead resistance, intracardiac electrograms, and stored histograms of pace and sensed data retrievable from telemetry
Telemetry

Biotronik Home Monitoring®

Medtronic CareLink®
Network Monitoring Device
Improving SNR

• Federica Censi, et al. studying the effects of electromagnetic interference on pacemakers.

• RF feedthrough filters
References