Introduction to Biomedical Engineering
Cardiac Bioelectricity

Part 7. Cardiac implantable devices

http://efimov.cwru.edu/teaching

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References

Handouts and slides are at my WEB-site:
http://efimov.cwru.edu/teaching

Username: member
Password: member

Approaches to the Heart Disease Therapy

- Healthy lifestyle and diet: the best, but often too late :o(
- Invasive therapy: cardiac surgery, angioplasty or ablation procedure: excellent outcome, but not always possible :o(
- Pharmacological (drug) antiarrhythmic therapy: a chain of disappointments in clinical trails of 1980-90s…
- Device therapy: impressive results, yet still has unresolved questions…

Types of Implantable Devices

- Fully implantable artificial heart (replaces the heart)
- Left ventricular assist device (takes over part of the function)
- Implantable pacemaker (controls heart rhythm)
- Implantable defibrillator (jump-starts the heart in case of cardiac arrest)
- Implantable ECG monitors (precise diagnostics of rare events)
- Implantable drug delivery systems (yet to be produced)
Kaplan–Meier Estimates of the Rates of Overall Mortality According to Whether the Patients Received Treatment with a Defibrillator

The P value refers to two comparisons: between the patients in the group assigned to electrophysiologically guided (EPG) therapy who received treatment with a defibrillator and those who did not receive such treatment, and between the patients assigned to electrophysiologically guided therapy who received treatment with a defibrillator and those assigned to no antiarrhythmic therapy.


Kaplan–Meier Estimates of the Rates of Cardiac Arrest or Death from Arrhythmia According to Whether the Patients Received Treatment with a Defibrillator

The P value refers to two comparisons: between the patients in the group assigned to electrophysiologically guided (EPG) therapy who received treatment with a defibrillator and those who did not receive such treatment, and between the patients assigned to electrophysiologically guided therapy who received treatment with a defibrillator and those assigned to no antiarrhythmic therapy.

Cardiac implantable devices

- Implantable Pacemaker (treatment of bradycardia)
- Implantable Cardioverter Defibrillator (treatment of tachycardia and fibrillation)
- ECG Loop Recorders (Implantable Holter monitor)
Indications for Implantable Cardiac Pacemaker

- Complete Heart Block (AV node does not conduct impulses)
- Sinus Bradicardia (slow SA node)
- Following AV node ablation (treatment for atrial arrhythmias)

Unipolar and bipolar pacing
Passive Implantable Lead

Active Fixation Pacing Lead
Encapsulation of implantable lead results in additional resistive isolation of the lead

Implantation causes local inflammation process, which results in collagen network formation around implantable lead. Worsening of sensing and pacing efficacy results.

Steroid-eluting lead design is used to prevent inflammation and resulting encapsulation
Asynchronous cardiac pacemaker (VOO)

- Power supply → Oscillator → Output circuit → Lead wires → Electrodes

Constant voltage pacing: ~ 5.0 V, ~ 0.5 msec
Constant current pacing: ~ 10 mA, ~ 1 msec
Rate: 60-150 bpm

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Rate-responsive pacemaker (DDDR)

- Sensor → Controller circuit → Output circuit → Electrode system
- Telemetry → Control algorithm
- Programmer

Two functions of leads: Pacing & Sensing

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Pacemaker Nomenclature (NBG Code)

<table>
<thead>
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<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s) paced</td>
<td>Chamber(s) sensed</td>
<td>Response to sensing</td>
<td>Programmability, rate modulation</td>
</tr>
<tr>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>T = Triggered</td>
<td>P = Simple programmable</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td>I = Inhibited</td>
<td>M = Multiprogrammable</td>
</tr>
<tr>
<td>D = Dual (A+V)</td>
<td>D = Dual (A+V)</td>
<td>D = Dual (T+I)</td>
<td>C = Communicating R = Rate modulation</td>
</tr>
</tbody>
</table>

Examples

- VVIR – Pace ventricle, sense ventricle, inhibit on sensed beat, rate responsive (problems with atrium)
- DDDR – Pace both chambers, sense both chambers, inhibit on V or trigger on A, rate responsive (problem with AV node)
- AAIR – pace atrium, sense atrium, inhibit on sensed beat, rate responsive (problems with low atrial signal)
Implantable cardioverter-defibrillator

Three types of ICD lead configurations:

<table>
<thead>
<tr>
<th></th>
<th>sensing</th>
<th>shock anode and cathode</th>
<th>connector</th>
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<td>I</td>
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Indications for Implantable Cardioverter-Defibrillators (ICD)

• History of Ventricular Tachycardia (VT)

• History of Ventricular Fibrillation (VF)

• Defibrillation: Application of a large electric shock to terminate VF and reset normal sinus rhythm

• Cardioversion: Application of a large appropriately synchronized electrical shock to terminate VT and reset normal sinus rhythm

Important Considerations

• Most people will not survive the first episode of VT/VF ⇒ better methods are needed to identify people at risk of sudden cardiac death !!!

• 50% change of surviving second episode without ICD

• 98% chance of survival the second episode with ICD
Implantable Defibrillator

heart rhythm normal? → deliver defibrillation shock

sensor → controller circuit → output circuit → electrode system

telemetry → control algorithm → implanted

ICD development during 1980-2000

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Components of an implantable ICD

**Electronic packaging**

Custom-designed Ventrithex components

- Optimize shape, size and performance, making the Angstrom device the thinnest, smallest ICD ever.
- Flatcap™ Capacitors
- Transformer

More efficient electronic packaging

- Means a customized shape without compromised performance.
- Telemetry Coil
- Protect Module
- Passives
- Reed Switch
- SRAM
- Charge Module
- EMI Filter
- MCM
- Exo-frame
- Output Module
- Transformer
Implantable subcutaneous loop recorder

The Reveal Insertable Loop Recorder continuously monitors the rate and rhythm of the heart. It works much like a black box in an airplane, whereby vital information is recorded during the actual fainting episode and can be played back later for detailed analysis. The Reveal Insertable Loop Recorder can continuously record the heart's rate and rhythm for up to 14 months.

© http://www.medtronic.com/reveal/new.html

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Next:

TEST

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