Right Ventricular Pacing: The Evidence and Ways to Optimize for Patients

Melanie T. Gura, RN, MSN, CNS, CCDS, FHRS, FAHA
Director, Pacemaker & Arrhythmia Services
Northeast Ohio Cardiovascular Specialists
Akron, OH
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Clinical History

- 69 year-old Female
- Sick Sinus Syndrome
- Dual Chamber Pacing System 2004
- Very Active, Avid Golfer
Presenting Rhythm Strip 1.10.05.

DDI/50
Reports Fatigue, SOB, Unable to Golf 5.11.06

DDI/50

When to Pace?
How Much do we Pace?
How do we Minimize RV Pacing?
Objectives: Minimizing RV Pacing

- Brief Review Clinical Trial Data
  - Clinical Significance
  - Deleterious Effects of RV Pacing

- Strategies to Minimize RV Pacing
  - Advantages
  - Disadvantages

- New Paradigm for Physiologic V Pacing
Physiologic Pacing 2008: BD and AD

1990 AV Sequential Pacing

2008 Atrial pacing with intrinsic Ventricular Conduction

Clinical attempts to preserve normal ventricular activation
Maintain AV Synchrony
Maintain Ventricular Synchrony
## Forced RV-Pacing: Detrimental Effects
### Desynchronization of ventricular activation & conduction

<table>
<thead>
<tr>
<th></th>
<th>Danish II Trial</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>AAI(R) vs DDD(R) w/short AV vs DDD(R) w/long AV</td>
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</table>

<table>
<thead>
<tr>
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<th>CTOPP Trial</th>
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<tbody>
<tr>
<td></td>
<td>DDD(R) or AAI(R) vs VVI(R)</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>DAVID Trial</th>
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<tbody>
<tr>
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<td>DDD(R) vs VVI ICDs</td>
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<table>
<thead>
<tr>
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<th>MOST Substudy</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>DDDR vs VVIR</td>
</tr>
</tbody>
</table>

### HF Hospitalization
- Not specifically measured; study indicates that high proportion of RV pacing reduces LV function
- Not measured
- 1 yr event-free rate of composite endpoint (death or HFH) was worse in DDDR group when %V-pacing > 40%
- 2.6-fold increased risk when % V-pacing > 40% (for DDDR group)

### Hemodynamic Performance
- Long-term DDDR pacing induces LA dilation and a high proportion of RV pacing decreases LV function
- Patients with preserved LV function, no history of MI or CAD derived most benefit from physiologic pacing
- Supports conclusion that ventricular dysynchrony imposed by RV-pacing may be most dramatic in patients with failing left ventricles

### Incidence of AF
- Freedom from AF during follow-up is significantly better with AAIIR pacing (p = 0.03); 17% RV-pacing in DDDR-I group
- Physiologic pacing reduces annual rate of development of chronic AF
- Not measured
- Risk increased linearly by 1% for each 1% increase in V-pacing (up to ~ 85%)
Mode Selection Trial

Hypothesis

DDDR would be Superior to VVIR in Patient Outcomes
MOST Sub-Study:
Relationship between Mode, % VP & HF

- Cum%VP was greater in DDDR (90%) vs. VVIR (51%)
- AF increased by 1% for each 1% VP
- The rates of CHF hospitalization increased with Cum% VP
- For every 10% increase in VP, 50% increase in HFH


2.6-fold increase in risk when % VP > 40% (DDDR Group)
Hypothesis:

DDDR Pacing at 70 PPM would enable optimal HF Management and reduce HFH and death compared to Ventricular back-up pacing.
# DAVID: Results

<table>
<thead>
<tr>
<th></th>
<th>VVI-40</th>
<th>DDDR-70</th>
<th>HR</th>
<th>(p-value, adj.)</th>
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</thead>
<tbody>
<tr>
<td>CHF Hospitalization or Death</td>
<td>16.1%</td>
<td>26.7%</td>
<td>1.61</td>
<td>(p = 0.03)</td>
</tr>
<tr>
<td>CHF Hospitalization</td>
<td>13.3%</td>
<td>22.6%</td>
<td>1.54</td>
<td>(p = 0.07)</td>
</tr>
<tr>
<td>Death</td>
<td>6.5%</td>
<td>10.1%</td>
<td>1.61</td>
<td>(p = 0.15)</td>
</tr>
</tbody>
</table>

More than 40% ventricular pacing was associated with increased CHF hospitalizations.

DAVID Subanalysis

**Number at risk:**

<table>
<thead>
<tr>
<th></th>
<th>Months</th>
<th>DDDR&gt;40%</th>
<th>VVI</th>
<th>DDDR≤40%</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>126</td>
<td>195</td>
<td>59</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>70</td>
<td>118</td>
<td>35</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>26</td>
<td>47</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDDR&gt;40% vs. DDDR&lt;40%</td>
<td>0.03</td>
</tr>
<tr>
<td>DDDR&gt;40% vs. VVI</td>
<td>0.07</td>
</tr>
</tbody>
</table>

DDDR >40% VP Increased risk of HFH

Sharma AD. Heart Rhythm 2: 830-834, 2005
DAVID: Consistent with the pacing literature

- AAI was associated with slightly better survival and lower rate of severe CHF compared to VVI pacing mode in patients with SSS \(^1\)

- QOL was better in elderly patients with sinus node disease with VVI compared to DDD pacing \(^2\)

- **More than 40% ventricular pacing** was associated with increased CHF hospitalizations \(^3\)

- The benefit of DDDR pacing was most evident in patients who needed continuous pacing \(^4\)

---

Deleterious Effects of RV Apical Pacing

- Dysynchronous activation & contraction sequence
  - Early and Delayed regions
- ↓ Systolic function
  - Highly predictive of ↓ LVEF >7 EF points
- ↓ Diastolic function
  - Impaired relaxation
- Asymmetric hypertrophy
  - Early: thinned
  - Late: hypertrophied
- ↓ Coronary flow
- Cellular disarray

Inhibition of Unnecessary RV Pacing with AV Search Hysteresis in ICDs

**INTRINSIC RV**

Does DDDR pose an inherent safety risk?
AV Search Hysteresis (AVSH) in ICDs

Inhibition of unnecessary RV Pacing

ICD-recipients RV Pacing <20% at 1 wk
No permanent AF.

AV Search Hysteresis (AVSH) in ICDs

U-Curve—is less better?

Conclusion: Culprit is % VP not Device

- Compared to back-up VVI pacing, DDDR pacing does not adversely affect outcomes in ICD recipients when RV pacing is kept to a minimum.

- The notion that dual-chamber programming poses an inherent safety risk is incorrect.

- With AV Search Hysteresis, outcomes with dual-chamber programming were as good, if not better, than with single-chamber programming.

- Dual-chamber programming should strongly be considered for appropriate patients.
The Dual Chamber And VVI Implantable Defibrillator Trial

DAVID II
Primary Outcome
Death or Re-hospitalization for New or Worsened CHF

---AAI-70
---VVI-40

Wilkoff et al. DAVID II 2007
Conclusions

In patients with LV dysfunction who need an ICD but have no indications for pacing . . .

- The effect of atrial-based pacing (AAI-70) on event-free survival is not substantially worse than, and is likely equivalent to ventricular back-up pacing (VVI-40)

- Atrial (AAI-70) pacing may be considered a “safe alternative,” but affords no clear advantage nor disadvantage over ventricular back-up (VVI-40) pacing

Wilkoff et al. DAVID II 2007
Forced RVA-Pacing: Cascade of Events Resulting in Structural & Electrical Remodeling

- Atrial Stretch
- Valvular Regurgitation
- Neurohormones
- PACs
- Retrograde conduction
  - Asymmetric hypertrophy
- AERPs
- Ventricular Function
  - Systolic & Diastolic
- Dysynchronous Contraction
Physiologic Pacing: The Weight of Evidence

AV Synchrony

RV Pacing frequency rather than lack of AV synchrony increases risk of HF

Potential benefits of “Physiologic Pacing” may be offset by RV Pacing

Ventricular Activation Sequence
Optimization of pacemaker programming to minimize unneeded RV pacing is encouraged

The New Goals of Pacing Therapy

- **Bradycardia-indicated patients** (pacemaker and ICD patients)
  - Prevent symptomatic bradycardia
  - Provide chronotropic competence when necessary
  - Maintain AV Synchrony when possible
  - Maintain normal ventricular activation sequence whenever possible

- **Non-Bradycardia Patients** (ICD patients with no brady indications)
  - VT/VF detection
  - Maintain normal ventricular activation sequence whenever possible
Strategies to Minimize RV Pacing

**Traditional Approaches**
- VVI, VVIR
- AAI, AAIR
- DDI, DDIR
- Long Fixed AVD

**Limitations**
- Non-optimal in SND
- Risk of AV Block
- Functionally VVIR (no AV Synchrony if SR>LRL)
- Limits UR & AT/AF detection: PMTs
**AAI/R Pacing: Too Risky?**

- **AAI Pacing**
  - Preserves a normal ventricular activation sequence
  - Requires stable long-term AV conduction and sinus rhythm

- **SND is a spectrum of electrical disorders that includes AF and AV block**

- **AAI pacing is ineffectual for ventricular bradycardia during**
  - Paroxysmal and permanent AF
  - AV block
AAI/R Pacing: Too Risky?

Incidence of Syncope During AV Block

<table>
<thead>
<tr>
<th>% Patients</th>
<th>AVB</th>
<th>SYNCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson 1998</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Clarke 1998</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Kristensen 2001</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Nielsen 2003</td>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>

First Clinical Manifestation may be Syncope due to High Grade AVB

Incidence of AVB 4.5% per annum

Mean 0.6%
DDI/R Mode

- Permits long AV delays without the possibility of upper rate limit tracking during AF (unlike DDDR).
  - However, limitations of long AV delays in reducing ventricular pacing still persist.

- Unique limitations imposed by DDIR mode
  - Operationally VVIR during AV block if sinus rate exceeds lower rate limit.
  - Competitive atrial pacing during sensor-modulation may precipitate AF.
    - Can be mitigated with a non-competitive atrial pacing algorithm

- May be more applicable to the ICD population
  - Lower prevalence of AV block compared to conventional brady pacing population.
Strategies to Minimize RV Pacing

DDI, DDIR
What is the most appropriate next step?

- A: Reprogram to DDDR
- B: Reprogram to DDD
- C: Decrease AVD
- D: Increase AVD
- E: Increase URL
B: Reprogram to DDD
Strategies to Minimize RV Pacing

**DDD/R + Long AV Delays**

- **Advantages**
  - AV Synchrony
  - Provides VP Support during AVB
  - “Functional” AAI/R if AV conduction is reliable
  - Reduces RV Pacing

- **Efficacy**
  - Mean cum% VP can be reduced to 10-20% in many patients but is still > 50% in some patients
Strategies to Minimize RV Pacing

**DDD/R + Long AV Delays**

- RVA Pacing at long AVD (>300 ms) non-physiologic
  - Impaired LA function
  - Diastolic MR
  - Reduced Cardiac output

- DDD operation lockouts
  - Reduced URL
  - PMTs

- ICDs:
  - Interlocks: URL, MSR, VTDI
  - Competitive pacing: VT detection failure
Risks of a Long AV Delay
Repetitive Non-reentrant VA Synchrony (RNRVAS)

Better Option: AVD of 250 ms with Auto Functions

What is the most appropriate next step?

- A: Increase AVD
- B: Increase the URL
- C: Increase the A output
- D: Decrease the AVD
- E: Program off AMS
Better Option: AVD of 250 ms with Auto Functions
Strategies to Minimize RV Pacing
Pacemaker/ICD DDD+ Algorithms

- Search AV+
- Search AVD hysteresis
- Intrinsic conduction search
- AAI to DDD(R) mode switch: AAI<-->DDD
  - AAI safe R pacing mode
  - Managed Ventricular Pacing
  - Ventricular Intrinsic Preference
Atrioventricular Interval Search

- Search AV periodically measures AV intervals
- Adapts PAV/SAV to encourage intrinsic conduction
- Continuously adapted to promote intrinsic conduction in patients with intact or intermittent conduction

Search AV extension
Auto Search A-V Histograms

Collected Data - Auto Search A-V Histogram

Over Last 29 days

Initial Interrogation
- Mode: DDDR
- Lower Rate: 60 ppm
- Upper Track: 120 ppm
- Upper Sensor: 155 ppm
- Paced AV: 150 ms
- Sensed AV: 120 ms
- Search AV: Adaptive

A-V Sequences
- Total Sequences: 2,726,367
- A-VS: 3.1%
- VS from Search: 63.4%
- A-VP: 13.4%
AutoIntrinsic Conduction Search™

- In Dual chamber modes, this feature searches for intrinsic ventricular (R-wave) conduction and adjusts the AV/PV delay to encourage intrinsic conduction.

- Automatically searches for intrinsic R-wave conduction every 5 minutes for 1 cycle.

- Adds the programmed delta to the AV/PV delay (AV/PV hysteresis).
**AutoIntrinsic Conduction Search**

- Program the desired AV/PV delay as if AV block were present
  - AV 225 ms, PV 175 ms

- Program desired delta (e.g. 100 ms)

![Diagram showing functional AR and programmed AV]
Clinical History

- 53 y.o. presents for ICD evaluation
- ASHD
- HTN
- Hyperlipidemia
- S/P Inferior Wall MI 1998
- S/P CABG 3/98
- LVD w EF 40% (+/- 5% 2000)
- Freq long episodes NSVT
- EPS
  - IVT at initial cycle length of 230 ms
  - Mild first degree AVB at or below the level of the His bundle
Clinical & Device History

- Dual Chamber ICD implanted 2002
- Clinical VT with appropriate HV shock therapy and conversion
- Second ICD implanted 2004 due to ERI
  - ICD: GDT: A155 Vitality AVT 12.16.02
  - A Lead: 2.4.00 Intermedics 438-10 Thinline
  - V Lead: 2.4.00 GDT 0144
- Very active, hunts, works construction
Brady Counters and Histograms

<table>
<thead>
<tr>
<th>counters - Brady</th>
<th>05-FEB-2008 to 09-MAY-2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>atrial</td>
<td>Percent</td>
</tr>
<tr>
<td>paced</td>
<td>21%</td>
</tr>
<tr>
<td>single PACs</td>
<td>76%</td>
</tr>
<tr>
<td>double PACs</td>
<td>2.4K</td>
</tr>
<tr>
<td>pace or More PACs</td>
<td>2.1K</td>
</tr>
<tr>
<td>R Switches</td>
<td>00:00</td>
</tr>
<tr>
<td>minimum Duration</td>
<td>00:00</td>
</tr>
<tr>
<td>maximum Duration</td>
<td>970</td>
</tr>
<tr>
<td>SPO Switch Time</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

intricular

| paced | 31% | 3.1M | 38% | 39.0M |
| paced | 69% | 7.1M | 70% | 92.4M |
| single or Double PVCs | 614.4K | 8.1M | 6.0K | 614.4K |
| pace or More PVCs | 1.1K | 2.6K | 5.4K | 1.1K |
| tachy or Rapidly | stage | | | |
| Hysteretic Searches | 0 | 0 | 0 | 0 |
| successfull Searches | 0 | 0 | 0 | 0 |
| Hysteretic Successfull Searches | 0 | 0 | 0 | 0 |
| successfull Searches | 0 | 0 | 0 | 0 |
| tachy Hysteretic Searching | | | | |
| atrial | | | | |
| paced | | | | |
| single or Double PVCs | | | | |
| pace or More PVCs | | | | |
| intricular | | | | |
| paced | | | | |
| single or Double PVCs | | | | |
| pace or More PVCs | | | | |
| of Report | | | | |

MT Gura 521 JL
Presenting ECG & EGM
## AV Delay Brady Programming

### AV Delay

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic AV Delay</td>
<td>On</td>
</tr>
<tr>
<td>Maximum Delay</td>
<td>300 ms</td>
</tr>
<tr>
<td>Minimum Delay</td>
<td>100 ms</td>
</tr>
<tr>
<td>Sensed AV Offset</td>
<td>Off ms</td>
</tr>
<tr>
<td>AV Search Hysteresis</td>
<td>Off cycles</td>
</tr>
<tr>
<td>Search Interval</td>
<td></td>
</tr>
<tr>
<td>AV Increase</td>
<td>-- %</td>
</tr>
</tbody>
</table>

### Refractory

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic PVARP</td>
<td>On</td>
</tr>
<tr>
<td>Maximum PVARP</td>
<td>250 ms</td>
</tr>
<tr>
<td>Minimum PVARP</td>
<td>240 ms</td>
</tr>
<tr>
<td>PVARP after PVC</td>
<td>Off ms</td>
</tr>
<tr>
<td>Dynamic VRP</td>
<td>On</td>
</tr>
<tr>
<td>Maximum VRP</td>
<td>250 ms</td>
</tr>
<tr>
<td>Minimum VRP</td>
<td>240 ms</td>
</tr>
</tbody>
</table>
What is the most appropriate programming step?

- A: Program off Dynamic AVD
- B: Program Sensed AV offset to 30 ms
- C: Program on AV Search Hysteresis
- D: Increase the minimum AVD
- E: Don’t know
### Brady Counters and Histograms

09-MAY-2008 to 12-AUG-2008

#### Atrial

<table>
<thead>
<tr>
<th>Event</th>
<th>Percent</th>
<th>Since Last Reset</th>
<th>Percent</th>
<th>Device Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paced</td>
<td>8%</td>
<td>798.6K</td>
<td>24%</td>
<td>31.2M</td>
</tr>
<tr>
<td>Sensed</td>
<td>92%</td>
<td>9.2K</td>
<td>76%</td>
<td>100.8K</td>
</tr>
<tr>
<td>Single PACs</td>
<td>146.8K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double PACs</td>
<td>5.3K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three or More PACs</td>
<td>2.1K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATR Switches</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Duration</td>
<td>00:00 m:s</td>
<td></td>
<td>00:00 m:s</td>
<td></td>
</tr>
<tr>
<td>Maximum Duration</td>
<td>00:00 m:s</td>
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<td>00:00 m:s</td>
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<tr>
<td>VT</td>
<td>0</td>
<td></td>
<td></td>
<td>970</td>
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</table>

#### Ventricular

<table>
<thead>
<tr>
<th>Event</th>
<th>Percent</th>
<th>Since Last Reset</th>
<th>Percent</th>
<th>Device Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paced</td>
<td>2%</td>
<td>234.3K</td>
<td>28%</td>
<td>39.2K</td>
</tr>
<tr>
<td>Sensed</td>
<td>98%</td>
<td>10.7K</td>
<td>72%</td>
<td>103.1K</td>
</tr>
<tr>
<td>Single or Double PVCs</td>
<td>784.5K</td>
<td></td>
<td></td>
<td>8.9K</td>
</tr>
<tr>
<td>Three or More PVCs</td>
<td>1.7K</td>
<td></td>
<td></td>
<td>5.3K</td>
</tr>
</tbody>
</table>

#### Histograms - Since Last Reset

- **Atrial**: VT, SVT, Rhythm
- **Ventricular**: PVC, VF, VT, SVT
Strategies to Minimize RV Pacing: MVP™

MVP is designed to provide functional AAI(R) pacing mode while providing the safety of dual chamber ventricular pacing in the presence of persistent or transient loss of conduction.

The key benefit is a reduction in unnecessary RV pacing due to the promotion of AV synchrony.
Ventricular intrinsic Preference: VIP™

PAVD/SAVD extended 160 ms x 3 cycles

If it does not find an intrinsic R wave the AVD returns to its programmed value

Can operate up to rates of 110 ppm. ACIS up to rates of 90 ppm

Longest AV/PVD 350 ms
<table>
<thead>
<tr>
<th>Pacing Indication</th>
<th>Potential Strategy to Reduce RV Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus node disease</td>
<td>AAI(R) pacing mode</td>
</tr>
<tr>
<td>First-degree AV block (PR&lt;250ms)</td>
<td>Long programmed AV delay</td>
</tr>
<tr>
<td></td>
<td>Automatic AV prolongation algorithms</td>
</tr>
<tr>
<td>First-degree AV block (PR&gt;250ms)</td>
<td>Proprietary algorithms</td>
</tr>
<tr>
<td>Mobitz I AV block</td>
<td>– MVP</td>
</tr>
<tr>
<td>Intermittent high-grade AV block</td>
<td>– AAISafeR</td>
</tr>
<tr>
<td>Permanent high-grade AV block</td>
<td>RV septal pacing</td>
</tr>
<tr>
<td>AF with bradycardia</td>
<td></td>
</tr>
<tr>
<td>AV node ablation</td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis

Dual Chamber Pacing incorporating to minimize RV pacing would lead to a lower risk of developing persistent atrial fibrillation compared to conventional dual chamber pacing in patients with SNS.
**SAVE PACe**

**Results**

- **Trial stopped early** after interim analysis met superiority criteria of dual-chamber minimal ventricular pacing

- **Median % of ventricular beats paced ↓** in dual-chamber minimal ventricular pacing group vs. conventional dual-chamber pacing group (9.1% vs. 99.0%, p < 0.001)

- **No difference in % of atrial beats paced** between groups (71.4% vs. 70.4%, p = 0.96)

- **Primary endpoint of persistent AF ↓** in minimal ventricular pacing group (Figure, HR 0.60)

- **No difference in mortality**

*N Engl J Med 2007;357:1000-8*
Clinical History

- 79 year-old male
- CAD
- S/P AWMI 2001
- EF 30%
- MDT Intrinsic 7288 5.6.06
  - A: 5076 CapsureFix Novus
  - V: 6949 Sprint Fedelis
### Clinical History: Programmed Parameters

#### Detection

<table>
<thead>
<tr>
<th>Enable</th>
<th>Initial</th>
<th>Redetect</th>
<th>V Interval (Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>On</td>
<td>18/24</td>
<td>6/8</td>
</tr>
<tr>
<td>FVT</td>
<td>via VF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VT</td>
<td>Monitor</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### PR Logic

- AFib/AFflutter: On
- Sinus Tach: On
- Other 1:1 SVTs: Off
- SVT Limit: 280ms

#### Modes/Rates

<table>
<thead>
<tr>
<th>Mode</th>
<th>AAIR&lt;&gt;DDDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode Switch</td>
<td>On</td>
</tr>
<tr>
<td>A. Detect Rate</td>
<td>175bpm</td>
</tr>
<tr>
<td>Lower Rate</td>
<td>60ppm</td>
</tr>
<tr>
<td>Upper Tracking Rate</td>
<td>120ppm</td>
</tr>
<tr>
<td>Upper Sensor Rate</td>
<td>120ppm</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>A-V Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paced AV</td>
</tr>
<tr>
<td>Sensed AV</td>
</tr>
<tr>
<td>Rate Adaptive AV</td>
</tr>
<tr>
<td>Start Rate</td>
</tr>
<tr>
<td>Stop Rate</td>
</tr>
<tr>
<td>Minimum Paced AV</td>
</tr>
<tr>
<td>Minimum Sensed AV</td>
</tr>
</tbody>
</table>

#### Brady Pacing

##### Atrial Lead

- Amplitude: 2V
- Pulse Width: 0.5ms
- Sensitivity: 0.3mV
- Pace Blanking: 200ms

##### Ventricular Lead

- Amplitude: 2V
- Pulse Width: 0.5ms
- Sensitivity: 0.3mV
- Pace Blanking: 200ms

<table>
<thead>
<tr>
<th>Refractory</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVARP</td>
</tr>
<tr>
<td>PVAB</td>
</tr>
</tbody>
</table>

#### Rate Response

- Rate Response: 7
- Activity Threshold: Medium Low
- Activity Acceleration: 30 sec
- Activity Deceleration: 5 min
Reports ICD Therapy during Sleep
Remote Evaluation
Clinical History

- A 69 y.o. female recently in the hospital for respiratory failure-discharged to Rehab facility
- PMH: CAD, CHF, COPD, SSS, A Fib
  - S/P dual chamber pacemaker
- Presents to ED with reports
  - Feeling very weak over the last couple of days
  - Increase in SOB
  - Increase in fatigue
Physical Exam

- BP 107/77
- Pulse ox: 97% on her normal 3 liters
- Cor: Irregular heart rate
- Chest: Diminished breath sound bilaterally
- Ext: Trace pedal edema
- CXR revealed chronic changes-no acute findings
Presenting ECG
Switch from AAI(R) to Temporary DDD(R) Mode

Switch to DDD(R) if two out of four previous A-A intervals had loss of ventricular conduction.
<table>
<thead>
<tr>
<th></th>
<th>Boston Scientific&lt;sup&gt;1&lt;/sup&gt; ALTRUA™</th>
<th>Boston Scientific&lt;sup&gt;1&lt;/sup&gt; ALTRUA™</th>
<th>Medtronic&lt;sup&gt;2&lt;/sup&gt; ADAPTA™</th>
<th>Medtronic&lt;sup&gt;3&lt;/sup&gt; EnRhythm™</th>
<th>St Jude&lt;sup&gt;4&lt;/sup&gt; ZEPHYR™</th>
<th>St Jude&lt;sup&gt;5&lt;/sup&gt; VICTORY™</th>
<th>Biotronik&lt;sup&gt;6&lt;/sup&gt; CYLOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial Arrhythmia Management</td>
<td>Ventricular Rate Regulation (VRR)</td>
<td>Ventricular Rate Regulation (VRR)</td>
<td>Atrial Preference Pacing &amp; Conducted AF Response</td>
<td>Atrial ATP, Reactive ATP, Atrial Preference Pacing, Post Mode Switch Overdrive Pacing</td>
<td>Max AF Suppression™</td>
<td>Max AF Suppression™</td>
<td>n/a</td>
</tr>
<tr>
<td>Ventricular and Atrial Capture</td>
<td>Automatic Capture™ (V only)</td>
<td>None</td>
<td>Capture Management (A&amp;V)</td>
<td>None</td>
<td>AutoCapture™ (V) and ACap™ Confirm (A)</td>
<td>AutoCapture™ (V only)</td>
<td>Active Capture Control (ACC) (V only)</td>
</tr>
<tr>
<td>RV Pacing Minimization</td>
<td>AV Search Hysteresis (AVSH)</td>
<td>AV Search Hysteresis (AVSH)</td>
<td>MVP™ Search AV™ +</td>
<td>MVP™</td>
<td>Ventricular Intrinsic Preference (VIP)</td>
<td>Ventricular Intrinsic Preference (VIP)</td>
<td>AV Hysteresis</td>
</tr>
<tr>
<td>Longest Programmable AV Delay</td>
<td>400 ms</td>
<td>300 ms</td>
<td>350 ms</td>
<td>350 ms</td>
<td>350 ms</td>
<td>350 ms</td>
<td>300 ms</td>
</tr>
<tr>
<td>Consistent AV Synchrony</td>
<td>Yes</td>
<td>Yes</td>
<td>No – MVP</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
New Paradigm for Physiological Pacing

- **PROTECT Synchrony** = Atrial based pacing
  - The best site to pace the human heart with normal electrical & mechanical activation is the atrium

- **PREVENT Desynchronization** = Selective site
  - The best site to pace the human ventricle to maintain synchronous contraction is...

- **RESTORE Synchrony** = CRT
  - The best site to pace the human ventricle with abnormal electrical & mechanical activation if from a coronary vein