Richard and Annette Bloch Heart Rhythm Center
Ways and Means to Improving Response to Cardiac Resynchronization Therapy: Beyond Device Implantation

Martin Emert, M.D.
Kansas City Heart Rhythm Symposium 2012

Richard and Annette Bloch Heart Rhythm Center
Mid America Cardiology
University of Kansas Hospital

August 18, 2012
Welcome to Kansas
Overview

• CRT is Good!
• Definition of Response to CRT
• Differential for Causes of Non-Responders
• Evaluation to assess Causes
• Interventions to address Causes
• “Alerts” to Prevent/Identify Causes before next visit
Benefits of CRT

Meta-analysis found CRT 28% reduction in all-cause mortality
37% reduction in new CHF hospitalizations

- Reduced mitral regurgitation
- Optimized left ventricular filling
- Improved cardiac function
- Increased pulse pressure
- Increased left ventricular contractility
- Decreased left ventricular filling pressure
- Decreased myocardial oxygen consumption
- Possible reversal of cardiac remodeling
- Improves symptoms
- Improved LVEF
- Improves QOL
- Improves Exercise tolerance
- Improves NYHA Functional Class
- Decreases Heart failure hospitalizations
- Decreases mortality
- Etc.
<table>
<thead>
<tr>
<th>Study</th>
<th>Endpoints</th>
<th>Design</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUSTIC-SR²⁸</td>
<td>6MWT, QOL, pVO₂, Hosp</td>
<td>Single-blinded, controlled, crossover, 6 months</td>
<td>CRT-P improved: 6MWT, QOL, pVO₂; reduced Hosp</td>
</tr>
<tr>
<td>MIRACLE⁹</td>
<td>NYHA class, QOL, pVO₂</td>
<td>Double-blinded, controlled, 6 months</td>
<td>CRT-P improved: NYHA, pVO₂, 6MWT</td>
</tr>
<tr>
<td></td>
<td>6MWT, QOL, pVO₂</td>
<td>Single-blinded, controlled, crossover, 6 months</td>
<td>CRT-P (high dropout rate); improved all: reduced Hosp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single-blinded, controlled, crossover, 12 months</td>
<td>CRT-P improved: 6MWT, pVO₂</td>
</tr>
<tr>
<td>PATH CHF¹¹</td>
<td>6MWT, pVO₂</td>
<td>Double-blinded, ICD vs CRT-D 6 months</td>
<td>CRT-D improved all from baseline (not ICD)</td>
</tr>
<tr>
<td>MIRACLE ICD²¹</td>
<td>Mortality + Hosp HF + VA, pVO₂, 6MWT, NYHA class, QOL, LVEDD + LVEF</td>
<td>Double-blinded, ICD vs CRT-D 6 months</td>
<td>CRT-D improved: pVO₂, 6MWT; reduced LVEDD; increased LVEF</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>CONTAK CD¹³</td>
<td>VE/CO₂, pVO₂, NYHA, QOL, 6MWT, LV volumes/LVEF</td>
<td>Double-blinded, ICD vs CRT-D 6 months</td>
<td>CRT-D improved: NYHA, VE/CO₂, volumes, LVEF</td>
</tr>
<tr>
<td>MIRACLE ICD TT¹⁴</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPANION¹⁶</td>
<td>(1) All-cause death or Hosp</td>
<td>Double-blinded, controlled, OPT, CRT-D, CRT-P, about 15 months</td>
<td>CRT-P/CRT-D: reduced (1)</td>
</tr>
<tr>
<td>CARE-HF¹⁷</td>
<td>(1) All-cause death or Hosp for major CV event</td>
<td>Double-blinded, controlled, OPT, CRT-P, 29 months</td>
<td>CRT-P reduced (1) and (2)</td>
</tr>
<tr>
<td>REVERSE¹⁹</td>
<td>(2) Death from any cause Hosp for HF</td>
<td>Double-blinded, controlled, OPT, CRT-P ± ICD, 12 months</td>
<td>Primary endpoint NS</td>
</tr>
<tr>
<td></td>
<td>(1) Percent worsened by clinical composite endpoint</td>
<td></td>
<td>CRT-P/CRT-D reduced (2) and (3) but not (4)</td>
</tr>
<tr>
<td>MADIT-CRT²⁰</td>
<td>(3) Hosp for HF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAFT²¹</td>
<td>(4) Mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1) HF events or death</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) LVEF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1) Death from any cause or Hosp for HF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Death from any cause</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Death from CV cause</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Controlled, CRT-P, CRT-D, 2.4 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controlled, CRT-P vs CRT-D 40 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CRT reduced (4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Effect of CRT on Mortality and Morbidity

<table>
<thead>
<tr>
<th>Study, No. Randomized</th>
<th>Follow-Up mo.</th>
<th>Treatment</th>
<th>Mortality + Hospitalization</th>
<th>Mortality + HF Hospitalization</th>
<th>HF Mortality</th>
<th>HF Hospitalization</th>
<th>Risk Reduction with CRT Versus Control, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPANION (N=1520)</td>
<td>12</td>
<td>CRT + ICD</td>
<td>19.3</td>
<td>39.5</td>
<td>43.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CRT</td>
<td>18.6</td>
<td>35.8</td>
<td>23.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIRACLE (N=453)</td>
<td>6</td>
<td>CRT</td>
<td></td>
<td>39</td>
<td>27</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Meta-analysis N=1634</td>
<td>3-6</td>
<td>CRT</td>
<td></td>
<td>23</td>
<td>51</td>
<td></td>
<td>29</td>
</tr>
</tbody>
</table>
Defining a Responder to CRT

Abnormal is “Relative”

Depends on your Perspective
Defining a Responder to CRT

• We know that ~ 30% of pts are “Non-Responders”
• What does that mean?
• Measures for CRT Response are Subjective-symptomatic response and Objective-clinical outcomes or Surrogate measures of outcome:
  – The pt. feels better: “I have more energy, Doc.”
  – KCCQ-Kansas City Cardiomyopathy Questionnaire-QOL
  – NYHA Functional Class
  – 6 minute Walk Test, MvO2
  – Improved LVEF, LV volumes, LV dimensions, LV remodeling
Causes of Non-Responder to CRT

What’s the Differential:

- Implant Issues, e.g. “Bad Lead Location”
- Issues related to patient selection
- Lack of 100% BiV pacing
- Other Morbidities: anemia, metabolic derangements, thyroid issues, worsening RF, etc.
- Non-compliance? Inadequate Drug Tx? No!

Beyond Device Implantation
Causes of Non-Responder to CRT

- **Implant Issues, e.g. “Bad Lead Location”**
  - 21% had inappropriate LV lead placement in an ANTERIOR vein branch.

- **Inadequate Drug Tx/Non-compliant:**
  - 24% not optimal drug Tx without contraindication. B-Blocker use at 89% and ACE/ARB at 84%
  - Additional 8% with dietary and med non-compliance

- **Other:** anemia, metabolic derangements, thyroid issues, worsening RF,
  - 30% had anemia-Hb less than 12 for men, but only 4% less than 10 Hb.

W. Mullens... B. Wilkoff, W. Tang; JACC; 2009; 53; 765-73
Causes of Non-Responders

Issues related to Patient Selection: Pre-implantation

- Up to 20% of patients with QRS >120 ms do not have significant dyssynchrony
- Patient with significant Diastolic Dysfunction
- Anemia, metabolic abnlities, thyroid issues, worsening RF
- Patient with poor medication or dietary compliance
- Avoiding true “End-stage” patient--High 1 yr mortality
- Inadequate/Not optimal Medical therapy
Predictors of Response to CRT Therapy in the Multicenter Automatic Defibrillator Implantation Trial With Cardiac Resynchronization Therapy (MADIT-CRT)

- Prior hospitalization for HF—had lowest contribution
- Female sex
- Nonischemic cardiomyopathy—intermediate contribution
- Left bundle-branch block
- QRS 150 milliseconds
- LVEDV
- Left atrial volume—highest contribution
Lack of 100% BiV Pacing

- Do you review the % BiV Pacing in all pts with a CRT device?
- Do you review the % BiV Pacing at every check
- What % BiV Pacing are you looking for?
- What % BiV Pacing would prompt you to investigate further?
- What would you do to investigate further?
What is the Optimal % of BiV Pacing

Lattitude Project: 36,935 pts at 1,243 US centers

- > 99.6% pacing had 24% reduction in mortality
- < 95% pacing had 19% increase in mortality
- > 98% CRT pacing greatest magnitude Reduction in Mortality (adjusting for AFIB, age, gender)
- Worsening HF Sxs associated with a decrease in % CRT pacing
- followed up in a remote monitoring network
- Pts implanted for a mean of about 3 years and followed up for a mean of about 2 years
- Tracked weekly % CRT pacing and clinical status
Assess % BiV-Pacing

> 98% CRT pacing greatest Reduction in Mortality

- % pacing in the device: but...VSt/VSr/Bi-V Trigger...
- Heart Rate Histograms
Causes of Non-Responders
Why NOT > 98%% BiV Pacing
What’s the Differential

• Issues related to the Lead
• Issues related to Device Settings/Optimization
• Issues related to the Rhythm

> 98% CRT pacing greatest Reduction in Mortality
Causes of Non-Responders
Why NOT > 98% BiV Pacing
Issues related to the Lead

• Lead dislodgement- macro or micro
• Lead with failure to capture (FTC)--high threshold, above set output
• Lead tip not fully past the set screw in the header
• Lead fracture-rare

> 98% CRT pacing greatest Reduction in Mortality
Causes of Non-Responders
Why NOT > 98% BiV Pacing

Issues related to Device Settings/Optimization

- Maximum tracking rate (MTR) too low
- Programmed AV delay too long
- Rate-responsive AV delay is off
- Programmed Pace Output is too low---Failing/intermittent capture
- V-V timing not optimal

> 98% CRT pacing greatest Reduction in Mortality
Causes of Non-Responders
Why NOT > 98% BiV Pacing

Issues related to the Rhythm

- Sinus Tachycardia- above MTR
- Frequent or Prolonged AFIB
  - Related to RVR
  - V-rate Regularization
  - Loss of A-V kick
- Frequent VPDs
- Frequent VT events
Evaluation of Causes of Non-Responders
Why NOT > 98% BiV Pacing
Evaluation of Causes of Non-Responders
Why NOT > 98% BiV Pacing

• Review the Device Check in Detail

• Obtain a CXR-PA and Lateral
Review the Device Check in Detail

"Gee, I don't know. Can I ask my implanted device?"
Evaluation of: Not > 98% BiV Pacing
Review the Device Check in Detail

• Assess lead function—capture, impedance trends
• Assess underlying Rhythm-current, historically
• AV delays/ PR interval
• Surface and egm morphology
• % Arrhythmias
• V-sensed events
Evaluation of: Not >98% BiV Pacing

Review the Device Check in Detail

- Oversensing
- AV delays- inhibit for underlying conduction
  - Paced AV
  - Sensed AV
Evaluation of: Not > 98% BiV Pacing

Consider ETT

- ETT or rate Histograms to Assess if Maximum tracking rate (MTR) too low
- Is Rate-responsive AV delay shorten adequately
Evaluation of: Not > 98% BiV Pacing
Review the Device Check in Detail

Arrhythmias:

• Sinus Tachycardia- above MTR– walk pt on TM
• % AFIB Burden/# Mode Switch events
  – Related to RVR
• % VPDs
• VT events
Assess AFIB Burden and Ventricular Response
Assess AFIB Burden and Ventricular Response

Atrial Burden
Total Time: 4.5 h
# of Events: 1680
Assess AFIB Burden and Ventricular Response
Evaluation of: Not > 98% BiV Pacing

Review the Device Check in Detail

• Review “Sensed Event” egm’s:
  – VT below detection
  – AFIB “too brief”
  – VPDs
  – Essentially shows the rhythm and egm when not BiV pacing
  – Only Medtronic
Evaluation of: Not > 98% BiV Pacing
Review the Device Check in Detail

Review the Impedence Tools:
• Optivol: Medtronic
• CorVue: St. Jude
  • Correlate with pt. dietary or med non-compliance
  • At aTime increase in arrhythmia burden
Evaluation of: Not 100% BiV Pacing
Obtain and Review a CXR

• Lead movement/dislodgment
  • Compare to post implant CXR
• Set Screws past post
Case:

Close-up of section of chest x-ray from a pt who has not responded to CRT-Tx. Based on CXR finding, what is the most likely ECG correlation:

A. Ventricular failure to capture and/or output
B. Runaway pacemaker
C. Ventricular tachycardia
D. Atrial undersensing
E. Pacemaker mediated-tachycardia
F. Not a CRT device
Close-up of section of chest x-ray from a pt with recurrent syncope. Based on CXR finding, what is the most likely ECG correlation:

A. Ventricular failure to capture and/or output
B. Runaway pacemaker
C. Ventricular tachycardia
D. Atrial undersensing
E. Pacemaker mediated-tachycardia
F. Not a CRT-device
Interventions to Achieve >98% BiV Pacing

Patient Selection and Lead Related Issues

- Select pts with Wider QRS durations, medication compliance, not “endstage.”
- Re-Advance the lead at current site
- Change leads for better stability or change sites
Interventions to Achieve >98% BiV Pacing

Patient Selection and Lead Related Issues

• Advance lead in header/Reposition/New site

• Capture/Threshold Issues:
  – Change the pacing Vector
    • Use different poles of the lead
    • Go to lead to coil, ? Go to can
    • If using a Quadrapolar lead-change poles
      » Currently only St.Jude
Interventions to Achieve >98% BiV Pacing

Device Related Issues

• Adjust Threshold
• Adjust AV delay, rate responsive AV delay
• Adjust MTR-maximum tracking rate
• Different V-V timing
• A-V Optimization: Echo or Device based
Interventions to Achieve 100% BiV Pacing

Device Related Issues

Optimization

- A-V Optimization: Echo or Device based
- Different V-V timing
- 2 Companies have capability

To be discussed next in great detail by Dr. Mulhern
SmartDelay Optimization
Boston Scientific

QuickOpt-Timing-Cycle-Optimization
St. Jude Medical

QuickOpt® Timing Cycle Optimization
QuickOpt® Optimization collects rhythm measurements to propose optimal settings for the delays parameters. The test will take about one minute to complete.

Manual Testing & Results
Obtain measurements manually, and review results if available.

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Interventions to Achieve 100% BiV Pacing

Rhythm Related Issues

• Sinus Node suppressive Tx if MTR and issue
• AV Node suppressive Tx to avoid intrinsic conduction
• Anti-Arrhythmic drug Tx for AFIB events
• Increase/Initiate rate controlling AVN blocker for AFIB with RVR
• Anti-Arrhythmic drug Tx for frequent VPDs
• Anti-Arrhythmic drug Tx for VT events
Remote Monitoring Alert Systems: USE THEM!

- St. Jude-Merlin
- Medtronic-Carelink
- Boston Scientific-Lattituded
- Biotronik-Cardiomessenger
Remote Monitoring Alert Systems: USE THEM!

- An AT/AFIB episode of a programmed duration
  - All companies
- Avg V-rate during AFIB
  - Only Medtronic-Carelink and St. Jude-Merlin, +/-BSI
- AT/AFIB total burden threshold
  - St. Jude, Boston Sci, Biotronik only
Remote Monitoring Alert Systems: USE THEM!

- BiV Pacing % Lower Threshold
  - St. Jude, Boston Sci, Biotronik only
- Any VT/VF
  - All companies
- Weight, BP and Symptoms
  - Only Boston Sci
**St. Jude Merlin Alerts**

Here's CHERRY KLASSEN (ID: 6811415)'s Patient Profile.

<table>
<thead>
<tr>
<th>Alert Type</th>
<th>Alert Classification</th>
<th>Inform Patient **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Programmed to Emergency Pacing Values</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Backup VVI</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Device at ERI</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Atrial Pacing Lead Impedance Out of Range</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>RV Pacing Lead Impedance Out of Range</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>*AT/AF Episode Duration &gt; Threshold</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>*AT/AF Burden &gt; Threshold</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>*Average Ventricular Rate during AT/AF &gt; Threshold</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>High Ventricular Rate episodes recorded</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**When patient is informed of an alert, so will their emergency contact**
Medtronic Carelink Alerts
### Medtronic CareAlert® Notification Patient Settings

**How to Program CareAlert™ Settings**

- **Step 1:** Using the wireless programmer: Program audible device tone alerts in the device.
- **Step 2:** Using the wireless programmer: Program Patient “Home Monitor” alerts (individual patient alerts customized here).
- **Step 3:** From the CareLink® Website: If additional notifications are desired, set up additional CareAlert Notifications (Voice Message and/or Pager).

**Note:** Voice Message, Pager, Email Message, Text Message, and/or Live Call.

<table>
<thead>
<tr>
<th>Medtronic Device Alerts</th>
<th>Wireless Programmer</th>
<th>CareLink Website</th>
<th>Additional Notification Methods (selected for entire clinic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLINICAL MANAGEMENT ALERTS</td>
<td></td>
<td></td>
<td>Voice Message, Pager, Email Message, Text Message, and/or Live Call</td>
</tr>
<tr>
<td>Daily AT/AF Burden &gt; Threshold</td>
<td>H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Fast Ventricular Rate during AT/AF</td>
<td>H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Number of Shocks Delivered in an Episode</td>
<td>H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>All Therapies in a Zone Exhausted</td>
<td>H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>LEAD/DEVICE INTEGRITY ALERTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VF Detection/Therapy Off</td>
<td>*H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Low Battery Voltage Recommend Replacement</td>
<td>H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Right Ventricular Lead Integrity</td>
<td>*H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Excessive Charge Time End of Service</td>
<td>*H L O</td>
<td>On Off</td>
<td></td>
</tr>
<tr>
<td>Artifial Pacing</td>
<td>Impedance out of range</td>
<td>*H L O</td>
<td>On Off</td>
</tr>
<tr>
<td>RV Pacing</td>
<td>Impedance out of range</td>
<td>*H L O</td>
<td>On Off</td>
</tr>
<tr>
<td>LV Pacing</td>
<td>Impedance out of range</td>
<td>*H L O</td>
<td>On Off</td>
</tr>
<tr>
<td>Ventricular Defib</td>
<td>Impedance out of range</td>
<td>*H L O</td>
<td>On Off</td>
</tr>
<tr>
<td>SVC (RVX) Defib</td>
<td>Impedance out of range</td>
<td>*H L O</td>
<td>On Off</td>
</tr>
</tbody>
</table>

**Impedance out of range alert should be programmed OFF in connector ports that are plugged, due to open circuit status.**

<table>
<thead>
<tr>
<th>NONPROGRAMMABLE ALERTS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Reset</td>
<td>*Always On</td>
<td>On if Home Monitor “On”</td>
</tr>
<tr>
<td>Pacing Mode DOO, VOO, or AOO</td>
<td>*Always On</td>
<td>On if Home Monitor “On”</td>
</tr>
<tr>
<td>Active Can* Off without SVC</td>
<td>*Always On</td>
<td>On if Home Monitor “On”</td>
</tr>
<tr>
<td>Charge Circuit Timeout</td>
<td>*Always On</td>
<td>On if Home Monitor “On”</td>
</tr>
</tbody>
</table>

*Device tones are nominally ON in these devices.
Lattitude: HF PERSPECTIV™
Device-based and Remote Diagnostics

- Weight
- Blood Pressure
- Symptoms
- Heart rates
- Activity Level
- Heart Rate Variability (HRV) Footprint
- SDANN
- Atrial burden
- Arrhythmias
- Histograms and counters
Summary

• CRT is Good!
• Definition of Response to CRT
• Differential for Causes of Non-Responders
• Evaluation to assess Causes
• Interventions to address Causes
• “Alerts” to Prevent/Identify Causes Immediately
Causes of Non-Responder to CRT

What’s the Differential:

- Implant Issues, e.g. “Bad Lead Location”
- Issues related to patient selection
- Lack of 100% BiV pacing
- Other: anemia, metabolic derangements, thyroid issues, worsening RF, etc.
- Non-compliance? Inadequate Drug Tx? No!

Beyond Device Implantation
Causes of Non-Responders

Why NOT 100% BiV Pacing

What’s the Differential

• Issues related to the Lead
• Issues related to Device Settings/Optimization Program
• Issues related to the Rhythm

> 98% CRT pacing greatest Reduction in Mortality
Remote Monitoring Alert Systems: USE THEM!
Never stop being inquisitive.
There’s No Place Like Home…
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### Table 1 Survival from CRT-P and CRT-D over a patients’ lifetime

<table>
<thead>
<tr>
<th>Age</th>
<th>Survival OPT</th>
<th>CRT-P</th>
<th>CRT-D</th>
<th>Additional life CTR-P</th>
<th>CRT-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>7.31</td>
<td>9.00</td>
<td>10.39</td>
<td>1.69</td>
<td>3.08</td>
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<tr>
<td>40</td>
<td>7.23</td>
<td>8.92</td>
<td>10.31</td>
<td>1.69</td>
<td>3.08</td>
</tr>
<tr>
<td>50</td>
<td>7.15</td>
<td>8.76</td>
<td>10.08</td>
<td>1.62</td>
<td>2.92</td>
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<tr>
<td>60</td>
<td>6.15</td>
<td>7.15</td>
<td>8.00</td>
<td>1.00</td>
<td>1.85</td>
</tr>
<tr>
<td>70</td>
<td>4.46</td>
<td>5.39</td>
<td>5.85</td>
<td>0.92</td>
<td>1.39</td>
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<td>80</td>
<td>3.08</td>
<td>3.77</td>
<td>4.31</td>
<td>0.54</td>
<td>1.23</td>
</tr>
<tr>
<td>90</td>
<td>2.31</td>
<td>2.69</td>
<td>2.92</td>
<td>0.39</td>
<td>0.62</td>
</tr>
<tr>
<td>Overall</td>
<td>3.77</td>
<td>4.62</td>
<td>5.15</td>
<td>0.85</td>
<td>1.39</td>
</tr>
</tbody>
</table>

All values are expressed as medians (years).
Reproduced with permission from the Peninsula Technology Assessment Group.³
³Refers to survival advantage over optimum medical therapy alone (OPT).
⁴Age at the time of implantation.
Never stop being inquisitive.
THE WIZARD OF OZ
Change in Quality-of-Life Score

MIRACLE MUSTIC SR CONTAK CD MIRACLE ICD

<table>
<thead>
<tr>
<th>Device</th>
<th>Control</th>
<th>CRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIRACLE</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>MUSTIC SR</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>CONTAK CD</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>MIRACLE ICD</td>
<td>9</td>
<td>19</td>
</tr>
</tbody>
</table>
Early CRT Trials: Impact of CRT on Reducing NYHA Functional Class

% That Decreased ≥ 1 Class

- PATH-CHF: 1 Year P<0.001, 6 months P<0.05
- MUSTIC: 1 Year P<0.05, 6 months P<0.03
- MIRACLE: 6 months P<0.03
- MIRACLE ICD: 6 months P<0.03
- CONTAK CD: 6 months P<0.03
Change in Distance Walked in 6 Minutes

Meters

MIRACLE  MUSTIC SR  CONTAK CD  MIRACLE ICD

Control  CRT
Change in Peak VO$_2$

![Bar chart showing change in Peak VO$_2$ for different groups.

- MIRACLE: Control group shows a decrease of 0.5 mL/kg/min.
- MUSTIC SR: CRT group shows an increase of 2.5 mL/kg/min.
- CONTAK CD: CRT group shows an increase of 2.0 mL/kg/min.
- MIRACLE ICD: CRT group shows an increase of 0.5 mL/kg/min.]
QRS duration & Mortality in heart failure

QRS complex and mortality

- VEST (Vesnarinone) study analysis
- NYHA class II-IV
- 3,654 ECGs
- QRS duration was found to be an independent predictor of mortality
- Relative Risk of widest QRS group was 5 x greater than narrowest

Adapted from V Gottipaty, MD.
Benefit of CRT in Atrial Fibrillation: Role of Rate

• Control of Ventricular Rate in Atrial Fibrillation is important

• A significant difference in percentage of clinical responders in patients who had AV node ablation (44 of 51 (86%)) compared with patients who did not have ablation (81% pacing) (14 of 23 (61%), p < 0.05).

• Kies et al Heart 2006
Case - Answer

- Atrial undersensing should not be responsible for syncope. The only CXR correlation of undersensing would be gross dislodgment of the atrial lead.
- VT could certainly cause syncope but no radiographic correlation. (Lead dislodgement might provoke VT.)
- Would be uncommon for PMT to cause syncope, and, again, no radiographic correlation.
- With recurrent syncope, be concerned about the lead, either loss of integrity or loss of connection. Then inspect connector block and entire length carefully. In this CXR incomplete insertion of the ventricular pin in the connector block is noted.
SmartDelay Optimization

SmartDelay provides recommended settings for programming PAV and SAV Delay based on measurements of:
1. Intrinsic AV intervals
2. Interventricular timing
3. LV lead location
   • LV dP/dtmax is a clinical standard for measuring contractility and evaluating CRT response
   • SmartDelay is designed to recommend an optimal AV Delay to maximize global LV contractile function (LVdP/dtmax) based on an individual’s intrinsic conduction characteristics
   • SmartDelay is designed to maximize LV dP/dtmax without the need for pressure measurements