Master Class Devices (1) - Achieving Optimal CRT

The Physiologist in CRT Clinic perspective

Stuart Allen
Principal Cardiac Physiologist
Manchester Heart Centre
• (CRT Implant)
• CRT follow up
• CCRTC follow up
• CRT remote follow up
• (Alert based follow up only)
GIRFT

• Getting It Right First Time is a national programme designed to improve the quality of care within the NHS by reducing unwarranted variations

• The GIRFT team visit every trust carrying out the specialties they are reviewing, investigating the data with their peers and discussing the individual challenges they face.
Optimal LV Lead Position = Optimal CRT follow up

‘You Cant Polish a Turd’

No amount of programming can rectify poor patient selection and poor lead position!
Case study 1

- 45y Male
- IDCM EF <20%
- Frequent clinic DNA’s
- Previous device checks ‘all normal’
Lateral CXR
One for the medics...

The importance of getting both PA and lateral views on CXR.
Pre-implant ECG
What device would you have chosen?

A  ICD-VR
B  ICD-DR
C  S-ICD
D  CRT-D
<table>
<thead>
<tr>
<th>QRS interval</th>
<th>NYHA class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;120 milliseconds</td>
<td>ICD if there is a high risk of sudden cardiac death</td>
</tr>
<tr>
<td>120–149 milliseconds without LBBB</td>
<td>ICD</td>
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<tr>
<td>120–149 milliseconds with LBBB</td>
<td>ICD</td>
</tr>
<tr>
<td>≥150 milliseconds with or without LBBB</td>
<td>CRT-D</td>
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</tbody>
</table>

LBBB, left bundle branch block; NYHA, New York Heart Association
• What are the main reasons for a CRT non-responder/ineffective CRT pacing?
Causes of poor CRT response

- 75 patients
- Single centre
- NYHA III-IV

Mullens et al. J Am Coll Cardiol 2009
Let's start at the implant
what can we do at the CRT implant to reduce non responders?

• Appropriate indication for CRT!
• 12 lead ECG during implant
• Select the right vein/ LV anatomical position
• Select the right LV lead
• QLV/ thresholds/ phrenic nerve
• Most appropriate LV pacing vector
• Correct programming
Left Ventricular Lead Electrical Delay Is a Predictor of Mortality in Patients With Cardiac Resynchronization Therapy

Tomas Roubicek, MD, PhD; Dan Wichterle, MD, PhD; Pavel Kucera, MD; Pavel Nedbal, MD; Jindrich Kupec, MD; Jana Sedlakova, MD; Jan Cerny, MSc; Jan Stros, MD; Josef Kautzner, MD, PhD; Rostislav Polasek, MD

Background—Electric left ventricular lead position, assessed by the electric delay from the beginning of the QRS complex to the local LV electrogram (QLV), was found in previous studies to be a strong predictor of short-term response to cardiac resynchronization therapy. We hypothesized that suboptimum electric position of the left ventricular lead is associated with an excess of heart failure events and mortality.

Methods and Results—We analyzed the clinical outcome of patients with left bundle branch block or intraventricular conduction delay treated with cardiac resynchronization therapy at our institution during 9 years. Baseline clinical characteristics, QLV/QRS duration (QLV ratio) at cardiac resynchronization therapy implant, and data about heart failure hospitalization and mode of death were collected in 329 patients who were followed for a period of 3.3±1.9 years. Of them, 83 were hospitalized for heart failure and 83 died. Event rates for all-cause mortality, cardiac mortality, noncardiac mortality, heart failure mortality, and sudden death were 25.2%, 14.9%, 10.3%, 12.2%, and 2.1%, respectively. Patients with a QLV ratio ≤0.70 had significantly worse event-free survival for all study end points—hazard ratio, 1.6; 95% confidence interval, 1.0 to 2.4; P=0.05 for heart failure hospitalization; hazard ratio, 2.9; 95% confidence interval, 1.6 to 5.5; P=0.001 for heart failure mortality; hazard ratio, 1.8; 95% confidence interval, 1.1 to 2.7; P=0.01 for cardiac mortality; and hazard ratio, 2.1; 95% confidence interval, 1.2 to 3.7; P=0.01 for all-cause mortality. In multivariable analysis, QLV ratio ≤0.70 remained associated with all study end points.

Conclusions—Electric left ventricular lead position in cardiac resynchronization therapy patients was a significant predictor of heart failure hospitalization and mortality. (Circ Arrhythm Electrophysiol. 2015;8:1113-1121. DOI: 10.1161/CIRCEP.115.003004.)
qLV

Once the LV lead is in situ and connected to PSA measure qLV via PSA. (Optimal value >90ms, or final 3rd of QRS). Ensure a clean unfractionated signal.
Abbott CRT implant guide

Pre-Implant Set-up
Attach 12 lead ECG in Lab
Measure and record pre-implant QRS duration – QRS <130ms must be discussed with cardiologist before implant start

RA/RV Lead Implant
RA and RV implant as per standard protocol.
Ensure negative V1/ LBBB with RV Pacing
Consider impact of decreased LVS-RVS interval with septal RV lead position
Once RV lead is in situ connect to PSA at 30bpm for back up pacing during CS cannulation

LV lead Placement. (TARGET study)
Optimal Vessel location – Basal Lateral.
Obtain multiple radiographic views in order to fully assess
  a) Optimal Lead choice
  b) Optimal lead location
Patient response to CRT therapy improved as the site of pacing moved further from the apex, with lowest mortality and heart failure events occurring with basal pacing\(^1\).

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**Heart Failure Event or Death**
- Apical vs Mid-V: 1.54 (p=0.069)
- Mid-V vs Basal: 1.54 (p=0.093)
- Apical vs Basal: 2.38 (p=0.005)

**Heart Failure Event**
- Apical vs Mid-V: 1.38 (p=0.214)
- Mid-V vs Basal: 1.60 (p=0.086)
- Apical vs Basal: 2.20 (p=0.018)

**Death**
- Apical vs Mid-V: 2.45 (p=0.018)
- Mid-V vs Basal: 2.15 (p=0.161)
- Apical vs Basal: 5.27 (p=0.005)

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BHRS log books

- Approximately 100 CRT cases – implant/ follow up/ case studies
- 73 cases – LV vector programming cathode LV1
- 11 cases – LV vector programming cathode LV2
>1000 patients
Choose the right lead for the right target vein
**LV lead Tests**

LV1 – Can *, LV2 – Can, LV3 – Can, LV4 – Can *

Where possible but (*) as a minimum, and assess optimal vector according to order of importance:

- Longest qLV
- Latest V1 to V6 transition point
- Highest lead impedance
- Lowest Threshold with no PNS or high PNS margin

**Device connection**

Pin Check in header

**Lead checks through the device**

Assess lead measurements as normal to ensure values are consistent with values seen via PSA and within acceptable limits.
ECG

*When LV pacing is initiated ensure V1 is positive and note the latest transition point on chest lead – later transition point indicates more basal LV capture (optimal V5/V6)
LV Basal pacing - positive V1 to v6

Dominant R wave V1 to V6 consistent with LV basal pacing
CRT baseline optimisation – To be performed in device lab before patient leaves the lab

- CRT Toolkit – located in tests
- Using AutoVet Select, alter test method to RV pacing and press ‘Perform Measurements’
  - This paces from the RV lead and will measure conduction time to each cathode on the Quartet lead
  - Activation times will be displayed and we are looking to pace from the latest site of activation
The ‘ideal’ post implant CRT ECG
Bi V pacing (RV lead at apex)

Right superior axis
Dominant R in V1

No fusion with native QRS; VVI pacing produced the same QRS
Before the patient leaves the lab

• Correct programming – Mode, LR, RR, LV pacing vector, O/P’s etc
• Follow optimisation guide
• 12 lead of LV, RV, Bi V pacing
• HF follow up/ Plan for titration of HF meds
• Plan for AV node ablation (if required)
• Remote follow up
The CRT clinic(s)  
what's the ideal Follow up??

• Routine FU 3/12 – combination of F2F and RFU

• Remote follow up – HF diagnostics

• 6 month ‘optimisation/ comprehensive’ for all new CRT
How much time do you need to follow up a CRT?

- 9 hospitals surveyed
- 5 hospitals <15 minutes
- 6 hospitals – have no separate CRT clinic
- 2 hospitals have non responder/optimisation clinic
The Cleveland non responder clinic

• “The first clinic visit takes about two hours,” Dr. Rickard notes. To evaluate biventricular pacing, the patient has an ECG with and without CRT pacing. Device positioning of the LV lead is checked CxR. Laboratory tests (standard electrolyte and renal panel, complete blood count) are performed to determine if anaemia or renal dysfunction is involved.
The most frequent reasons for nonresponse include poor left ventricular lead position, a poor substrate for biventricular pacing, and suboptimal AV timing, but our recommendations are often not mutually exclusive,” says Dr. Rickard. He notes that the team often finds they can help with one or more of the following measures:

- Repositioning the left ventricular lead
- Altering AV device programming
- Treating arrhythmias either medically or invasively
- Adding and up-titrating medical therapy
- Changing advice on diet and fluid intake
The Cleveland non responder clinic

• The CRT optimization clinic, held twice a month, is fully integrated with Cleveland Clinic’s heart failure disease management program and accessible to patients of any referring cardiologist. Appropriate patients include those who experience persistent advanced heart failure symptoms (New York Heart Association functional class III or IV) and/or continuation or lack of reversal of adverse cardiac remodelling following CRT device implantation.
CRT Follow Up Check List

- Battery Status
- Lead impedances
- P and R wave amplitude
- Thresholds with appropriate output (V1 needed to ensure RBBB morphology when LV pacing)
- % Biventricular pacing
- % Atrial pacing – consider a lower base rate/ sleep or rest rate
- Ventricular Ectopic Burden
- AF burden
- Heart Rate Histograms - Rates predominately over 70ppm refer for titration of beta blocker/ Ivabradine
- Any Atrial/ ventricular events
- Pacing mode – is rate response really needed?
- Upper Sensor Rate should be judged on an individual basis, but in most cases not more than 100bpm.
- Check underlying rhythm (QRS duration and morphology, Sinus Rhythm?, Ventricular Ectopics? AF? Any brady pacing indication
- In Medtronic consider Adaptiv BiV and LV (SR with no brady indication and SAV <220ms)/ Adaptiv BiV (Patients with occasional AV block/ Non-adaptive (no underlying rhythm and AF patients)
- V-V delays should be optimised with a 12 Lead aiming for a biphasic complex in V1 (initial positive deflection) with a narrow complex.
- Smart Delay optimisation/ QuickOpt / CardioSync/ SyncAV
- AV delays to be optimised using ECG and rate adaptive AV delays turned on.
- V-V delays
- Review Tachy settings to ensure they are following ICD guidelines
- Check on optimal medical therapy (ACE inhibitor, Beta Blocker, diuretic +/- Anti-coagulant, +/- anti-arrhythmic)
Routine CRT Clinic - Check list

• 12 lead ECG if not previously optimised
• Periodically check underlying rhythm – substrate reversal, poor indication for CRT and use of CRT algorithms eg Adaptiv CRT, SyncAV, SmartAV
• 100% True Bi V pacing (except when LV pacing algorithms, NOT LV pacing algorithms for conducted AF etc
• Check HF meds (+/- rate control/ OAC for AF)
• Electrically optimise
• Histograms – sinus rates/ RR
• HF diagnostics
The Manchester Heart Centre CCRTC
The Comprehensive CRT clinic

• **All** new CRT implants – assessment at 6/12
• One a month clinic 12 patients, 2 rooms, 1 x HF cardiologist and 4 physiologists

2 weeks pre CCRTC – echo: EF, EDD, EDV, ESV
bloods: NT pro-BNP, iron & iron saturation, U&E’s, LFT/ TFT’s, FBC
6 month CCRT evaluation Clinic
Once a month – 12 patients

• Evaluate lead position (implant X Ray)

• Check list
  – 12 Lead ECG - underlying rhythm (QRS duration), RV pacing, LV pacing, Bi V pacing
  – Evaluate % Bi v / LV pacing
  – Optimise as per SOP
NEW CRT IMPLANT
Baseline Echo, EF, EDD, EDV, ESV
NT pro-BNP & Full Blood Count
PA, RAO & LAO x-ray Images saved

P/T DEVICE CHECK
Ensure all patients have remote follow-up

CRTC as required if wound or lead issues

3/12 CLDC
Request Echo

6/12 COMPREHENSIVE CRT FOLLOW UP
Consultant review: Echo, NT pro-BNP, medications, patient symptoms/ NYHA status/ CCS
CP's 12 lead ECG (intrinsics, RV, LV, DVI pacing), device check and optimise as per guidelines
Blood Test: NT pro-BNP and Full Blood Count

2/5/2 before CRTC
Attend for Echo + Bloods

3 X CLDC
1 X CRTC – 12 lead ECGs every 12 months
Echo every 18 months

Now Improved/ Unchanged CCS plus - Ve Echo

Worsened or CCS plus - Ve Echo

Worsened or Unchanged CCS/ Echo

Patient deterioration (worsening symptoms)

3/12 CRTC – Reassess, CCS, Echo, Bloods

*Request echocardiogram on ice stating, "Patient has CRT in situ, echo prior to CRTC. Please record EF, Echo and Echo. Please forward the report to the device Cardiac Physiologist. Bloods: on ice request NT pro-BNP, Iron & iron saturation, U/S's, LFT/ PT/ INR, Hb, hct, protein

*no for patients who have refused remote follow up, exchange CRTC for CRT.
6/12 COMPREHENSIVE CRT FOLLOW UP

Consultant review: Echo, NT pro-BNP, medications, patient symptoms/ NYHA status/ CCS

CP's: 12 lead ECG (intrinsic, RV, LV, BiV pacing), device check and optimise as per guidelines

Blood Test: NT pro-BNP and Full Blood Count*

Now Improved/ Unchanged CCS plus +Ve Echo

3 X CLDC
1 X CRTD – 12 lead ECGs every 12mths
Echo every 18mths

Patient deterioration (worsening symptoms)

Worsened or CCS plus - Ve Echo

Now Improved CCS/ Echo

3/12 CCRTC – Reassess, CCS, Echo, Bloods

Worsened or Unchanged CCS/ Echo

2/52 before CCRTC

Attend for Echo + Bloods

*Request Echocardiogram on ICE stating: "Patient has CRT in situ, echo prior to CCRTC. Please record EF, EDD and EDV. Please forward the report to the device Cardiac Physiologists.

Bloods: On ICE request NT pro-BNP, Iron & Iron saturation, U&E’s, LFT/ TFT’s, FBC, Ferritin

NB: For patients who have refused remote follow up, exchange CLDC for CRTD.
<table>
<thead>
<tr>
<th>CRT RESPONSE</th>
<th>Before implant</th>
<th>At CCRTC</th>
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<tbody>
<tr>
<td><strong>Echo</strong></td>
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<tr>
<td>LVEF (%)</td>
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<td></td>
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<tr>
<td>LVEDD (mm)</td>
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<td>LVEDV (ml)</td>
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<tr>
<td>LVESV (ml)</td>
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<tr>
<td><strong>NYHA class</strong></td>
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<tr>
<td>HF admission since implant</td>
<td></td>
<td>Yes/No</td>
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<tr>
<td>Patient global assessment</td>
<td></td>
<td>Markedly improved</td>
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<td>(select one option)</td>
<td></td>
<td>Moderately improved</td>
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<td>Mildly improved</td>
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<td>No change</td>
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<td>Mildly worsened</td>
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<td>Moderately worsened</td>
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<td>Markedly worsened</td>
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<tr>
<td>Clinical Composite Response*</td>
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<td>Improved</td>
</tr>
<tr>
<td>(select one)</td>
<td></td>
<td>Unchanged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worsened</td>
</tr>
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*Definition of Clinical Composite Response:

**Worsened:** death or HF admission after implant regardless of current symptoms

**Improved:** improvement in NYHA class and/or moderate/marked improvement in Patient Global Assessment

**Unchanged:** all patients not ‘Improved’ or ‘Worsened’
Reasons for <90% Biv pacing (should be 99/100%)

- Left ventricular lead dislodgement
- Increase in LV or RV pacing thresholds
- Right ventricular lead dislodgement
- Atrial tachyarrhythmias with rapid ventricular rate
- Low maximal tracking rate
- Frequent ventricular premature beats
- Atrial undersensing
- T Wave oversensing
- Far-field atrial sensing
- Ventricular double counting
Prior to Last Session
21-Jan-2015 to 22-Jan-2016
12 months

<table>
<thead>
<tr>
<th>% of Time</th>
<th>Prior to Last Session</th>
<th>Since Last Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS-VS</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>AS-VP</td>
<td>96.1%</td>
<td>97.4%</td>
</tr>
<tr>
<td>AP-VS</td>
<td>&lt; 0.1%</td>
<td>&lt; 0.1%</td>
</tr>
<tr>
<td>AP-VP</td>
<td>0.4%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Total VP</td>
<td>94.9%</td>
<td>98.1%</td>
</tr>
<tr>
<td>VSR Pace</td>
<td>1.5%</td>
<td>1.7%</td>
</tr>
<tr>
<td>VS</td>
<td>3.5%</td>
<td>0.2%</td>
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</table>

CRT Pacing
Bi-V       96.9%     100.0%
LV         0.0%       0.0%

* Total VP may decrease 1% to 2% due to periodic AdaptivCRT sensing.

Atrial

% of Time

> 5% of AS may be due to FFRW

Ventricular

% of Time

> 5% of AS may be due to FFRW
A more ideal histogram...
Presenting ECG – Echo Optimised?? AVD 100ms/100ms, RV first 40ms
BiV Simultaneous
LV/RV -0
Underlying Rhythm
RV Pacing
LV only pacing
BiV LV first 20ms
BiV LV first 30ms
BiV LV first 40ms
BiV LV first 50ms
BiV LV first 60ms
BiV LV first 70ms
Optimised with Quick Opt – BiV, LV 60ms early, AVD 100ms/150ms
Latency and activation time
V-V delay and LV only with fusion
Negative QRS in V1 during CRT + RV apical pacing

• Incorrect placement of V1
• No LV capture
• LV lead displacement
• Significant LV latency
• Ventricular fusion with QRS
• MCV or anterior vein pacing
Heart Failure Diagnostic Tools

are they useful??
Physiological Markers of Acute HF Decompensation

In the beginning!!
Fluid accumulation monitoring with OptiVol

“Dry” lungs ⇒ High impedance
Better

“Wet” lungs ⇒ Low impedance
Worse
• **Increase** in hospitalisation in RCT of OptiVol with audible patient alerts

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**C**

Hazard ratio, 1.79 (CI, 1.08-2.95)
P = 0.022

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<thead>
<tr>
<th>Hospitalization for Heart Failure (%)</th>
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<tr>
<td></td>
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<tr>
<td><strong>Access Arm</strong></td>
</tr>
<tr>
<td>100</td>
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<tr>
<td>40</td>
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<tr>
<td>30</td>
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<td>20</td>
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<td>10</td>
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| **Control Arm**                      |
| 100                                  |
| 40                                   |
| 30                                   |
| 20                                   |
| 10                                   |
| 0                                    |

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<thead>
<tr>
<th>Months since randomization</th>
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<tr>
<td>0</td>
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<td>18</td>
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<td>21</td>
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**No. at Risk**

<table>
<thead>
<tr>
<th>Access Arm</th>
<th>168</th>
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<tr>
<td>Control Arm</td>
<td>167</td>
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<th>144</th>
<th>130</th>
<th>97</th>
<th>66</th>
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<td>151</td>
<td>136</td>
<td>113</td>
<td>67</td>
<td>46</td>
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DOT-HF Circulation 2011
Congestion: accumulation of water in the thorax (body)

• Normal: Dry: Impedance

• Congested: Wet: Impedance
Heart Failure Sensor Suite

The Heart Failure Sensor Suite is intended to represent typical in-office questions that a physician or nurse would ask their patient.

Our Sensors:

- **Sleep Incline**
  - "How many pillows do you sleep on at night?"

- **Thoracic Impedance**
  - Listen to lung sounds for signs of pulmonary edema

- **Respiratory Rate**
  - "Are you out of breath? Have difficulty breathing?"

- **Activity Level**
  - "Have you been feeling tired?"

- **Weight**
  - "Have you gained weight?"
  - (check leg or abdominal swelling)

- **Blood Pressure**
  - Measure blood pressure
  - (Hypertensive? Hypotensive?)

- **Night Heart Rate**
  - Is resting heart rate elevated?
Physiological Markers of Acute HF Decompensation

- Pressure Changes
- Impedance Changes
- Weight Changes, BP, HF Symptoms
- Autonomic Adaptation

Medtronic Integrated Diagnostics
• It presents the future 30-day patient risk on the first page of the HF Management report

The risk status based is on an analysis of the device diagnostics data from the previous 30 days to calculate the probability of a heart failure event within the next 30 days.
New onset atrial fibrillation

Increase in V rate during AF

Decrease in % Bi V pacing
Heart failure management report

Risk of Heart Failure Event in Next 30 Days
(based on maximum daily risk status in prior 30 days)

Risk Factors
- OptVol
- Patient activity
- RTI/AF
- Ventricle rate during VT/AF
- % Ventricular pacing
- Shocks
- Treated VT/AF
- Night ventricular rate
- Heart rate variability
Action

• HF team notified
• Patient contacted – now sleeping downstairs as unable to manage stairs due to worsening SOB – no contact with hospital/ general practitioner as due for HF review in 2 months
• Anticoagulated
  – River registry
• Listed for DCCV
• Diuretics uptitrated at home – no hospital admission
Thank you for your attention
Prior to Last Session
21-Jan-2015 to 22-Jan-2016
12 months

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<td>B-I-V</td>
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<td>LV</td>
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Since Last Session
22-Jan-2016 to 20-Mar-2017
14 months

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Atrial

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Ventricular

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<tr>
<th>% of Time</th>
<th>VS</th>
<th>VP</th>
</tr>
</thead>
</table>

> 5% of AS may be due to FFRW
A more ideal histogram...