Device Troubleshooting

Flipped Classroom
Case 1

• A 48 year-old male with nonischemic cardiomyopathy, LVEF≤35% with dual chamber ICD (Boston Scientific Energen, model E142) since 9/2012, history of ventricular tachycardia with successful ATP, paroxysmal atrial fibrillation and atrial tachycardia on beta-blocker therapy, was seen following an ICD shock. Patient complained of palpitations but denied syncope or pre-syncope.

Rakesh Gopinathannair, MD Univ Louisville
• Device parameters:
• Brady: DDD 60-115; Paced and sensed AV delay of 300 msec
• Tachy: VF zone (200 bpm [300 msec]) with ATP during charging, VT zone (170 bpm [353 msec] with Rhythm ID), and a VT-1 monitor zone (140 bpm [428 msec])

Rakesh Gopinathannair, MD Univ Louisville
• Interrogation showed normally functioning device and leads. Tracings of the episode are shown in a sequential fashion. Why did the shock happen? Was it appropriate? What programming changes, if any, would you make?

Rakesh Gopinathannair, MD Univ Louisville
Question

• Interrogation showed normally functioning device and leads. Tracings of the episode are shown in a sequential fashion.

• The following statements are true about this event except:
  a. This is an inappropriate shock
  b. The device function was appropriate with respect to tachy detection and therapy delivery
  c. A programming change in device settings can prevent the same situation from happening again
  d. Rhythm ID in this case did not function appropriately during rhythm reconfirmation following ATP
  e. In Boston Scientific ICDs, reconfirmation requires only 2/3 fast beats and does not exclude a monitor zone

Rakesh Gopinathannair, MD Univ Louisville
Case 2

• The following tracing denotes an AMS (Automatic Mode Switch) episode in a patient with a dual chamber pacemaker (St.Jude Medical Accent DR) implanted for sick sinus syndrome. Patient complained of occasional, transient palpitations.
• The programmed parameters are as follows:
• DDDR 60-120 bpm (max sensor 125 bpm with fast reaction time)
• PAV 275 msec/SAV 250 msec (No AV search)
• PVARP 275 msec
• AMS was programmed to DDIR 65 bpm and initiated at atrial rates ≥180 bpm.

Rakesh Gopinathannair, MD Univ Louisville
• Which of the following statements is **false** about this scenario?

• 1. There is functional atrial undersensing
• 2. This AMS event was misclassified by the device
• 3. Ventriculoatrial conduction is a basic requirement for the initiation of this AMS event
• 4. Presence of sinus tachycardia significantly contributed to the initiation of the AMS episode
• 5. Programming to reduce the TARP interval can prevent these events in the future

Rakesh Gopinathannair, MD Univ Louisville
Case 3

• 67 yo man with known coronary artery disease referred for recurrent episodes of rapid heart rates associated with light-headedness. He underwent coronary artery bypass grafting 4 years ago. His most recent echocardiogram shows an LVEF of 30% with inferior hypokinesis. He is currently on sotalol 80 mg twice daily and lisinopril 20 mg daily.
The next step would be:

- A) Referral for cardiac catheterization and coronary angiography
- B) Increase the sotalol to 120 mg twice daily
- C) Stop the sotalol and start amiodarone
- D) Referral for ventricular tachycardia ablation
- E) Referral for electrophysiology study

Fred Kusumoto, MD
Case 4

• 60 year old female
• Chronic systolic heart failure d/t non-ischemic cardiomyopathy (LVEF 29%; IDd 5.5 cm)
• Paroxysmal atrial fibrillation
• Treated with apixaban, metoprolol, lisinopril, furosemide, potassium, dofetilide

Daniel J. Cantillon MD FACC FHRS
DDD 70 / 120
pAVD / sAVD 200/180 ms
AMS on 171 bpm

VF 250bpm, ATP / shocks (30 of 40)
FVT via VF 182 bpm, ATP / shocks
Monitor zone 167 bpm
Question #1

This ECG demonstrates which of the following:

A. Fusion pacing
B. Pseudo fusion pacing
C. Pseudo Pseudofusion pacing
D. A and C
E. None of the above
Case, cont.

- Patient continued to experience high AF burden (~65% by device diagnostics)
- Requiring DC cardioversion
- Resulting in HF hospitalization requiring ICU stay
- AV nodal therapies limited by hypotension
- PVI deferred. Referred for AV nodal ablation
Question #2

This ECG demonstrates which of the following:

A. Loss of left ventricular capture
B. Loss of right ventricular capture
C. Atrial undersensing
D. Excessive Ikr blockade effect
E. Excessive None of the above
Question #3

The tracing demonstrates all of the following EXCEPT:
A. Pseudo pseudo fusion
B. Ventricular non-capture
C. Ventricular safety pacing
D. Atrial undersensing
E. Polymorphic ventricular tachycardia
Off dofetilide
Case 5/6
Patient #1

- 71 yo female with Sjogren’s syndrome, permanent AF, and longstanding NICM EF 30% with NYHA III symptoms s/p CRT-D.

- 6 months later patient feeling poorly ever since device implant with multiple CHF exacerbations.

John Rickard MD, MPH
Presenting ECG
Patient #2

• 48 year old male with NICM EF 15%, s/p CRT-d, DM LBBB QRSd of 174 ms, and OSA underwent an attempted CRT-D system.

• Transcutaneous efforts failed due to anatomy and the patient underwent surgical placement of an LV lead.

• Patient has felt poorly ever since CRT was initiated.
Presenting 12 lead ECG
Which of the following is true?

• In patients with a CRT device which of the following can produce a LBBBoid paced pattern in lead V1?

  A. Posteriorly placed CS lead and apical RV lead
  B. LV non capture
  C. Anteriorly placed CS lead and apical RV lead
  D. Anodal Stimulation
  E. Significant latency in LV lead
  F. All of the above
Back to Patient #1

• 71 yo Sjogrens patient:
  – NICM 5 years duration
  – LVEDD 6.5 cm
  – NYHA class II symptoms
  – Pre CRT LVEF 30%
Suppression of Biventricular Pacing
Baseline

• **Medications**
  - Beta blocker: Coreg 12.5 mg po bid
  - Hydralazine/Nitrates: none
  - Ace inhibitor or ARB: lisinopril 5 mg daily
  - Aldosterone antagonists: none
  - Diuretic: lasix 80 mg daily
  - Digoxin 0.25 mg daily

• **Comorbidities**
  - Cardiomyopathy subtype: NICM
  - Anemia: not present
  - COPD: not present
  - CKD: not present
  - OSA: screen negative
  - Malignancies: not present
  - DM: not present
# Device Interrogation

<table>
<thead>
<tr>
<th>Device Interrogation</th>
<th>30 Apr 2013</th>
<th>Since Last Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brady/CRT Counters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% A Paced</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>% RV Paced</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>% LV Paced</td>
<td>97</td>
<td>98</td>
</tr>
<tr>
<td><strong>Intrinsic Promotion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate Hysteresis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Successful</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Atrial Burden</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial Burden %</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Episodes by Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 minute</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 min - &lt; 1 hr</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 hr - &lt; 24 hr</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24 hr - &lt; 48 hr</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 48 hr</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total PACs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Ventricular Counters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PVCs</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Three or More PVCs</td>
<td>0</td>
<td>2</td>
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# Device Interrogation

<table>
<thead>
<tr>
<th>Leads Data</th>
<th>Implant</th>
<th>Previous Session</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 Oct 2012</td>
<td></td>
</tr>
<tr>
<td><strong>Atrial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Amplitude</td>
<td>N/R mV</td>
<td>N/R mV</td>
</tr>
<tr>
<td>Pace Impedance</td>
<td>N/R Ω</td>
<td>&gt;2000 Ω</td>
</tr>
<tr>
<td>Pace Threshold</td>
<td>N/R V @ N/R ms</td>
<td>3.0 V @ 0.4 ms</td>
</tr>
<tr>
<td><strong>Right Ventricular</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Amplitude</td>
<td>N/R mV</td>
<td>PVC mV</td>
</tr>
<tr>
<td>Pace Impedance</td>
<td>500 Ω</td>
<td>418 Ω</td>
</tr>
<tr>
<td>Pace Threshold</td>
<td>0.8 V @ 0.4 ms</td>
<td>1.1 V @ 0.8 ms</td>
</tr>
<tr>
<td><strong>Left Ventricular</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic Amplitude</td>
<td>N/R mV</td>
<td>PVC mV</td>
</tr>
<tr>
<td>Pace Impedance</td>
<td>500 Ω</td>
<td>547 Ω</td>
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<tr>
<td><strong>Pace Threshold</strong></td>
<td>3.4 V @ 0.5 ms</td>
<td>2.0 V @ 1.8 ms</td>
</tr>
<tr>
<td><strong>Shock Vector</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock Impedance</td>
<td>N/R Ω</td>
<td>65 Ω</td>
</tr>
</tbody>
</table>

**Highlighted Data**

- **Pace Threshold** in the Left Ventricular section: 3.4 V @ 0.5 ms
Lead Position
Presenting ECG
RV pacing
Biventricular Pacing
• 48 year old male with NICM EF 25%, s/p CRT-D, DM, NYHA class II symptoms, and OSA underwent a surgically placed LV lead following failure to place a percutaneous CS lead.

• 6 months following CRT, LVEF has dropped to 15% and symptoms have progressed to NYHA class III.
Presenting ECG
Suppression of Biventricular Pacing
Baseline

- **Medications**
  - Beta blocker: Toprol XL 100 mg daily
  - Hydralazine/Nitrates: none
  - Ace inhibitor or ARB: losartan 50 mg daily
  - Aldosterone antagonists: eplerenone 25 mg daily
  - Diuretic: lasix 40 mg daily

- **Comorbidities**
  - Cardiomyopathy subtype:
    - NICM: 1 year duration
  - Anemia: not present
  - COPD: not present
  - CKD: not present
  - OSA: screen positive
  - Malignancies: not present
  - DM: present
## Device Interrogation

### Counters (Since Last Reset)

<table>
<thead>
<tr>
<th>Detection</th>
<th>Therapies</th>
<th>RA</th>
<th>RV</th>
<th>Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF (VHR)</td>
<td>Shocks Delivered</td>
<td>0</td>
<td>0</td>
<td>RA: 0.04 % AS-VS: 0.25 %</td>
</tr>
<tr>
<td>Fast VT</td>
<td>Shocks Aborted</td>
<td>0</td>
<td>0</td>
<td>RV: 99.56 % AS-VP: 99.71 %</td>
</tr>
<tr>
<td>Slow VT</td>
<td>ATP Delivered</td>
<td>0</td>
<td>1</td>
<td>LV: 99.54 % AP-VS: 0.00 %</td>
</tr>
<tr>
<td>VSlow VT</td>
<td>Mode Switch Detections</td>
<td></td>
<td></td>
<td>CRT: 99.54 % AP-VP: 0.04 %</td>
</tr>
<tr>
<td>VT-NS</td>
<td>Burden</td>
<td></td>
<td></td>
<td>AT/AF Burden: 0 %</td>
</tr>
<tr>
<td></td>
<td>Avg. Daily Burden</td>
<td></td>
<td></td>
<td>Max. Duration:</td>
</tr>
</tbody>
</table>

### Lead Data

#### Lead Impedance / Thresholds

<table>
<thead>
<tr>
<th>RA</th>
<th>RV</th>
<th>LV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacing Impedance: 513</td>
<td>494</td>
<td>323</td>
</tr>
<tr>
<td>Capture Amplitude: 1</td>
<td>0.5</td>
<td>1.875</td>
</tr>
<tr>
<td>Capture Duration: 0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Sensing Amplitude: 4</td>
<td>8.75</td>
<td>mV</td>
</tr>
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</table>

#### Lead Information

<table>
<thead>
<tr>
<th>RA</th>
<th>RV</th>
<th>LV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Status:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrity Count:</td>
<td>0</td>
<td>mV</td>
</tr>
<tr>
<td>Polarization:</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Evoked Response:</td>
<td>ms</td>
<td></td>
</tr>
</tbody>
</table>
PA/Lat CXR
Case 7

• 55yo s/p anterior MI in 2005 with severely reduced EF.
• Primary prevention CRT-ICD one year earlier
  • Boston Scientific COGNIS 100-D N119
• Underlying Rhythm: Normal sinus rhythm with LBBB
• Admitted with pneumonia
• Patient noted to have non-sustained wide complex tachycardia, occurring 2 to 3 times per hour on telemetry

Jeanne E Poole, MD
INTERROGATION AND PROGRAMMING

**Mode:** DDD, lower rate 50ppm, Upper rate 130ppm
- ATR Mode Switch 170bpm DDI
- Paced A-V delay 130ms
- PVARP 240-280ms

**VF zone:**
- VF ON >240bpm 41J, 41J, 41Jx6
- VT On >180bpm ATPx2 41J, 41J, 41Jx4
- VT-1 ON >150bpm monitor only

**A paced <1%**

**RV paced 88%**  • Thresholds, sensing and impedances are all

**LV paced 87%**  • Multiple episodes PMT in log
Case 7

Representative Episode
Question: This episode demonstrates -

A. Ventricular Tachycardia
B. Pacemaker mediated tachycardia
C. Normal upper rate behavior
D. Discrimination error
Features used by all manufacturers to promote CRT pacing

- Boston Scientific: Tracking preference
- Medtronic: Atrial tracking recovery
- St. Jude Medical: Negative AV/PV Hysteresis
- Biotronik: Negative AV Hysteresis
CASE 8

81 year old woman with NIDCM

- NYHA Class III HF symptoms
- EF 23%
- LBBB
- QRS 130ms
- DDD-PM placed years earlier for sinus brady, occ. paces
- Upgraded to a CRT-P from a DDD-PM
Case 8
Baseline non pacing ECG
Case 8

Baseline dual chamber paced ECG
Case 8

Post-op CRT upgrade
Case 8

Post-CRT ECG

Threshold LV Tip to LV 2 = 2.8V at 1.0ms
Programmed 3.0V at 1.0ms
Day after implant, device nurse notes threshold has increased and no capture tip to ring. Capture is obtained at higher outputs with:

**Programmed LV tip to RV ring 3.5 at 0.5ms**
You decide to check the thresholds

LV only pacing threshold is performed, pulse width 0.5ms

3.0V  2.6V  2.5V  2.4V

Lead VI

LV
Case 8

Lead VI

LV

2.3V = 2.2V
Case 8

Lead VI

2.1V - 2.0V - 1.9V - 1.8V - 1.7V - 1.6V - 1.5V

LV
Case 8

Her CXR shows stable LV lead position. What is the best next step?

A. Reprogram the pacing vector from LV3 to RV ring and check threshold
B. Keep the pacing vector LV4 to RV ring and program the pacing output higher than the threshold (1.8V at 0.5ms)
C. Reposition the LV lead
D. Reprogram the pacing vector LV1-Can and check threshold
Case 9

A) Atrial lead dislodgement
B) Atrial lead fracture
C) Atrial lead electrically isolated
D) End of service

- DDDR 60 bpm
- Max Tracking 130 bpm
- Max Sensor 130 bpm
- AV 250 ms
- PVARP Auto Min 250 ms
- A 2.0 V 0.4 ms
- V 3.0 V 0.4 ms

Paul J. Wang, MD
What is the abnormality?

- DDDR  60 bpm
- Max Tracking  130 bpm
- Max Sensor  130 bpm
- AV    250 ms
- PVARP Auto Min 250 ms

A) Atrial lead dislodgement
B) Atrial lead fracture
C) Atrial lead electrically isolated
D) End of service
- A) Atrial lead dislodgement
- B) Atrial lead fracture
- C) Atrial lead electrically isolated
- D) End of service

Paul J. Wang, MD
Case 10

- St. Jude Identity DR model 5370
- DDDR 70bpm; Max Tracing 120 bpm
- Max sensor 120 bpm
- AV Interval 200 ms
- Ventricular AutoCapture: On


AV interval, VA interval, RR interval, bipolar atrial electrogram, and bipolar ventricular electrogram. Asterisk indicates ventricular premature beat.
• St. Jude Identity DR model 5370
• DDDR 70bpm; Max Tracing 120 bpm
• Max sensor 120 bpm
• AV Interval 200 ms
• Ventricular AutoCapture: On

Al-Ahmad A, Tsiperfal A, Wang PJ

AV interval, VA interval, RR interval, bipolar atrial electrogram, and bipolar ventricular electrogram. Asterisk indicates ventricular premature beat.
- The most likely explanation of pacing rate is:
  - A) Autocapture algorithm
  - B) Atrial based timing
  - C) Rate smoothing
  - D) Auto PVARP

Al-Ahmad A, Tsiperfal A, Wang PJ
## Case 11

<table>
<thead>
<tr>
<th>Pulse Generator</th>
<th>Medtronic InSync II Marquis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>DDDR</td>
</tr>
<tr>
<td>Lower rate limit</td>
<td>70 ppm</td>
</tr>
<tr>
<td>Maximum tracking rate (MTR)</td>
<td>150 ppm</td>
</tr>
<tr>
<td>AV Interval (AVI)</td>
<td>Dynamic (minimum 70ms)</td>
</tr>
<tr>
<td>PVARP</td>
<td>310 ms</td>
</tr>
<tr>
<td>PMT</td>
<td>On</td>
</tr>
</tbody>
</table>

Why is Biventricular pacing lost?

Why is Biventricular pacing lost?

• A) PMT algorithm
• B) Rate above URL
• C) Auto PVARP
• D) Rate adaptive AV delay
• E) Atrial undersensing

You are changing an end of service ICD generator. After confirming lead function with the old generator and PSA, you induce VF, but 2 shocks from the new generator fail at 20 J. The figure shows the 2nd 20 J shock, and diagnostic values from the PSA, the explanted generator, and the new generator after external defibrillation. The lead appears normal on fluoroscopy. What is your next step before you retest defibrillation?

A. Replace the new pulse generator.
B. Insert a new lead and retest.
C. Add a subcutaneous defibrillation lead or array.
D. Correct the loose set screw.

Courtesy of Chuck Swerdlow, MD
What is your next step before you retest defibrillation?

### Pre-Shock Testing

<table>
<thead>
<tr>
<th></th>
<th>Old ICD</th>
<th>PSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacing Z (Ω)</td>
<td>480</td>
<td>515</td>
</tr>
<tr>
<td>Painless HV Z</td>
<td>46</td>
<td>NA</td>
</tr>
<tr>
<td>R wave (mV)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Pacing threshold (V)</td>
<td>1.0</td>
<td>1.25</td>
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</tbody>
</table>

### Post-Shock Interrogation

- **HV Therapy**
  - Last HV Lead Impedance: 0 Ω
  - First Charge Time: 3.4 sec
  - Last Charge Time: 0.1 sec
  - Delivered PW: +0.2 ms, -0.2 ms

*Courtesy of Chuck Swerdlow, MD*
What is the delivered energy?

A. < 1 J  B. 18 - 20 J  C. 20 J  D. 30 J

HV Therapy
Last HV Lead Impedance 0 Ω
First Charge Time 3.4 sec
Last Charge Time 0.1 sec
Delivered PW +0.2 ms, -0.2 ms

Courtesy of Chuck Swerdlow, MD
**Shock Waveform: Stored & Delivered Energy, Duration**

**Key Points**
- Defibrillation requires 3-5 ms phase 1
- If the shock waveform is too short, little energy is delivered

**HV Therapy**
- Last HV Lead Impedance: 0 Ω
- First Charge Time: 3.4 sec
- Last Charge Time: 0.1 sec
- Delivered PW: +0.2 ms, -0.2 ms

What is your next step before you retest defibrillation?

A. Replace the new pulse generator.
B. Insert a new lead.
C. Add a subcutaneous defibrillation lead or array.
D. Correct the loose set screw.