My ICD patient just received their first inappropriate shock: what do I do now?

Greg Smith
Lead Invasive Physiologist
Northern General Hospital - Sheffield
Importance of ICD Shocks

- Anxiety
- Depression
- Quality of Life
- PTSD
Driving

Battery longevity

Detrimental effects of ICD shocks

Poole, Jeanne E., et al. 2008
Patient History

- Symptoms
  - Syncope / Pre-syncope
  - Palpitation
  - Chest Pain

- What were they doing
  - Sports
  - Arm Movements
  - Using electronic equipment
  - Medical procedure
  - Potential EMI Exposure

- Recent device reprogramming
- Previous arrhythmias
Inappropriate ICD shock rate

Inappropriate Shock Rate

- MADIT II
- AVID
- PAINFREE
- MIRACLE ICD
- DEFINITE
- SCD-HeFT
- PREPARE
- MADIT-RIT

Inappropriate Shock Rate
Types of inappropriate shocks

Inappropriate Shocks

- Device or lead Issues
- Arrhythmia
- External Sources
Inappropriate Shock Reasons

- Atrial Fibrillation: 49%
- Other SVT (Sinus Tach, Atrial Tach, etc.): 25%
- Committed shock after appropriate therapy: 13%
- EGM noise: 8%
- T-wave oversensing: 5%

<table>
<thead>
<tr>
<th>Supraventricular Tachycardia</th>
<th>Ventricular Arrhythmias</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Atrial Fibrillation</td>
<td>• Asymptomatic VT</td>
</tr>
<tr>
<td>• Atrial Flutter</td>
<td>• Potentially self limiting ventricular arrhythmias</td>
</tr>
<tr>
<td>• AVNRT / AVRT</td>
<td></td>
</tr>
<tr>
<td>• Atrial Tachycardia</td>
<td></td>
</tr>
<tr>
<td>• Sinus Tachycardia</td>
<td></td>
</tr>
</tbody>
</table>
How do we reduce inappropriate arrhythmic shock?

Detection Rate

Detection Intervals

Single Chamber
- Morphology
- Onset
- Stability

Dual Chamber
- Morphology
- Stability
- V to A Relationship
MADIT-RIT
- Primary Prevention Implants
- Longer Detection Times
- Higher Rate Zones
- Reduction in inappropriate therapy
- Reduction in all cause mortality

PREPARE
- Primary prevention Implants
- Longer Detection Intervals 30/40
- Significant reduction in both appropriate and inappropriate shocks
- Reduction in morbidities

ADVANCE III
- Primary and Secondary Prevention
- Longer Detect 30/40 Intervals
- Significant reduction in inappropriate therapy
- No effect on mortality or syncope rates

Detection rate and occurrence of ICD shocks in single chamber devices

Sheffield Experience

Inappropriate Therapies Pre and Post MADIT-RIT: 1 Year Follow Up

<table>
<thead>
<tr>
<th></th>
<th>ICD</th>
<th>CRTD</th>
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<tbody>
<tr>
<td>Pre MADIT-RIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post MADIT-RIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre MADIT-RIT</td>
<td>[4]</td>
<td>[1]</td>
</tr>
<tr>
<td>Post MADIT-RIT</td>
<td>[2]</td>
<td>[1]</td>
</tr>
</tbody>
</table>

- Inappropriate Shocks
- Inappropriate ATP
How do we reduce inappropriate arrhythmic shock?

**Detection Rate**

**Detection Intervals**

**Single Chamber**
- Morphology
- Onset
- Stability

**Dual Chamber**
- Morphology
- Stability
- V to A Relationship
Problem with Discriminators

- Aberrancy during SVT
- Stable ventricular rate during atrial fibrillation
- Sudden on SVT
- Atrial undersensing
**Diagnosis Summary**

<table>
<thead>
<tr>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVT</td>
</tr>
</tbody>
</table>

**Time to Diagnosis**: 11.75 sec

**Rate (CL)**: 180 bpm (315 ms)

**Zone**: VT-1

**VT Diagnosis Criteria**: All

**Rate Branch Classification**: AF/AFL (V < A) Rate Branch

**Morphology**: On, ≥ 45% is a match, ≥ 5 matches indicate SVT

**Min Match Score**: 94%

**Max Non-Match Score**: n/a

**No. Template Matches**: 8 of 8 (SVT Indicated)

**Interval Stability**: On, ≥ 40 ms indicates SVT (AVA Delta Passive, < 80 ms indicates SVT)

**Stability Delta**: 135 ms (SVT Indicated)
Atrial Fibrillation
Diagnosis Summary

<table>
<thead>
<tr>
<th></th>
<th>Initial Diagnosis</th>
<th>Diagnosis</th>
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</thead>
<tbody>
<tr>
<td>VT</td>
<td>24.25 sec</td>
<td>Sinus Tach (VT = A) Rate Branch</td>
</tr>
<tr>
<td>VT-1</td>
<td>190 bpm (315 ms)</td>
<td>VT-1 Rate Branch</td>
</tr>
<tr>
<td>Rate (CL)</td>
<td>181 bpm (330 ms)</td>
<td>All</td>
</tr>
</tbody>
</table>

Morphology
- On: ≥ 65% is a match, ≥ 7 matches indicate SVT
- Min Match Score: 87%
- Max Match Score: 53%
- No. Template Matches: 10 of 12 (SVT indicated)
- Stability Delta: 85 ms (SVT indicated)

(SVT indicated)
Management

• Check parameters
  ▫ Discriminators
  ▫ Rate
  ▫ Detection Intervals
• Review medication
• Referral for electrophysiology study

2015 HRS/EHRA/APHRS/SOLAECE expert consensus statement on optimal implantable cardioverter-defibrillator programming and testing
T wave oversening
RV sensing adjustments

Madhavan, M & Friedman, P 2013
Medtronic Twave Discrimination

<table>
<thead>
<tr>
<th>V. Detection</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>320 ms (188 bpm)</td>
</tr>
<tr>
<td>FVT</td>
<td>OFF</td>
<td></td>
<td>240 ms (250 bpm)</td>
</tr>
<tr>
<td>VT</td>
<td>On</td>
<td>16</td>
<td>400 ms (150 bpm)</td>
</tr>
<tr>
<td>Monitor</td>
<td>Monitor</td>
<td>20</td>
<td>450 ms (133 bpm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PR Logic/Wavelet</th>
<th>Other Enhancements</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF/Afl</td>
<td>Stability</td>
<td>Off Atrial 0.30 mV</td>
</tr>
<tr>
<td>Sinus Tach</td>
<td>Onset...</td>
<td>Off RV     0.30 mV</td>
</tr>
<tr>
<td>Other 1:1 SVTs</td>
<td>High Rate Timeout...</td>
<td>Off</td>
</tr>
<tr>
<td>Wavelet...</td>
<td>TWave</td>
<td>On</td>
</tr>
<tr>
<td>SVT V. Limit</td>
<td>260 ms</td>
<td>RV Lead Noise...</td>
</tr>
</tbody>
</table>

![Image showing waveforms and settings]
Integrated V’s Bipolar ICD’s Leads

Myopotential oversensing

Boston Sci – Dynamic Noise Algorithm
Twiddler’s Syndrome

Abbott SecureSense

SecureSense™ RV Lead Noise Discrimination

<table>
<thead>
<tr>
<th>Lead Noise</th>
<th>True VT/VF</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Tip: RV Ring (near field)</td>
<td>![Signal]</td>
</tr>
<tr>
<td>RV Cord: Cap (far field)</td>
<td>![Signal]</td>
</tr>
<tr>
<td>Rate Correlation</td>
<td>Different rates</td>
</tr>
<tr>
<td>Failure Type</td>
<td>Tip or ring conductor noise</td>
</tr>
<tr>
<td>Decision</td>
<td>Inhibit therapy</td>
</tr>
</tbody>
</table>

Alerts

- SecureSense™ is On, and it inhibited therapy due to RV lead noise.
  (Patient Notifier triggered 15 Oct 2016 at 12:07)
- SecureSense™ is On, and it detected Non-sustained RV Oversensing Episodes with alert conditions (8)
- High V. Rates during AT/AF
Performance of an ICD algorithm to detect lead noise and reduce inappropriate shocks

Scott Beau¹ · Stephen Greer² · Christopher R. Ellis³ · Jeffrey Keeney⁴ · Shubha Asopa⁴ · Edith Arnold⁴ · Avi Fischer⁴

RESULTS: The algorithm detected noise and withheld inappropriate therapy in 231 of 238 recordings of sustained lead noise that would otherwise have been diagnosed as VT/VF (97.1%). Non-sustained lead noise was correctly diagnosed in 47 of the 52 recordings (90.4%). The device appropriately identified all 853 recordings of VT/VF (100%), without an increase in the time to detection (0.01 ± 0.14 s).
Lead Fracture
Lead Fracture
Lead Fracture

<table>
<thead>
<tr>
<th>Type</th>
<th>ATP Seq</th>
<th>Shocks</th>
<th>Success</th>
<th>ID#</th>
<th>Date</th>
<th>Time hh:mm</th>
<th>Duration hh:mm:ss</th>
<th>Avg bpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>39</td>
<td>16-Jun-2009</td>
<td>19:24</td>
<td>:57</td>
<td>214</td>
</tr>
</tbody>
</table>

Treated VT/VF Episode #39

Detection: 24.8 J, 34.6 J, 34.8 J

Term.: 34.7 J

Interval (ms)

- 1500
- 1200
- 900
- 600
- 400
- 200

Time (sec)

-50  -40  -30  -20  -10   0   10  20  30  40  50
Medtronic Lead Integrity Alert (LIA)

- Abnormal RV lead impedance (defined as impedance that is significantly higher or lower than a calculated baseline impedance level)
- Two or more High Rate-NS (nonsustained VTs) with intervals that are shorter than 220 ms
- At least 30 short V-V interval counts (SIC) within 3 consecutive days

**PERFORMANCE DATA**

The RV Lead Noise Discrimination algorithm can withhold 83.7% of inappropriate detection for lead sensing noise.\(^1\) Using the Protecta Performance Model, the RV Lead Noise Discrimination algorithm, combined with ATP Before/During Charging, \(**TWave Discrimination**,\) and SVT discriminators applied in the VF zone, significantly reduced shock frequency when tested on stored episodes from the SCD-HeFT Trial. This model that combined existing and new shock reduction features predicted 98% of patients would be free of inappropriate shocks 1 year after implant, and 92% at 5 years post-implant.\(^2\)
OBSERVATIONS (3)

- Alert: RV Lead Noise warning on 12-Sep-2016. 1 or more V. Oversensing-Noise episodes. [RV Lead Integuity Counter](#), [Sensing Integrity Counter](#), High Rate-NS episodes, and RV Lead Impedance. The oldest High Rate-NS episode associated with this observation is dated 03-Aug-2016. [High Rate-NS](#), [Sensing Integrity Counter](#), [RV Lead Integuity Counter](#)

- Alert: RV bipolar lead impedance warning on 02-Sep-2016.
<table>
<thead>
<tr>
<th>Type</th>
<th>ATP Seq</th>
<th>Shocks</th>
<th>Success</th>
<th>ID#</th>
<th>Date</th>
<th>Time hh:mm</th>
<th>Duration hh:mm:ss</th>
<th>Avg bpm V</th>
<th>Max bpm V</th>
<th>Activity at Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Oversensing Noise</td>
<td>330</td>
<td></td>
<td></td>
<td></td>
<td>12-Sep-2016</td>
<td>19:40</td>
<td>.06</td>
<td>222</td>
<td>261</td>
<td>Active</td>
</tr>
</tbody>
</table>

- V-V

VF = 300 ms
FVT = 250 ms
VT/VF Detection Withheld

Term.
Other Causes
Management

• Device reprogramming
  ▫ Integrated bipolar
  ▫ Myopotential / T wave algorithms ON

• Temporary therapy deactivation

• Imaging

• Lead replacement

• Consider effect on bradycardia pacing
Electromagnetic Interference EMI

- Improperly grounded electrical equipment
- Electrocautery
- TENS
- Industrial Equipment
- MRI
- Voltage power cords
Electromagnetic Interference from Swimming Pool Generator Current Causing Inappropriate ICD Discharges
Roberto Case
Reports in Cardiology 2017:67143072017 2090-6404
Electrocautery
Prevention

- Identify source
- Patient education
- Work place assessment
Summary

*My ICD patient just received their first inappropriate shock: what do I do now?*

- Understand the importance of inappropriate ICD shock
- Correctly identify the mechanism
- Understand the benefits and limitation of specific manufacturers feature
- Understand the hardware limitations
- Understand what requires addition intervention are required
- DO something to stop it happening again.