Optimal ICD programming

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Optimal ICD programming

ICD shock-reduction strategies

Overview
Rate and Duration for Initial Detection
SVT-VT discrimination
Antitachycardia Pacing
Bradycardia pacing
Conventional Definitions of ICD shocks

• **Appropriate**
  – ICD shocks for VT or VF

• **Inappropriate**
  – ICD shocks for SVT, EMI, lead noise, oversensing, etc.

Wilkoff et al. JACC 2008;52:541-50
**Frequency of Inappropriate ICD shocks in MADIT II**

<table>
<thead>
<tr>
<th>Shock Therapy Group</th>
<th>Patients (n)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>One or more inappropriate shock episodes</td>
<td>83</td>
<td>11.5%</td>
</tr>
<tr>
<td>1 inappropriate shock episode</td>
<td>51</td>
<td>7.1%</td>
</tr>
<tr>
<td>2–4 inappropriate shock episodes</td>
<td>23</td>
<td>3.2%</td>
</tr>
<tr>
<td>≥5 inappropriate shock episodes</td>
<td>9</td>
<td>1.3%</td>
</tr>
<tr>
<td>Both inappropriate and appropriate shock episodes</td>
<td>27</td>
<td>3.8%</td>
</tr>
<tr>
<td>Inappropriate but not appropriate shock episode(s)</td>
<td>56</td>
<td>7.8%</td>
</tr>
<tr>
<td>No inappropriate shock episodes</td>
<td>636</td>
<td>88.5%</td>
</tr>
<tr>
<td>Appropriate shock episode(s)</td>
<td>101</td>
<td>14.1%</td>
</tr>
<tr>
<td>No appropriate shock episodes</td>
<td>535</td>
<td>74.4%</td>
</tr>
<tr>
<td>Total patients</td>
<td>719</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**Inappropriate shock: 11.5%**

**Appropriate shock: 14.1%**

Daubert J, et al. JACC 2008;51:1357-65
ICD Shock-Reduction Strategies: Overview

Device process
- Heart rate threshold
- Duration/no. intervals
- Detection enhancements/SVT-VT discrimination
- Anti-tachycardia pacing
- Reconfirmation

Tachycardia detected
- VT confirmed
- Shock

Rationale
- Ignore slow rhythms (VT, SVT)
- Ignore non-sustained VT, SVT
- Reject SVT
  - Terminate VT
  - Allow time for self-termination
  - Terminate some SVT
- Confirm ongoing arrhythmia

Hardware independent
Hardware dependent
Appropriately Detected Episodes

303 ± 54 ms vs 366 ± 71 ms, P < 0.0001

**PREPARE: Programming**
(Primary Prevention Parameters Evaluation)

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### Table 1: PREPARE VT/VF Programming Parameters

<table>
<thead>
<tr>
<th>Detection</th>
<th>Threshold</th>
<th>Beats to Detect</th>
<th>Therapies</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>On</td>
<td>250 beats/min</td>
<td>30 of 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30 to 35 J (max output) × 6</td>
</tr>
<tr>
<td>FVT</td>
<td>via VF</td>
<td>182 beats/min</td>
<td>30 of 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Burst (1 sequence), 30 to 35 J (max output) × 5</td>
</tr>
<tr>
<td>VT</td>
<td>Monitor</td>
<td>167 beats/min</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Off</td>
</tr>
</tbody>
</table>

Supraventricular tachycardia criteria on (dual chamber, biventricular implantable cardioverter-defibrillator): atrial fibrillation/flutter, sinus tachycardia (1:1 VT-ST boundary = 66%); supraventricular tachycardia criteria on (single chamber): wavelet morphology discrimination (match threshold = 70%); supraventricular tachycardia limit = 300 ms; burst antitachycardia pacing: 8 intervals, pacing cycle length = 88% of tachycardia cycle length.

FVT = fast ventricular tachycardia; PREPARE = Primary Prevention Parameters Evaluation study; VF = ventricular fibrillation; VT = ventricular tachycardia; VT-ST = ventricular tachycardia-sinus tachycardia.

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240 ms (250 bpm) 330 ms (182 bpm)
PREPARE: Shock Frequency

Inappropriate Shocks

Appropriate Shocks

Wilkoff et al. JACC 2008;52:541-50
PREPARE: Overall Mortality

Wilkoff et al. JACC 2008;52:541-50
Harm from ICD Shocks?

Sweeney et al. Heart Rhythm 2010;7:353-60

Bhaynani et al. Heart Rhythm 2010;7:755-60
MADIT-RIT  
*(Reduction in Inappropriate Tx)*

1500 Patients with Primary Prevention ICD Indication:

<table>
<thead>
<tr>
<th></th>
<th>Slow VT</th>
<th>Fast VT</th>
<th>VF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>170-199 bpm</td>
<td>2.5 sec</td>
<td>≥ 200 bpm 1 sec</td>
</tr>
<tr>
<td></td>
<td>170-199 bpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5 sec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-Rate</td>
<td></td>
<td></td>
<td>≥ 200 bpm 2.5 sec</td>
</tr>
<tr>
<td>Delayed Detection</td>
<td>170-199 bpm</td>
<td>200-249 bpm</td>
<td>&gt; 250 bpm 2.5 sec</td>
</tr>
<tr>
<td></td>
<td>60 sec</td>
<td>12 sec</td>
<td></td>
</tr>
</tbody>
</table>

Moss et al. NEJM 2012;367:2275-83
Table 2. First Occurrence, Any Occurrence, and Total Occurrences of Appropriate and Inappropriate Device Therapy According to Treatment Group.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional Therapy (N=514)</th>
<th>High-Rate Therapy (N=500)</th>
<th>Delayed Therapy (N=486)</th>
<th>P Value for High-Rate Therapy vs. Conventional Therapy</th>
<th>P Value for Delayed Therapy vs. Conventional Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First occurrence of therapy — no. of patients (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate therapy</td>
<td>114 (22)</td>
<td>45 (9)</td>
<td>27 (6)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shock</td>
<td>20 (4)</td>
<td>22 (4)</td>
<td>17 (3)</td>
<td>0.68</td>
<td>0.74</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>94 (18)</td>
<td>23 (5)</td>
<td>10 (2)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inappropriate therapy</td>
<td>105 (20)</td>
<td>21 (4)</td>
<td>26 (5)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shock</td>
<td>20 (4)</td>
<td>11 (2)</td>
<td>13 (3)</td>
<td>0.12</td>
<td>0.28</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>85 (17)</td>
<td>10 (2)</td>
<td>13 (3)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Any occurrence of therapy — no. of patients (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>28 (5)</td>
<td>26 (5)</td>
<td>19 (4)</td>
<td>0.86</td>
<td>0.25</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>111 (22)</td>
<td>38 (8)</td>
<td>20 (4)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inappropriate therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>31 (6)</td>
<td>14 (3)</td>
<td>15 (3)</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>104 (20)</td>
<td>20 (4)</td>
<td>25 (5)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Total occurrences of therapy — no. of occurrences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate therapy</td>
<td>517</td>
<td>185</td>
<td>196</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shock</td>
<td>71</td>
<td>72</td>
<td>53</td>
<td>0.35</td>
<td>0.15</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>446</td>
<td>113</td>
<td>143</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inappropriate therapy</td>
<td>998</td>
<td>75</td>
<td>264</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shock</td>
<td>105</td>
<td>25</td>
<td>49</td>
<td>0.001</td>
<td>0.16</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>893</td>
<td>50</td>
<td>215</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Crude rates of the first occurrence of therapy and any occurrence of therapy were compared with the use of chi-square tests, and mean counts of total occurrences of therapy were compared with the use of negative binomial regression models.
MADIT-RIT
(Reduction in Inappropriate Tx)

Inappropriate Therapy
Hazard Ratios:
High rate: 0.21 (p<0.001)
Delayed: 0.24 (p<0.001)

Overall Mortality
Hazard Ratios:
High rate: 0.45 (p=0.01)
Delayed: 0.56 (p=0.06)

Moss et al. NEJM 2012;367:2275-83
Effect of Long-Detection Interval vs Standard-Detection Interval for ICD on ATP and Shock Delivery

Treatment Effect Regarding the Primary End Point and Its Components

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Incidence Rate Ratio (95% CI)</th>
<th>Favors</th>
<th>Favors</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antitachycardia pacing and shocks</td>
<td>0.63 (0.51-0.78)</td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Shocks</td>
<td>0.77 (0.59-1.01)</td>
<td></td>
<td></td>
<td>.06</td>
</tr>
<tr>
<td>Antitachycardia pacing</td>
<td>0.58 (0.47-0.72)</td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Long-Detection Interval (30/40) Standard-Detection Interval (18/24)

ADVANCE III. JAMA. 2013;309(18):1903-1911
Effect of Long-Detection Interval vs Standard-Detection Interval for ICD on ATP and Shock Delivery

Treatment Effect Regarding the Primary End Point and Its Components

The analysis population included patients for whom device memory data were available for at least 1 follow-up visit.

ADVANCE III. JAMA. 2013;309(18):1903-1911
ICD Programming for Primary Prevention of Sudden Death

<table>
<thead>
<tr>
<th>Zone</th>
<th>Rate</th>
<th>Detection</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapy zone</td>
<td>200 bpm</td>
<td>5-9 second delay</td>
<td>ATP during charge, Maxium-energy shock</td>
</tr>
<tr>
<td>Monitor-only zone</td>
<td>170-199 bpm</td>
<td>9-60 second delay</td>
<td>None</td>
</tr>
</tbody>
</table>

*Circulation.* 2013;128:659-672
Tachycardia Detection: Heart Rate

Overlap Zone: Detection enhancement needed

Circulation. 2013;128:659-672
<table>
<thead>
<tr>
<th>DETECTION</th>
<th>Primary Prevention</th>
<th>Secondary Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DETECTION</strong></td>
<td>General comments</td>
<td>Consider slower cutoff rates if receiving antiarrhythmic drugs</td>
</tr>
<tr>
<td>Monitoring zone</td>
<td>150 bpm</td>
<td>130–140 bpm</td>
</tr>
<tr>
<td>Rate cutoff</td>
<td>VT zone 182–220 bpm (250 bpm if FVT via VF with Medtronic ICDs)</td>
<td>10–20 bpm slower than clinical arrhythmia (30–60 ms) or 150–162 bpm if unknown</td>
</tr>
<tr>
<td></td>
<td>VF zone 220 bpm</td>
<td>220 bpm</td>
</tr>
</tbody>
</table>

**Stability** passive or on (with AVA if stability is used) with Association programmed to ANY; Onset: passive

**Boston Scientific**
- VR and DR: Rhythm ID

**Sorin**
- VR: onset and stability
- DR: PARAD+

**Biotronik**
- VR: onset and stability
- DR: SMART

**Discriminator time out**
- Program off; more conservative programmers could extend short nominal values to 5 minutes

<table>
<thead>
<tr>
<th>THERAPY</th>
<th>VT zone</th>
<th>Secondary Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Four bursts (or mix of bursts and ramp); 8–10 pulses; 91–88% of BCL; 10 ms SCAN; readaptive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIV ATP pacing in ischemic cardiomyopathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximal shocks (pending further data)</td>
</tr>
<tr>
<td></td>
<td>VF zone</td>
<td>ATP during (or before charging)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximal shocks</td>
</tr>
</tbody>
</table>
ICD Shock-Reduction Strategies: Overview

Circulation. 2013;128:659-672
Single-Chamber Algorithms

Onset

Stability

Morphology

Abrupt onset of VT

Stable RR intervals in VT

VT – morphology does not match template

Slow warm up of sinus tachycardia

Irregular RR intervals in AF

SVT – morphology matches template
Dual-Chamber SVT-VT Discriminators

Medtronic (PR Logic)

St. Jude Medical (Rate branch algorithm)
Dual-Chamber SVT-VT Discriminators

1. Tachycardia detected in VT zone
2. V-rate > A-rate by $\geq 10$ bpm
   - Yes: VT
   - No
3. Morphology (VTC) match?
   - Yes: SVT
   - No
4. A-rate $>200$ bpm & V-rate unstable $>20$ ms
   - Yes: SVT
   - No: VT

Boston Scientific (Rhythm ID)
ICD Shock-Reduction Strategies: Anti-tachycardia pacing

Circulation. 2013;128:659-672
Frequency of Recorded HR during VT/VF: painFREE Rx II

VT > 320 ms (188bpm), FVT 320-240 ms (188-250 bpm), VF < 240 ms (250 bpm)

Compared with shocks, empirical ATP for FVT is highly effective, is equally safe, and improves quality of life.

Wathen et al. Circ 2004;110:2591-6
ATP Success for Slow VT (<200 bpm)

Antitachycardia pacing success for “slow” VT (<200 beat/min). n, Number of VT episodes documented with a rate <200 beat/min.

Wathen, AHJ 2007;153:S44-52
How to Program pacing for ICDs: DAVID

• Standard ICD Indication
  – LVEF < 40% with VT or VF
  – No bradycardia requiring pacing
  – No atrial arrhythmias

• Therapy: Dual Chamber ICD
  – VVI 40 bpm (1% RV pacing)
  – DDD 70 bpm (AV 180 ms: 60% RV pacing)
DAVID: Results

For patients with standard indications for ICD therapy, no indication for cardiac pacing, and an LVEF ≤ 40%

Death or First Hospitalization for New or Worsened CHF

First Hospitalization for New or Worsened CHF

Death From Any Cause

Relative Hazard (95% CI),
1.61 (0.84-3.09)
DAVID – Results

- Pacing percentage and outcome in the DDDR-70 group:
  - Two subgroups
    - % RV pacing ≤40%
    - % RV pacing 41%-100%

- Patients who survived to the 3-month follow-up visit had better 12-month event-free survival in the ≤40% group.
  - 41%-100% RV Pacing 75.9%
  - ≤40% RV Pacing 86.9%
Intrinsic RV
VVI versus DDD with AV Search Hysteresis

Event=Death or CHF hospitalization

Event=Death

Olshansky et al, Circ 2007;115:9
Survival free from heart failure hospitalization and all cause mortality

Koplan et al. JACC 2009;53:355-60
Paradox of Cardiac Device Therapy

- The best outcomes for patients with defibrillators come from avoiding defibrillation unless absolutely necessary

- The best outcomes for patients with non-CRT pacemakers/ICDs come from avoiding ventricular pacing unless absolutely necessary (the opposite is true for CRT)

Koplan et al. JACC 2009;53:355-60
ICD Programming: Simple Take Home Message

• For most ICD patients, the following programming demonstrated superior outcomes in randomized trials and should be considered the standard of care:
  • Pacing: VVI 40 bpm (unless symptomatic bradycardia or CRT)
  • Tachy: MADIT-RIT high rate cutoff
    - 170-199 bpm: monitor only
    - ≥ 200 bpm: 2.5 sec detection, ATPx1 then shock
Thank you for your attention!
ATP Success by VT Cycle Length

Schoels et al. Heart Rhythm 2007;4:879-85
Others

- Single- Versus Dual-Chamber ICD Selection
- Detection Zones and SVT-VT Discriminator Programming
- Rhythm Discrimination in the s-ICD
- Redetection and Reconfirmation
- Programming Therapy Zones
- Shock Strength, Polarity, and DFT
- Optimization of Sensing to Prevent Shocks
- Preventing T-wave Oversensing
- Noise-Detection Algorithms
- Surveillance of Lead Fracture
- ICD programming during Electrical Storm
- Remote Monitoring
DAVID: Analysis by % RV pacing

Endpoint: Death or Hospitalization for CHF

JAMA 2002;288:3115-21
Required FVT Therapy

<table>
<thead>
<tr>
<th>ATP Arm</th>
<th>Shock Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx 1</td>
<td>Burst ATP</td>
</tr>
<tr>
<td></td>
<td>- 1 sequence</td>
</tr>
<tr>
<td></td>
<td>- 8 pulses</td>
</tr>
<tr>
<td></td>
<td>- 88% of VTCL</td>
</tr>
<tr>
<td>Rx 2</td>
<td>Shock DFT+10 J</td>
</tr>
<tr>
<td>Rx 3-6</td>
<td>Shock max output</td>
</tr>
<tr>
<td></td>
<td>Shock max output</td>
</tr>
</tbody>
</table>
Distribution of ventricular arrhythmias by detection zone and median CL

- VT: 58%
- FVT: 32%
- VF: 10%

Pie chart showing the distribution of ventricular arrhythmias by detection zone.

Graph showing the median cycle length (ms) with distribution of episodes.

- <200 ms
- 200-220 ms
- 220-240 ms
- 240-260 ms
- 260-280 ms
- 280-300 ms
- 300-320 ms
- 320-340 ms
- 340-360 ms
- 360-380 ms
- 380-400 ms
- 400-420 ms
- 420-440 ms
- >460 ms

The graph illustrates the number of episodes across different median cycle length bins.
Primary prevention patients experience faster VTs with rates less likely to overlap SVT than secondary prevention.

Programming of faster VT rate cutoffs with prolonged detection time is recommended (PREPARE, RELEVANT, MADIT-RIT trials).
Required Detection Programming
Fast VT via VF

# intervals to detect = 18/24

VF

Fast VT

Slow VT

240 ms (250 bpm) 320 ms (188 bpm) ≥ 360 ms (167 bpm)

- PR Logic “ON” in all dual chamber ICDs
- SVT limit of 320ms
Hazard Ratios for a First Occurrence of Inappropriate Therapy, Death, and a First Episode of Syncope According to Treatment Group

Table 3. Hazard Ratios for a First Occurrence of Inappropriate Therapy, Death, and a First Episode of Syncope According to Treatment Group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional Therapy (N=514)</th>
<th>High-Rate Therapy (N=500)</th>
<th>Delayed Therapy (N=486)</th>
<th>High-Rate Therapy vs. Conventional Therapy</th>
<th>Delayed Therapy vs. Conventional Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>First occurrence of inappropriate therapy</td>
<td>105</td>
<td>21</td>
<td>26</td>
<td>0.21 (0.13–0.34)</td>
<td>0.24 (0.15–0.40)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Death</td>
<td>34</td>
<td>16</td>
<td>21</td>
<td>0.45 (0.24–0.85)</td>
<td>0.56 (0.30–1.02)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>First episode of syncope</td>
<td>23</td>
<td>22</td>
<td>22</td>
<td>1.32 (0.71–2.47)</td>
<td>1.09 (0.58–2.05)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.39</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Moss et al. NEJM 2012;367:2275-83
# ICD Programming for Primary Prevention of Sudden Death

<table>
<thead>
<tr>
<th></th>
<th>2⁰ prevention</th>
<th>Therapy</th>
<th>2⁰ prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor</td>
<td>130-140 bpm</td>
<td></td>
<td>130-140 bpm</td>
</tr>
</tbody>
</table>
| VT         | • 10-20 bpm < clinical  
            • 150-162 bpm if unknown | Burst x4 | 10-20 bpm < clinical  
                150-162 bpm if unknown |
| VF         | 220 bpm       | ATP during maximal shock | 220 bpm       |

*Rate Monitor*

- 170-199 bpm
- 130-140 bpm

**VT**

- 10-20 bpm < clinical
- 150-162 bpm if unknown

**VF**

- 220 bpm

*Detection time, Tx 5 second delay, ATP during charge, Maxium energy shock*

*Circulation. 2013;128:659-672*