Inappropriate electrical shocks: Tackling the beast

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Inappropriate electrical shocks: Tackling the beast

Presenter disclosure information:

Gerhard Hindricks has received honoraria for lectures from Biosense, Stereotaxis, St. Jude Medical, Biotronik

Gerhard Hindricks is a member of the Advisory Board / consultant for Biosense, St. Jude Medical, Biotronik, Stereotaxis, Cyberheart
Impact of ICD shocks

- SCD HeFT showed 33% incidence of ICD shocks

- Appropriate shocks resulted in a 5-fold increased risk of death

- Inappropriate shocks increased risk of death 2-fold

- Median time to death
  - 168 days after appropriate shock
  - 294 days after inappropriate shock

- Leading cause of death: progressive heart failure
Inappropriate electrical shocks: Tackling the beast

Impact of ICD shocks

- inappropriate shocks are a frequent problem of ICD therapy and account for 10 – 24% of ICD discharges

- clinical characteristics of pts. with inappropriate shocks:
  - tend to be younger
  - more likely to have / develop atrial fibrillation
  - more advanced heart failure

- incidence of inappropriate shocks
- causes of inappropriate shocks
- solutions for patients with inappropriate shocks and prevention
Impact of ICD shocks

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How common are ICD shocks?

Annual shock rate appr 10% (appr), 7.5% (inappr)

<table>
<thead>
<tr>
<th></th>
<th>AVID</th>
<th>MADIT II</th>
<th>DEFINITE</th>
<th>SCD-HeFT</th>
<th>COMpanion</th>
<th>PREPARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>492</td>
<td>719</td>
<td>227</td>
<td>811</td>
<td>594</td>
<td>700</td>
</tr>
<tr>
<td>24/12M</td>
<td>24M</td>
<td>22M</td>
<td>29M</td>
<td>45M</td>
<td>16M</td>
<td>12M</td>
</tr>
<tr>
<td>Study Type</td>
<td>Secondary</td>
<td>Primary</td>
<td>Primary</td>
<td>Primary</td>
<td>Primary</td>
<td>Primary</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>ICM + DCM</td>
<td>ICM</td>
<td>DCM</td>
<td>ICM + DCM</td>
<td>ICM + DCM</td>
<td>ICM + DCM</td>
</tr>
<tr>
<td>ICD</td>
<td>ICD</td>
<td>ICD</td>
<td>ICD</td>
<td>ICD</td>
<td>CRT-D</td>
<td>ICD + CRT-D</td>
</tr>
</tbody>
</table>

(single lead)
Impact of ICD shocks

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- clinical characteristics of pts. with inappropriate shocks:
  - tend to be younger
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- incidence of inappropriate shocks
- causes of inappropriate shocks
- solutions for patients with inappropriate shocks and prevention
Causes of inappropriate shocks

1. Atrial arrhythmias
2. Ventricular oversensing of cardiac signals
3. Lead fracture
4. Electromagnetic interference
Inappropriate electrical shocks: Tackling the beast

Causes of inappropriate shocks

- 39% Afib
- 25% Aflut
- 23% ST
- 5% SVT
- 5% NSVT
- 4% Oversen.

133/600 patients (22.6%)

→ 74% of inappropriate therapy due to different forms of SVT

Weber et al. Z Kardiol 1996;85:809
Recursent shocks in 49 year old man

- 46 year old male received an ICD for primary prevention of SCD according to MADIT II criteria.

- After 3 years he suddenly experienced 3 shocks during a period of mild palpitations. Subsequent hospital admission showed the following ECG:

- In the ICU, the patient received another inappropriate shock.
Inappropriate shocks due to AF
Inappropriate shocks due to AF: acute management

- device interrogation
- diagnosis / ECG documentation
- appropriate treatment
  - betablocker / Ca antagonist
  - AA-drugs
  - external cardioversion

Braunschweig et al., Europace 2010
### Table 2: Response to magnet of currently available ICDs from various manufacturers

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Response to magnet</th>
<th>Bradycardia therapies</th>
<th>Confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tachyarrhythmia therapies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston (Guidant/CPI)</td>
<td>Inhibition of detection and therapy delivery for VT/VF, lasting as long as the magnet is positioned over the ICD; if the ‘change tachy mode with magnet’ function is enabled (currently not a default programming), magnet application for more than 30 s results in deactivation of the device (the ICD remains inactive when the magnet is removed)</td>
<td>As programmed</td>
<td>R-wave synchronous beeping tones are emitted by the device if it is active, whereas a continuous tone is emitted if the device is inactive (these functions are currently the default programming)</td>
</tr>
<tr>
<td>Medtronic</td>
<td>Transient inhibition of detection and therapy delivery for VT/VF, lasting as long as the magnet is positioned over the ICD</td>
<td>As programmed</td>
<td>No confirmation</td>
</tr>
<tr>
<td>St Jude Medical</td>
<td>Transient inhibition of detection and therapy delivery for VT/VF, lasting as long as the magnet is positioned over the ICD</td>
<td>As programmed</td>
<td>No confirmation</td>
</tr>
<tr>
<td>Sorin</td>
<td>Transient inhibition of detection and therapy delivery for VT/VF, lasting as long as the magnet is positioned over the ICD</td>
<td>Pacing at magnet rate in the programmed pacing mode (VVI, DDD, DDI)</td>
<td>No confirmation</td>
</tr>
<tr>
<td>Biotronik</td>
<td>Transient inhibition of detection and therapy delivery for VT/VF, lasting as long as the magnet is positioned over the ICD</td>
<td>As programmed</td>
<td>No confirmation</td>
</tr>
</tbody>
</table>

Braunschweig et al., Europace 2010
Inappropriate shocks due to AF: options

- improve device programming, active appropriate algorithms
- adopt medical treatment with betablockers in adequate dosage
- antiarrhythmic drug therapy to suppress AF
- AV nodal ablation
- catheter ablation of AF
Inappropriate shocks due to AF: options

- improve device programming, active appropriate algorithms
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Inappropriate electrical shocks due to AF: enhanced programming

- **Sudden Onset → Activate!**
  - discriminates sinus tachycardia from VT
  - cave: AFL, AF, AVNRT have also “sudden onset”
  - cave: slow VT during sinus tachycardia may be “non-sudden”

- **Stability → Activate!**
  - discriminates atrial fibrillation from VT
  - cave: sinus tachycardia, AFL, AVNRT also regular
  - cave: irregular VTs

- **Ventricular EGM Morphology → Activate if it works!**
  - cave: SVT with aberrancy

- **Sustained Rate Duration → Deactivate (or ≥ 5 min)!**

- **Activate up to ≥ 200 bpm**
Inappropriate shocks due to AF: enhanced programming

Table 3 Algorithms for discrimination of atrial tachycardia and VT

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Principle algorithm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVT detection</td>
<td>Compares atrial and ventricular rates before further discrimination criteria are applied (dual-chamber ICDs)</td>
<td>Possible outcomes are that atrial and ventricular rates are equal (A = V), atrial rate is faster (A &gt; V), or vice versa (V &gt; A). In the case of V &gt; A, the diagnosis is VT. If A = V, additional criteria are required for discrimination</td>
</tr>
<tr>
<td>Sudden onset (SO)</td>
<td>The SO criterion is fulfilled if the RR interval shortens by a programmed percentage when compared with the average number of preceding beats</td>
<td>Allows discrimination of gradually accelerating sinus tachycardia from suddenly occurring VT. May fail if VT occurs during sinus tachycardia (e.g., exercise) with a small decrease in RR interval</td>
</tr>
<tr>
<td>Rate stability (RS)</td>
<td>RS is expressed as %deviation between RR intervals</td>
<td>Confirms AF. However, AF with pseudo-regular ventricular rhythm and irregular VTs can be falsely classified as VT or SVT, respectively, which may cause delivery of inappropriate therapy or delay of appropriate therapy</td>
</tr>
<tr>
<td>Sustained rate duration (SRD)</td>
<td>Initiates shock delivery after a programmable time interval (e.g. 1 min) even if the episode has been classified as SVT</td>
<td>Aims to prevent that VT therapies are erroneously inhibited by sudden onset and stability criteria. SRD may cause inappropriate shocks. Activation should be avoided, if possible, or programmed to a long-time interval</td>
</tr>
<tr>
<td>Morphology discrimination (MD)</td>
<td>Based on the comparison of intracardiac electrograms in sinus rhythm and during VT\textsuperscript{111}</td>
<td>Composes templates of electrogram morphology during normal rhythm that is expected to differ from that registered during ventricular arrhythmia. Especially useful in single-chamber devices due to the lack of atrial lead information. MD algorithms should not be activated in patients with bundle branch block or rate-dependent electrogram changes</td>
</tr>
</tbody>
</table>

Braunschweig et al., Europace 2010
Inappropriate shocks: enhanced detection criteria

Table 4 Total number of inappropriate therapy events*

<table>
<thead>
<tr>
<th>Group</th>
<th>Total no. of events</th>
<th>No. of patients (n)</th>
<th>Total no. of ATP therapy events</th>
<th>No. of patients (n)</th>
<th>Total no. of shock therapy events</th>
<th>No. of patients (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced</td>
<td>46</td>
<td>20</td>
<td>31</td>
<td>13</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>Control</td>
<td>131</td>
<td>31</td>
<td>106</td>
<td>23</td>
<td>40</td>
<td>19</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 Inappropriate therapy events* per patient per month over the entire study (intention to treat)

<table>
<thead>
<tr>
<th>Group</th>
<th>Total no. of events per patient per month</th>
<th>Total no. of ATP per patient per month</th>
<th>Total no. of shocks per patient per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced</td>
<td>0.08 ± 0.24</td>
<td>0.06 ± 0.21</td>
<td>0.04 ± 0.15</td>
</tr>
<tr>
<td>Control</td>
<td>0.71 ± 4.23</td>
<td>0.17 ± 0.40</td>
<td>0.58 ± 4.23</td>
</tr>
<tr>
<td>P value</td>
<td>.0097</td>
<td>.0065</td>
<td>.0425</td>
</tr>
</tbody>
</table>

ASTRID Studie
n = 149
Dorian et al., Heart Rhythm 2004;1:540-7
Inappropriate shocks due to AF: follow-up

- no further inappropriate shocks for 6 months

- then another shock during exercise, again due to AF with fast ventricular response.

- antiarrhythmic drug therapy to suppress AF?

- AV nodal ablation?

- catheter ablation of AF?
Inappropriate shocks due to AF: follow-up

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Inappropriate shocks due to AF: AF ablation
Inappropriate shocks: oversensing

1. Cardiac Signals
   - T Wave Oversensing
   - R Wave Double Counting
   - P Wave Farfield Sensing

2. Body Signals
   - Pectoral Muscle Potentials
   - Diaphragmatic Potentials

3. Electromagnetic Interference

4. Electrode Fracture/Insulation Defect
Inappropriate shocks: T wave oversensing

→ shock therapy for nsVT combined with T wave oversensing
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Inappropriate shocks: avoid T wave oversensing

- large R waves at implantation
- dedicated programming options

- R-T ratio: If stable, may be detected by algorithm
Inappropriate shocks: T wave oversensing

- accounting for inappropriate shocks in ≈ 3%

- can be transient, triggered by exercise or electrolyte imbalances

- can often be corrected by device reprogramming / change in sensitivity / adjustment of refractory period

- when the device is less sensitive, defibrillation testing may be recommended

- T-wave oversensing that can not be overcome by reprogramming may require lead repositioning or a new pace sense lead
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Inappropriate shocks: lead integrity problems

→ patient with 8 consecutive shocks in 2 hours
Inappropriate shocks: extracardiac sensing defects

- skeletal myopotentials
- electromagnetic interference
- mechanical lead problems
  - fracture
  - dislodgement
  - insulation break

- lead fracture (1-4%) should be suspected in patients presenting with multiple shocks in rapid succession
- interrogation reveals change in lead impedance, failure to sense or capture, however, defects may be transient.
- often lead revision or replacement necessary
Inappropriate electrical shocks: Tackling the beast

Inappropriate shocks: lead integrity alert

76% of patients with electrode fracture would have received alert ≥ 3 days before inappropriate shock

Swerdlow et al., Circulation 2008;118:2122-9
Inappropriate shocks due to lead fracture: prevention

- Data from 15,970 patients with Sprint Fidelis® electrodes (121 fractures)

Swerdlow et al., Circulation 2008;118:2122-9
General management of patients with ICD shocks

Mishkin JD et al., JACC 2011
General rules to minimize unnecessary or inappropriate shocks

- use detection zones appropriately
  - upper boundary for slow VT 188 bpm (320 ms) in SHD
  - fast VT 188 to 250 bpm (320-240 ms) in SHD
  - VF zone above 200 in SHD
- consider monitoring zone for slow VT
- apply individual programming in pts. without SHD

- adequate rate control in AF pts. (betablocker + amiodarone)
- adequate rhythm control (catheter ablation)
- activate discrimination algorithms according to specific device programming options