Electric storm  causes and treatment

Presented by:
Dr. Hamdy M. Saber, MD

Definition

• “occurrence of ≥3 distinct episodes of ventricular tachycardia (VT) and/or ventricular fibrillation (VF) within a 24-hour period resulting in device intervention (anti-tachycardia pacing [ATP] and/or shock delivery”* 

- *Proietti R, Sagone A.  Indian Pacing and Electrophysiology Journal 2011
Incidence

The incidence of ES is approximately 10-28% over a 1-3 year follow-up period when ICDs are placed for secondary prevention of cardiac arrest.

<table>
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<tr>
<th>Author</th>
<th>Definition</th>
<th>Incidence</th>
<th>Prognosis</th>
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<tbody>
<tr>
<td>Pries</td>
<td>≥ 2 VT/1 hr</td>
<td>60%, (34/57)</td>
<td>1 in mortality over mean follow up 3 y, 26% with ES vs 4% without ES (P &lt; .05)</td>
</tr>
<tr>
<td>Credner</td>
<td>≥ 3 VT/24 hr</td>
<td>10%, (14/136)</td>
<td>No 1 in mortality</td>
</tr>
<tr>
<td>Greene</td>
<td>≥ 3 VT/24 hr</td>
<td>18%, (40/227)</td>
<td>No † in mortality</td>
</tr>
<tr>
<td>Bansch</td>
<td>≥ 3 VT/24 hr</td>
<td>28%, (30/106)</td>
<td>RR 2.17 for mortality (CI 1.35-3.48, P = .031)</td>
</tr>
<tr>
<td>Exner</td>
<td>≥ 3 VT/24 hr</td>
<td>20%, (90/457)</td>
<td>RR 2.4 for mortality (CI 1.3-4.2, P = .03)</td>
</tr>
<tr>
<td>Verma</td>
<td>≥ 2 VT/24 hr</td>
<td>10%, (208/2028)</td>
<td>1 in mortality (P = .001, RR not listed)</td>
</tr>
<tr>
<td>Stuber</td>
<td>≥ 3 VT/2 weeks</td>
<td>24%, (51/214)</td>
<td>5-y survival of 67% with ES vs 91% without ES (P = .0007)</td>
</tr>
<tr>
<td>Gatzoulis</td>
<td>≥ 3 VT/24 hr</td>
<td>19%, (32/169)</td>
<td>RR 2.13 for mortality (CI 1.07-4.24, P = .031)</td>
</tr>
<tr>
<td>Hohnloser</td>
<td>≥ 3 VT/24 hr</td>
<td>23%, (148/633)</td>
<td>No † in mortality</td>
</tr>
<tr>
<td>Arya</td>
<td>≥ 3 VT/24 hr</td>
<td>14%, (22/162)</td>
<td>N/A</td>
</tr>
<tr>
<td>Brugada</td>
<td>≥ 2 Sep VT/24 hr</td>
<td>40%, (125/307)</td>
<td>No † in mortality</td>
</tr>
<tr>
<td>Sesselerberg</td>
<td>≥ 3 VT/24 hr</td>
<td>4%, (27/719)</td>
<td>RR 7.4 for mortality (CI 3.8-14.4, P &lt; .01)</td>
</tr>
</tbody>
</table>

*Secondary prevention population – AVID trial.
†Primary prevention population – MADIT II.
SR, sinus rhythm; VT, ventricular tachycardia; hr, hour; Sep, separate; RR, relative risk; CI, confidence interval.

Electrical Storm in the Era of Implantable Cardioverter Defibrillators
David T. Huang and Darren Traub
Incidence

- The time from ICD implant to first episode of electrical storm varies among published reports
- A sub-study of the MADIT II reported a 4% incidence of ES at a mean time of 11.1+/−9.4 months*


Frequent ICD shocks

- Appropriate shocks
  - VF
  - Monomorphic VT
  - Polymorphic VT
- Unnecessary shocks
  - Haemodynamically tolerated non sustained VT
  - Haemodynamically tolerated VT sensitive for ATP
- Inappropriate shocks
  - Supraventricular tachycardia
  - Atrial fibrillation
  - Atrial flutter
  - Atrial tachycardia
  - AVNRT/AVRT
  - Sinus tachycardia
- Signal misinterpretation
  - Frequent PVC
  - T-wave oversensing
  - Atrial far-field sensing
  - Diaphragmatic myopotentials
  - R-wave double-counting
  - Lead failure, insulation brake
  - Electromagnetic interference
- Phantom shocks

Modified from Gehi et al. JAMA 2006;296:2839–47.
CAUSES

The literature to date is far from comprehensive or conclusive, but does imply that storm is the result of a complex interplay between a predisposing electrophysiological substrate and acute alterations in autonomic tone and cellular milieu.

The critical role of increased sympathetic activity in precipitating storm is substantiated by the temporal relation to worsening CHF, concurrent medical illness and emotional stress.*

*Israel CW, Barold SS. Annals of Noninvasive Electrocardiology 2007

CAUSES

In a retrospective review of 40 secondary prevention patients with a total of 61 electrical storms, Greene et al*. reported

- no identifiable cause in 29%,
- new or worsened CHF in 15%,
- medication non-compliance or adjustment of antiarrhythmic medication in 20%,
- psychological stress in 10%,
- post-ICD placement in 13%,
- and excess alcohol use in 8%

Arrhythmias and ICD therapies during electrical storm

- The majority of storm episodes (86-97%) are caused by monomorphic ventricular tachycardia. VF alone accounts for 1%-21% of ES, mixed VT/VF 3%-14% and polymorphic VT 2-8%.

Although there is an extremely variable distribution in the number of tachycardias per episode of storm, as well as the number and types of therapies among different studies


<table>
<thead>
<tr>
<th>Study A</th>
<th>ES Arrhythmias</th>
<th>No. of VT/VF episodes per ES</th>
<th>ES Therapies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fries22</td>
<td>Majority VT, percentages not listed</td>
<td>NA</td>
<td>43% with ATP only, 25% ATP and shock, 23% shock only</td>
</tr>
<tr>
<td>Credner *</td>
<td>64% VT, 21% VF, 14% VT+VF</td>
<td>Mean = 17 ± 17 (range, 3 to 50)</td>
<td>NA</td>
</tr>
<tr>
<td>Greene7</td>
<td>97% VT, 3% pVT</td>
<td>Mean = 55 ± 90 (range, 4 to 465)</td>
<td>23% with ATP only, 77% ICD shock ± ATP</td>
</tr>
<tr>
<td>Bansch15</td>
<td>86% VT, 8% pVT/VF, 4% VTs with various morph.</td>
<td>Median = 19 (range, to 440)</td>
<td>NA</td>
</tr>
<tr>
<td>Exner12</td>
<td>86% VT, 14% VF or VT+VF</td>
<td>Median = 4 (range, 3 to 14)</td>
<td>46% shocks only, 28% ATP only, 26% shocks and ATP</td>
</tr>
<tr>
<td>Verma30</td>
<td>52% VT, 48% VF</td>
<td>NA</td>
<td>5 ± 5 shocks</td>
</tr>
<tr>
<td>Stuber16</td>
<td>93% VT, 7% pVT</td>
<td>Mean = 8 (range, 3 to 1200)</td>
<td>31% ICD shock only, 19% ATP followed by shock, 50% ATP only</td>
</tr>
<tr>
<td>Gatzoulis14</td>
<td>NA</td>
<td>NA</td>
<td>ATP 21 ± 33 per ES episode</td>
</tr>
<tr>
<td>Hohnloser18</td>
<td>91% VT, 8% VT+VF, 1% VF</td>
<td>Median = 5 (range, 3 to 11)</td>
<td>7% ICD shock only, 70% ATP only, 23% shocks and ATP</td>
</tr>
<tr>
<td>Brigadeau22</td>
<td>90% VT, 8% VF, 2% pVT</td>
<td>Range = 2 to ≥ 15</td>
<td>18% shocks only, 26% ATP only, 56% shocks and ATP</td>
</tr>
<tr>
<td>Jesselberg13</td>
<td>78% VT, 22% VF</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

VT, ventricular tachycardia; pVT, polymorphic ventricular tachycardia; VF, ventricular fibrillation; ATP, anti-tachycardia pacing
Clinical implications of ES

• The clinical presentation of storm can range from repetitive hemodynamically destabilizing episodes of VT/VF requiring multiple ICD shocks to asymptomatic tachycardias that are treated by ATP and discovered retrospectively through outpatient ICD interrogation.

• In the AVID trial* (38%) of the patients with ES died during follow-up, compared to 15% of those with VT/VF in the absence of ES, and 22% among the remaining patients. Electrical storm was independently associated with a 2.4-fold increase in the risk of death overall.


Clinical implications of ES

• Among patients who received an ICD for primary prevention reasons in MADIT II, those with electrical storm had a 7.4-fold higher risk of death compared to those without treated arrhythmias*.

• Once storm occurred, the incidence of a recurrent storm episode was 2.3%, 4.7%, and 6.2% for years 1, 2, and 3, respectively*.

Prognosis

- Analysis of these larger trials consistently indicates that in both populations of primary and secondary prevention indications for ICD implant, ES presages mortality, mostly due to non-sudden cardiac causes. Whether it is the progressive worsening of the substrate or the additive adverse effects of the armada of medical therapy that these patients are placed on (more likely a combination)*

Management

(1) Out-of hospital setting (patient advice)
After any ICD shocks

• In the absence of persisting severe symptoms the ICD clinic should be contacted within the next working day to initiate device interrogation.
• In the presence of persisting severe symptoms there is a need for immediate medical evaluation through a hospital Emergency Department or the ICD clinic.
• Multiple shocks (within minutes or hours) Need for immediate medical evaluation, usually through a hospital Emergency Department or immediate contact with the ICD clinic.

(2) Emergency Department (advice)

• Full clinical evaluation. This should include history and general clinical assessment of the patient, hemodynamic and ECG and routine lab and electrolytes …..
• Cardiac arrest: Deliver advanced cardiac life support according to guidelines, independent of the fact that the patient has an ICD implanted.
(2) Emergency Department (advice)

- Repetitive ICD shocks in the absence of tachyarrhythmia or due to tachyarrhythmia (atrial or ventricular) that haemodynamically well tolerated by the patient. Place a magnet over the device to inhibit further shock delivery.
- Skin contact with the patient during ICD discharge involves no immediate danger; however, the use of gloves (single or double) decreases conductivity and attenuates potential discomfort.

Management of electric storm

- General principles:
  1) Promptly identifying and treating precipitating causes or triggers such as drug toxicities, electrolyte imbalance or acute myocardial ischemia.
  2) Attempting to understand the underlying cardiovascular substrate for incessant ventricular arrhythmias (ischemia, decompensated heart failure, pause dependent polymorphic VT, etc.).
  3) Suppressing the ventricular arrhythmias via pharmacologic, device related or interventional mechanisms.
  4) Establishing a therapeutic regimen with frequent follow-up visits in an effort prevent further ES and mortality in the early vulnerable period.
Management of electric storm

Factors affecting the plane of management:
- Hemodynamic stability
- Tachycardia ECG:
  - Monomorphic VT (commonest).
  - Polymorphic VT, VF
  - TdP.

A) Haemodynamically stable

  1) Pharmacologic manipulation

  The cornerstone is sympathetic blockade achieved by the b-blocker therapy in patients already on oral b-blocker therapy adding intravenous beta-blocking agents beta-one selective used first, if ineffective, a nonselective beta-blocker such as propanolol combined with sedatives, usually benzodiazepines or propofol.*

  For highly symptomatic patients, intubation and anesthesia may be necessary and even therapeutic.**

**Huang DT, Traub D. A comprehensive review. Progress in Cardiovascular Diseases. 2008;51:229-236
Pharmacologic

• 2) Amiodarone is often the anti-arrhythmic agent of choice for treatment of ES, with demonstrated benefit in multiple clinical studies. If the combination of intravenous amiodarone and beta-blockers does not suppress ES, the addition of lidocaine is sensible. Also, procainamide, flecainide, and quinidine have been used successfully in some ICD patients.

  - Zipes DP et al. Europace 2006;8:746–837

Pharmacologic

• Azimilide

• In the SHIELD study, the 75 and 125 mg dose of azimilide significantly reduced the recurrence of shocks plus symptomatic arrhythmias treated by ATP*. However, in a prospective study **, of the 148 patients who experienced at least one episode of electrical storm, azimilide did not significantly reduce the number of patients with electrical storm.

  - **Hohnloser SH et al. Eur Heart J 2006; 27:3027–3032
Pharmacologic

- Polymorphic ventricular tachycardia
  In polymorphic VTs such as torsades de pointes, intravenous administration of magnesium sulphate, potassium, and overdrive pacing (e.g. at 90 bpm or more) may be effective in suppressing the re-initiation of polymorphic VT. In ES patients with inherited or drug-induced long QT syndrome, isoproterenol may prevent recurrent episodes of arrhythmia also in the setting of Brugada syndrome are often heart rate sensitive and can be suppressed by using isoproterenol to increase the sinus rate. Isoproterenol infusion has also been used to suppress the VF triggers during electrical storm in patients with Idiopathic VF.


Renal sympathetic denervation for treatment of electrical storm: first-in-man experience

Christian Ukena · Axel Bauer · Felix Mahfoud · Jürgen Schreieck · Hans-Ruprecht Neuberger · Christian Eck · Paul A. Sobotka · Meinrad Gawaz · Michael Böhm

CONCLUSION:
Our findings suggest that RDN is feasible even in cardiac unstable patients. Randomized controlled trials are urgently needed to study the effects of RD in patients with electrical storm and CHF
Device reprogramming

- Will not prevent tachycardia occurrence aims to reduce unnecessary shocks and increase ATP effectiveness.

Device reprogramming

- In patients with structural heart disease, recent studies have shown that it is useful to set upper boundary for slower VT around 188 bpm (320 ms), zone for fast VT between 188 and 250 bpm (320 – 240 ms), and VF zone from 200 bpm. These studies demonstrated high effectiveness of ATP in terminating both slow and fast VTs.*

Device reprogramming

- Optimization of ATP is the most effective strategy to reduce appropriate shocks.
- In the Pain-free-RX II study, a VT zone from 188 to 250 bpm was programmed and patients were randomized to receive one sequence of eight ATP pulses at 88% of the tachycardia cycle length followed by shock therapy, if necessary, or an immediate shock.
- Time to detection and therapy Studies also showed that it is important to increase the time to detection and therapy to allow spontaneous termination of nonsustained ventricular arrhythmias. It may vary from 16/18 to 30/40 beats without compromising safety.

B) Hemodynamically unstable ES

1) IABP: achieves patients stabilization before treatment of arrhythmia by catheter ablation and allows extensive treatment even in patients with severely depressed IV function
2) ECMO

Emergency ablation
Catheter ablation

- Catheter ablation of ventricular tachycardia is recommended

1. For symptomatic sustained monomorphic VT necessitating frequent ICD therapies despite antiarrhythmic drug therapy or when antiarrhythmic drugs are not tolerated or not desired (especially when VT recurrences fulfill definition of ES).

2. For control of recurrent symptomatic or incessant monomorphic VT not suppressible by antiarrhythmic drug therapy, regardless whether VT is stable or unstable, or multiple VTs are present.

3. For bundle branch re-entrant or interfascicular VTs.

4. For recurrent sustained polymorphic VT and VF refractory to antiarrhythmic therapy when there is a suspected trigger that can be targeted by ablation.

1. Identify etiology and try to reverse any potentially reversible causes
   - Causes
   - Enhanced sympathetic tone
   - Ischemia
   - Electrolytes (potassium, magnesium)
   - Endocrine disorders (thyroid disorders, pheochromocytoma)
   - Genetic abnormalities (such as Brugada syndrome, LQTS, etc.)
   - Iatrogenic
   - Consider obtaining
   - Electrolytes
   - Ischemia work up
   - Thyroid studies
   - Careful review of medication history

2. Mono-Pharmacotherapy
   - First Line: β-blocker
   - Consider using propranolol as beta antagonist of choice
   - If patient is intubated and on sedation, considering using propofol to enhance sympathetic tone attenuation

3. If mono-therapy is unsuccessful → Combination therapy
   - B-Blocker + Class III Antiarrhythmic
   - If amiodarone is chosen, consider using intravenous form
   - B-Blocker + Class III Antiarrhythmic + Class IB antiarrhythmic

4. Non-pharmacotherapy for drug refractory cases
   - Catheter ablation
   - Overdrive pacing
   - Intraaortic balloon pump or extracorporeal life support

*Acta Cardiol Sin. 2011;27:71–6*
Conclusion

- Electrical Storm not uncommon in ICD patients
- VT recurrences tend to cluster in ICD patients
- Most Storms without identifiable cause but heart failure, ischemia and metabolic abnormalities should be considered
- Medical management usually effective
- Storm probably associated with increased subsequent mortality, aggressive management may be indicated

Thank You