UKM
Universitätsklinikum
Münster

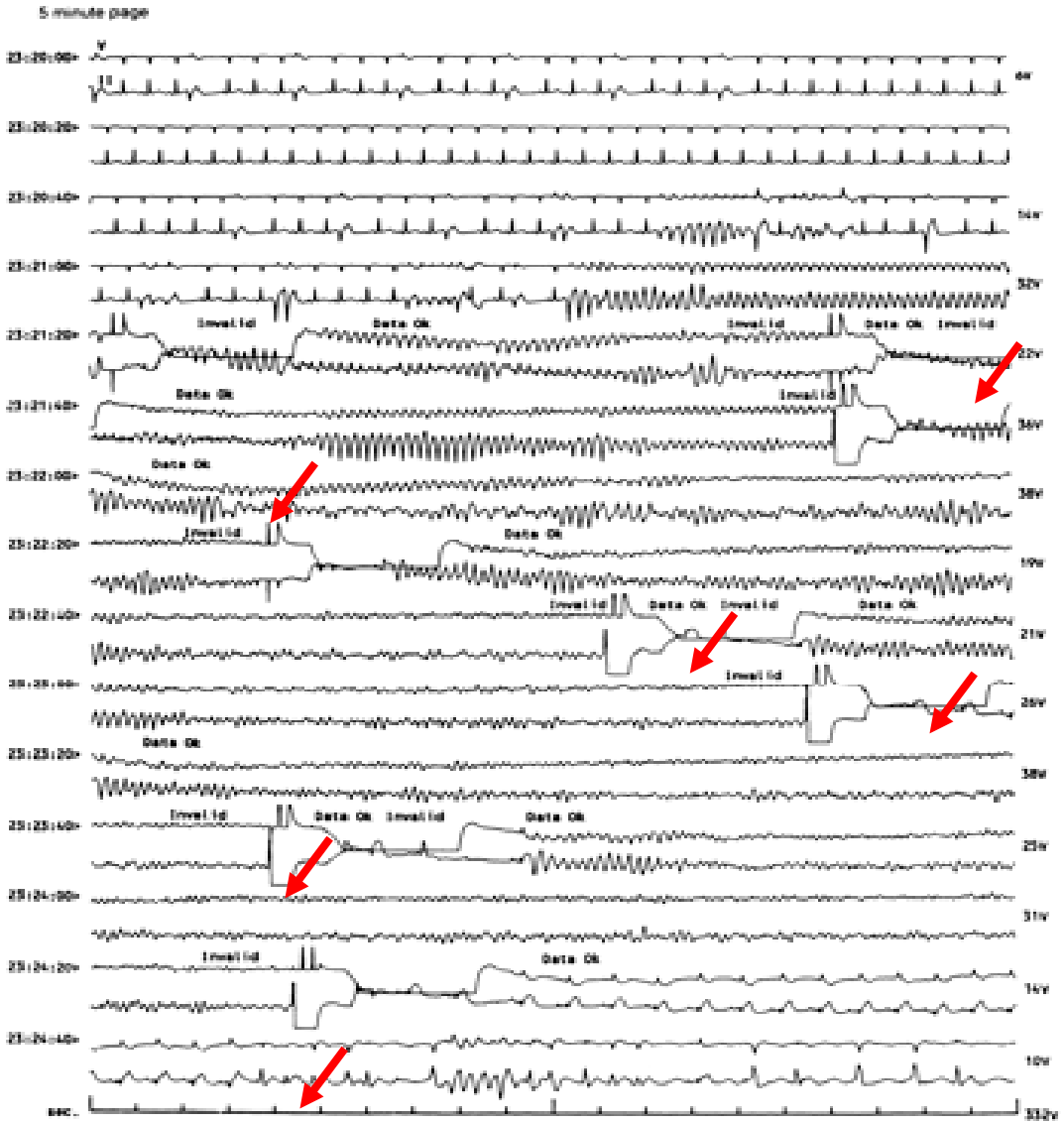
ISHNE Heart Failure Virtual Symposium 2008

The patient with (without) an ICD: Management of electrical storm

Westfälische
Wilhelms-Universität
Münster

Günter Breithardt, MD, FESC, FACC, FHRS
Professor of Medicine (Cardiology)
Hospital of the University of Münster
Dept. of Cardiology and Angiology
Münster, Germany

Recurrent VF



Nademanee et al.
Circ. 2000;102:3080

Management of electrical storm

- Definitions, mechanisms and clinical significance of frequent and refractory VT/VF
- Therapeutic interventions
- Prognosis
- Conclusions

Management of electrical storm

- **Definitions, mechanisms and clinical significance of frequent and refractory VT/VF**
- **Therapeutic interventions**
- **Prognosis**
- **Conclusions**

Management of electrical storm

Electrical storm refers to a situation when rapid clustering of episodes of malignant ventricular tachyarrhythmias develops requiring repetitive attempts at cardioversion

This situation is seen in patients with

- acute coronary syndrome (ACS),
- acute decompensated heart failure,
- other less frequent entities,
- with the implantable cardioverter-defibrillator (ICD) (for various indications), and
- in victims of out-of-hospital cardiac arrest in whom VT is the mechanism of out-of-hospital cardiac arrest.

Management of electrical storm

Presentation

- Refractory ventricular arrhythmias may occur as
  - recurrent short episodes of VT or VF
  - recurrent frequent episodes of sust. VT and/ or VF

in various settings like

  - recent myocardial infarction or
  - idiopathic dilated cardiomyopathy

with or without overt heart failure

Management of electrical storm

WWU Münster

Frequency of episodes

- may vary considerably ranging from
  - a cluster of VT/VF (e.g., defined as 2 or 3 or more episodes per 24 hour) to
  - electrical storms (e.g., rapidly clustering VT/VF) and
  - so-called incessant VT/VF (characterized by episodes that last > 50% of the time)

Management of electrical storm

VT (and VF) in the setting of acute decompensated heart failure may be

- **the cause of heart failure**
- **a sequelae of heart failure**

Clinical presentation (I)

- **often slow monomorphic VT (130 - 160 bpm), frequent, incessant or as storm**
- **significant LV-dysfunction**
- **previous MI or dilative CM**
- **broad QRS-complex during sinus rhythm**

incessant VT/VF: episodes that last > 50% of the time

Clinical presentation (II)

- dyspnea >> pulmonary edema
- angina
- VT-induced cardiogenic shock
- sometimes (initiating) infections

Management of electrical storm

WWU Münster

Underlying disorders

- coronary artery disease
  - during or after MI
  - acute ischemia
  - coronary spasm
- dilated cardiomyopathy
- LQT syndrome
- Brugada syndrome
- (severe valvular heart disease)

Management of electrical storm

- **Electrical storm (nowadays often in ICD pts) constitutes a medical emergency, which usually results in hospitalization**
- **Occasionally, individual pts may experience more than 50 consecutive shocks**
- **Most pts become anxious and agitated, and psychosocial consequences often outlast the acute event**
- **Electrical storm may also cause premature ICD battery depletion necessitating generator replacement**

Management of electrical storm

106 consecutive pts with DCM and ICDs
VT cluster: ≥3 sustained VTs/24 h

Mean follow-up of 33 ± 23 months

- **73 pts (68.9%) had recurrence of VT or VF**
  - **43 pts (40.6%) suffered only single VTs**
  - **30 pts (28.3%) had 52 clusters of VTs**

D Bänsch et al., JACC 2000; 36: 566 –73

Management of electrical storm

Independent predictors of VT clusters:

- **Heart failure before ICD implantation (p = 0.033)**
- **Presenting monomorphic VT (p = 0.044)**
- **EF < 0.40 (p = 0.014)**
- **Inducible mVT, especially with right bundle branch block and superior axis configuration (p < 0.001)**

D Bänsch et al., JACC 2000; 36: 566 –73

Management of electrical storm

Only 2 trials have prospectively assessed the clinical characteristics and prognostic relevance of electrical storm

- **AVID (Exner et al., Circ. 2001):**
  - **Electrical storm was a significant risk factor for death, independent of LVEF and other prognostic variables**
  - **Development of single episodes was not associated with increased risk**
- **SHIELD (Hohnloser at al., EHJ 2006):**
  - **Prespecified secondary endpoint (Azimilide)**

Management of electrical storm

European Heart Journal (2006) **27**, 3027–3032
doi:10.1093/eurheartj/ehl276

EUROPEAN SOCIETY OF CARDIOLOGY®

Clinical research
Arrhythmia/electrophysiology

Electrical storm in patients with an implantable defibrillator: incidence, features, and preventive therapy: insights from a randomized trial

Stefan H. Hohnloser[1]*, Hussein R. Al-Khalidi[2], Craig M. Pratt[3], Jose M. Brum[2], Daljit S. Tatla[2], Patrick Tchou[4], and Paul Dorian[5]on behalf of the SHock Inhibition Evaluation with AzimiLiDe (SHIELD) Investigators

SHIELD Trial

Management of electrical storm

- **148 (23%) out of 633 pts experienced at least 1 episode of ES (≥ 3 episodes < 24 h) within 12 months**
- **This incidence was only slightly higher than that described by the AVID analysis (20% of patients developed ES, mean follow-up 31+13 months)**

SHIELD Trial

Hohnloser et al., (SHIELD) Eur Heart J 2006; 27: 3027-32)

Management of electrical storm

- **A detailed analysis of clinical features of ES did not reveal independent predictors of the event**
- **In contrast to previous retrospective studies, the LVEF was not lower but significantly higher in pts with ES**
- **Identifiable precipitating /triggering causes for ES were rare (new or worsening of heart failure, 9%; electrolyte disturbances, 4%)**

SHIELD Trial

Hohnloser et al., (SHIELD) Eur Heart J 2006; 27: 3027-32)

Triggers of electrical storm

Precipitating or triggering factors are found in the minority of patients

- **Hypokalemia**
- **Acute or chronic heart failure**
- **Acute coronary syndromes**
- **Alcohol**
- **Non-cardiac surgery**
- **Medications**
- **Unknown**

(1) Credner 1998; Greene 2000; Verma 2004; Gatzoulis 2005; Bänsch 2000; Villacastin 1996; Stuber 2005
(2) Avid Exner 2001; OPTIC Connolly 2006; SHIELD Hohnloser 2006

Predictors of electrical storm (ES)

Predictors of electrical storm

- Worsening of heart failure
- Low EF
- Prior electrical storm
- Prior VT /VF
- No beta-blocker or ACE inhibitor or AT blocker
- Depression

(1) Credner 1998; Greene 2000; Verma 2004; Gatzoulis 2005; Bänsch 2000; Villacastin 1996; Stuber 2005
(2) Avid Exner 2001; OPTIC Connolly 2006; SHIELD Hohnloser 2006

Mechanisms of electrical storm

The mechanisms are mostly unclear in the individual patient. Possible mechanisms:

- **Poor LV: marked slowing of conduction, spontaneous reentry**
- **Ischemia: enhanced Purkinje fiber activity**
- **Subclinical channelopathies? Genetic?**
- **Modulation of autonomic tone?**

(1) Credner 1998; Greene 2000; Verma 2004; Gatzoulis 2005; Bänsch 2000; Villacastin 1996; Stuber 2005
(2) Avid Exner 2001; OPTIC Connolly 2006; SHIELD Hohnloser 2006

Do Atrial Tachyarrhythmias Beget Ventricular Tachyarrhythmias in ICD Recipients?

- **Dual tachycardia is common in ICD recipients with a history of AT/AF**
- **The duration of AT/AF preceding the first VT/VF detection is 1 h in about 50% of the time**
- **Termination of the AT/AF significantly delays the time to the next VT/VF detection.**

KM Stein et al., J Am Coll Cardiol 2002; 40:335-40

Incessant VT / VF

WWU Münster

Types and mechanisms

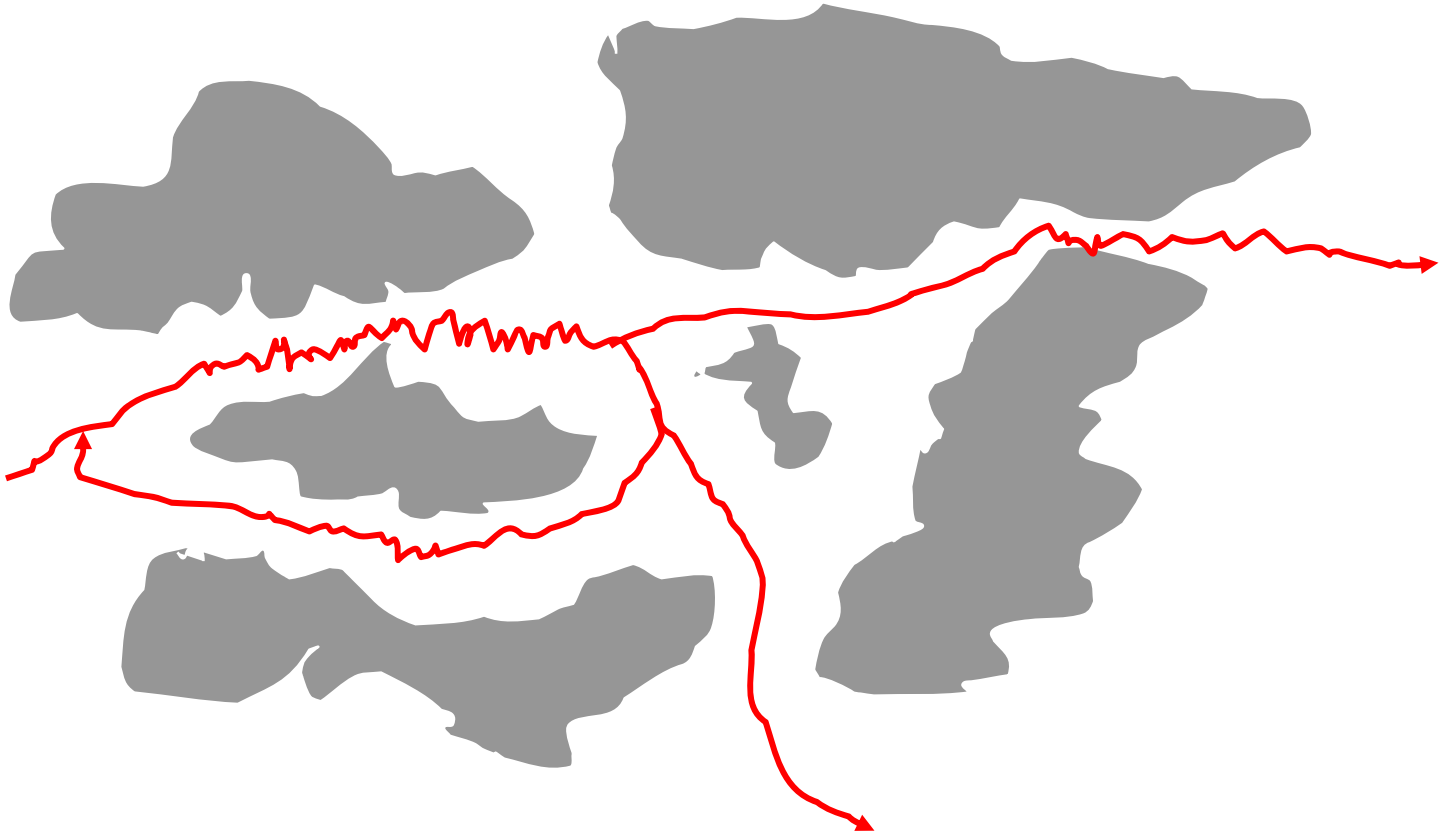
Monomorphic VT

↓

scarring, heart failure

Management of electrical storm

WWU Münster



Incessant VT / VF

WWU Münster

Types and mechanisms

Monomorphic VT → scarring, heart failure

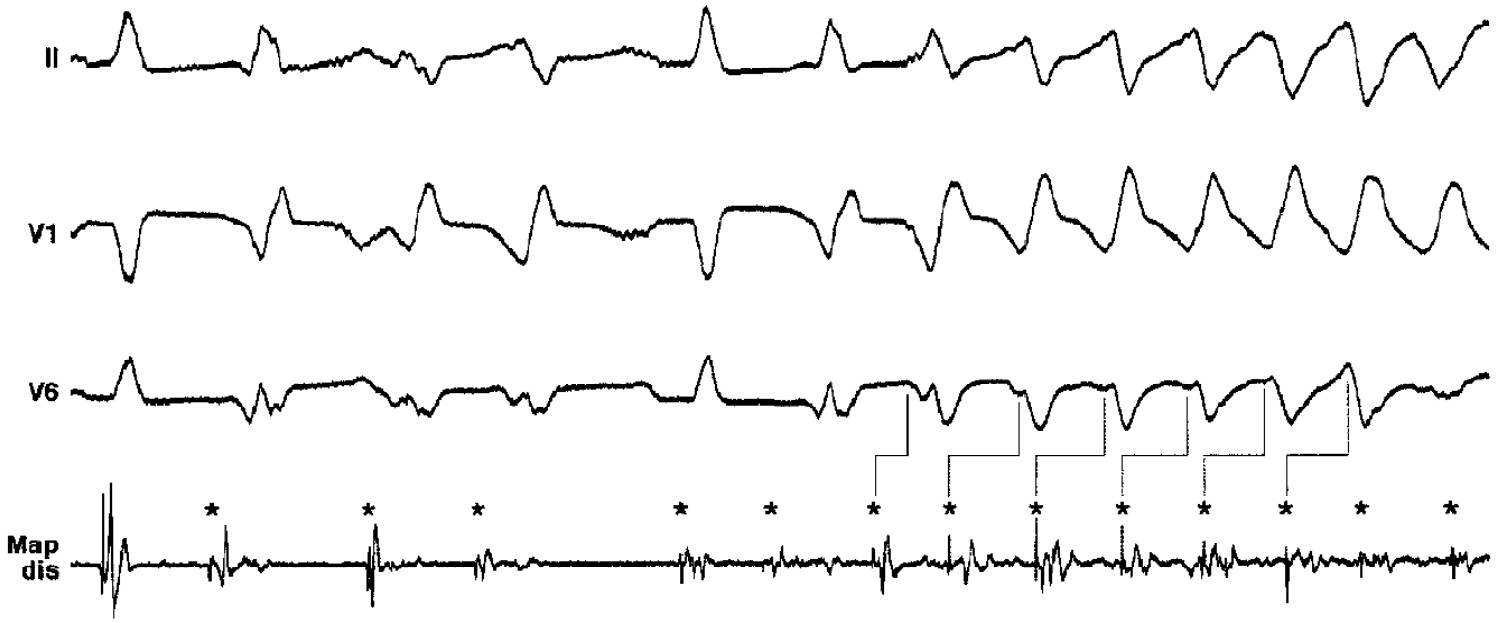
Polymorphic VT / VF → ischemia, advanced heart failure

Mechanisms of electrical storm

Successful Catheter Ablation of Electrical Storm After Myocardial Infarction

Dietmar Bänsch, MD*; Feifan Oyang, MD*; Matthias Antz, MD; Thomas Arentz, MD; Reinhold Weber, MD; Jesus E. Val-Mejias, MD; Sabine Ernst, MD; Karl-Heinz Kuck, MD

4 patients (aged 57 to 77 years; 3 men) who developed drug-refractory, repetitive ventricular tachyarrhythmias after acute myocardial infarction



Circulation 2003; 108: 3011- 6

Mechanisms of electrical storm

Mode of Initiation and Ablation of Ventricular Fibrillation Storms in Patients With Ischemic Cardiomyopathy

Nassir F. Marrouche, MD, Atul Verma, MD, Oussama Wazni, MD, Robert Schweikert, MD, David O. Martin, MD, Walid Saliba, MD, Fethi Kilicaslan, MD, Jennifer Cummings, MD, J. David Burkhardt, MD, Mandeep Bhargava, MD, Dianna Bash, RN, Johannes Brachmann, MD, Jens Guenther, MD, Steven Hao, MD, Salwa Beheiry, RN, Antonio Rossillo, MD, Antonio Raviele, MD, Sakis Themistoclakis, MD, Andrea Natale, MD

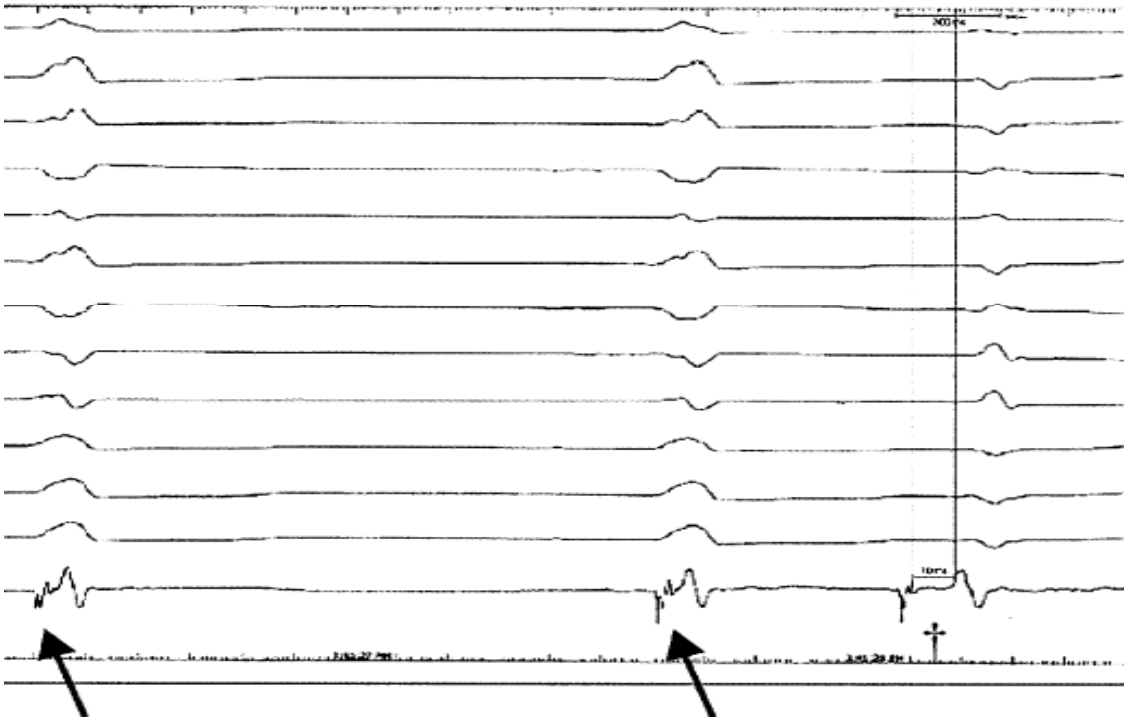


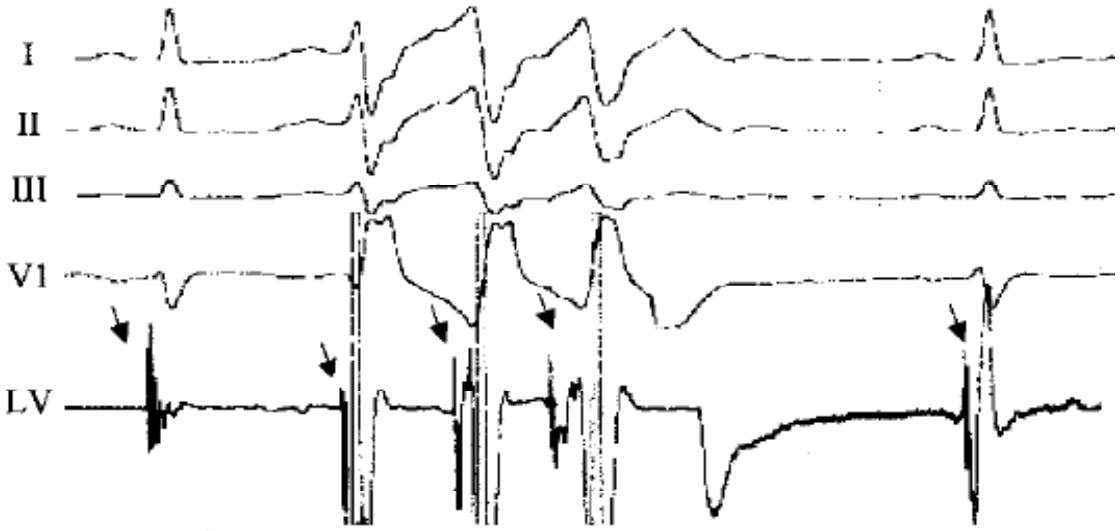
Figure 4. Local electrogram during VF initiation in patient 2. First beat is atrial paced beat with Purkinje potential that precedes ventricular activation. Second beat is VPB that is preceded by sharp, high-frequency potential. Third beat is probably fusion beat, fourth again is VPB followed by atrial paced beat. Subsequent VPBs induce VF. Initially, Purkinje potentials appear to drive the ventricle, inducing VT, which finally degenerates into VF. Note changes in activation time and morphology. *Purkinje potentialsduring sinus rhythm, before premature beats, and during VF initiation. Map dis indicates distal mapping catheter.

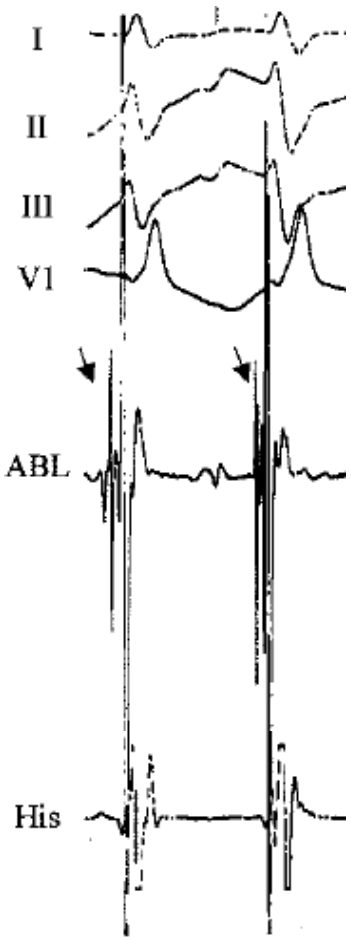
JACC 2004; 43: 1715–20

Mechanisms of electrical storm

Mapping and Ablation of Ventricular Fibrillation Associated With Long-QT and Brugada Syndromes

Michel Haïssaguerre, MD; Fabrice Extramiana, MD; Mélèze Hocini, MD; Bruno Cauchemez, MD; Pierre Jaïs, MD; Jose Angel Cabrera, MD; Geronimo Farre, MD; Antoine Leenhardt, MD; Prashanthan Sanders, MBBS; Christophe Scavée, MD; Li-Fern Hsu, MBBS; Rukshen Weerasooriya, MBBS; Dipen C. Shah, MD; Robert Frank, MD; Philippe Maury, MD; Marc Delay, MD; Stéphane Garrigue, MD; Jacques Clémenty, MD





Circulation. 2003; 108: 925-8

Management of electrical storm

Do Atrial Tachyarrhythmias Beget Ventricular Tachyarrhythmias in Defibrillator Recipients?

Kenneth M. Stein, MD, FACC,* David E. Euler, PHD,† Rahul Mehra, PHD,† Karlheinz Seidl, MD,‡
David J. Slotwiner, MD,* Suneet Mittal, MD, FACC,* Steven M. Markowitz, MD, FACC,*
Bruce B. Lerman, MD, FACC,* for the Jewel AF Worldwide Investigators

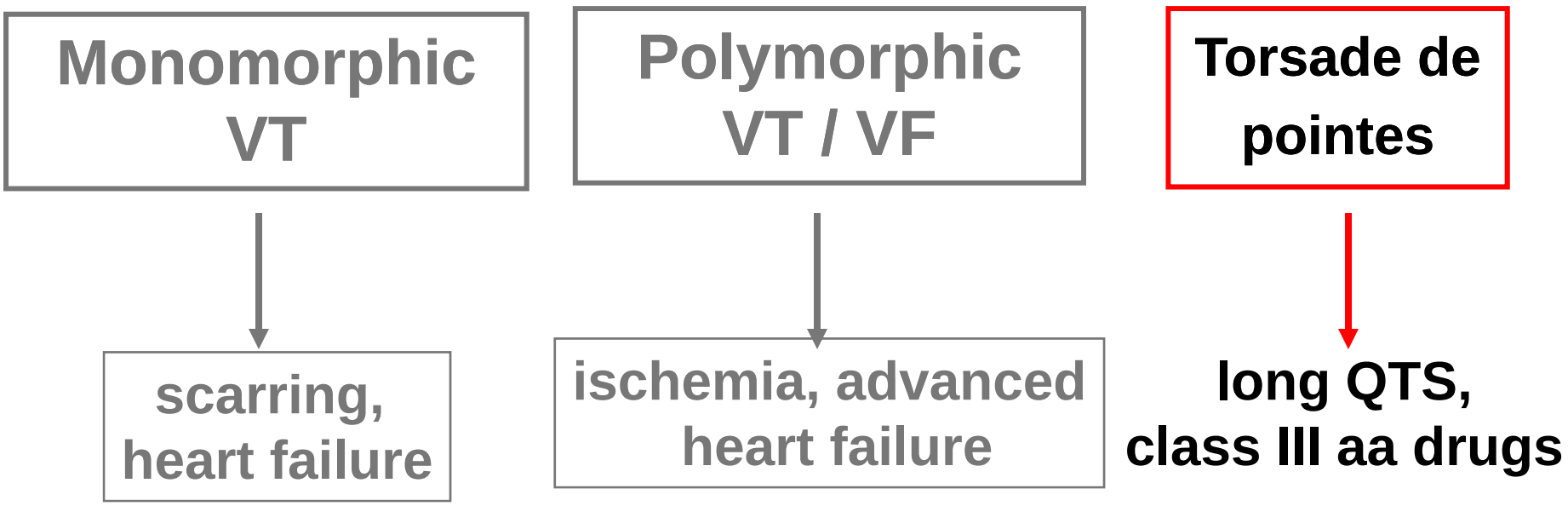
New York, New York; Minneapolis, Minnesota; and Ludwigshafen, Germany

KM Stein et al., J Am Coll Cardiol 2002; 40:335-40

Incessant VT / VF

WWU Münster

Types and mechanisms



Management of electrical storm

WWU Münster

- Definitions and clinical significance of frequent and refractory VT/VF
- **Therapeutic interventions**
- Prognosis
- Conclusions

Management of electrical storm

WWU Münster

Therapeutic interventions.

- antiarrhythmic drugs
- sympatholytic therapy
- sedation and anxiolytic therapy
- external cardioversion or defibrillation
- transvenous antitachycardia pacing
- antitachycardia pacing or internal cardioversion/ defibrillation via an ICD
- radiofrequency ablation
- PTCA / PCI, bypass surgery
- external cardiopulmonary support
- heart transplantation

Incessant VT / VF

WWU Münster

Acute interventions - polymorphic VT / VF

- (frequent) **defibrillation**
- **frequently due to ischemia** (but may also be due to severe LV dysfunction)
- **avoid class I antiarrhythmic drugs** **!!**
- **amiodarone i.v.**
- **beta-blocker i.v.**
- **magnesium sulfate i.v.**
- **coronary angiography** acutely (plus PTCA/PCI, avoid emergency bypass surgery)
- **bradycardia-induced:** isoproterenol, temporary pacemaker

Management of electrical storm

- **IN SHIELD, azimilide did not significantly reduce the number of patients with ES (only a trend):**
  - **of the 148 pts who experienced at least one episode of ES, 58 (27%) were on placebo, 51 (23%) on 75 mg and 39 (20%) on 125 mg azimilide**
- **Time-to-first ES event: no significant differences between treatment groups**
- **Compared with placebo, only the risk of recurrent ES was significantly reduced by azimilide (by 37% in the 75 mg group and by 55% in the 125 mg group, resp.)**

Hohnloser et al., (SHIELD) Eur Heart J 2006; 27: 3027-32)

Management of electrical storm

WWU Münster

Therapeutic interventions: Ischemia

- after MI, ongoing ischemia is frequently suspected
- coronary angiography as early as possible
- however, our *own experience* in this setting after MI
  - PCI on significant stenoses does not resolve the situation except when the patient has recurrent angina preceding VT or VF (despite antiischemic and antithrombotic therapy and beta-blockade)

Management of electrical storm

WWU Münster

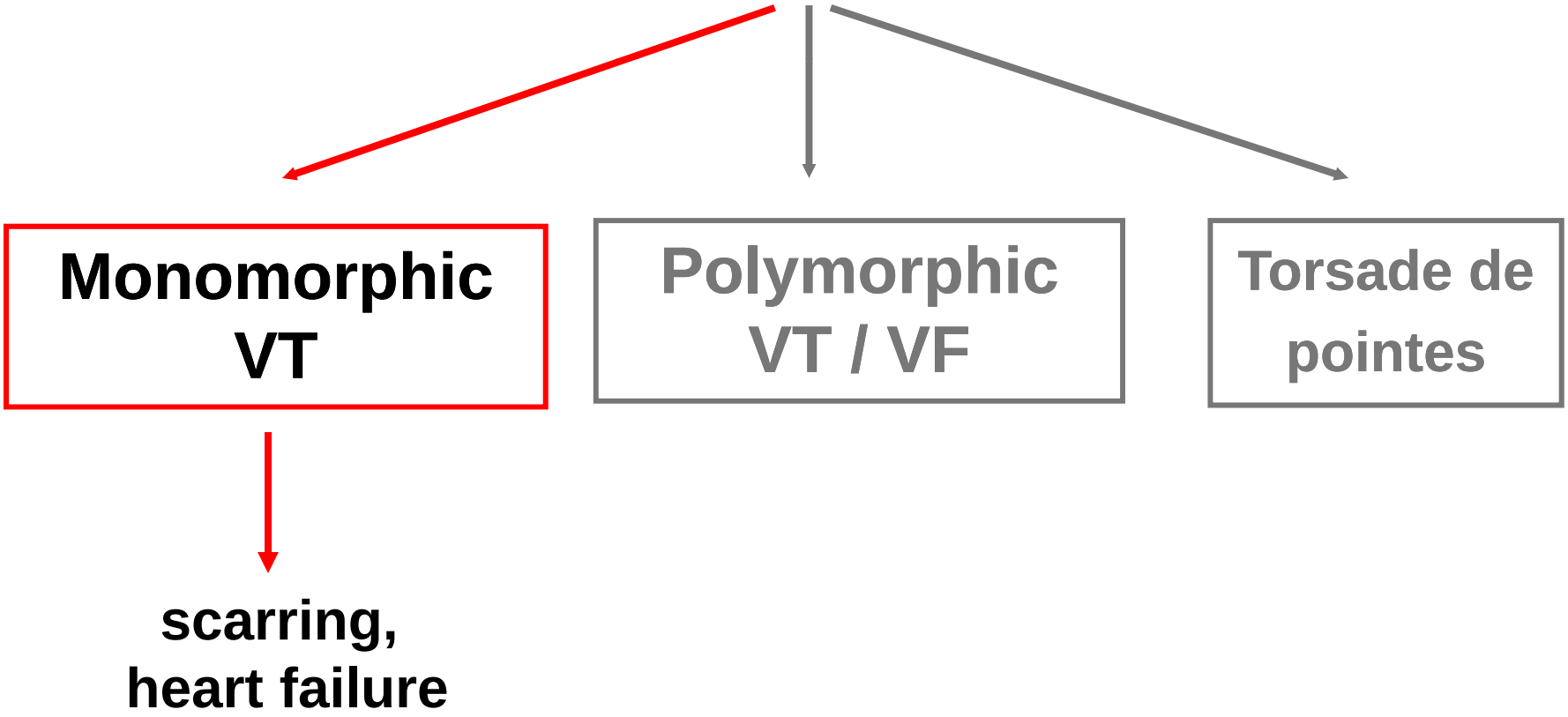
Therapeutic interventions: Ischemia

- hemodynamic significance of a given stenosis may be difficult to ascertain
- decision to perform PCI ex juvantibus
- but other interventions (e.g. catheter ablation) should be considered early on if PCI fails to resolve the critical situation

Incessant VT / VF

WWU Münster

Acute interventions



Incessant VT / VF

WWU Münster

Acute interventions
- monomorphic VT (I)

- **cardioversion** (low J)
- **electrical overpacing** (temporary pacing cable)
- substitution of **electrolytes**
- (administration of **magnesium)**

Acute interventions - monomorphic VT (II)

- **sedation / anesthesia**
- **betablocker, e.g. esmolol iv**
- if **proarrhythmia by antiarrhythmic drugs** is suspected
  - ✓ ***sodium* lactate iv**
  - ✓ **increase rate (class III AA)**
  - ✓ **decrease rate (class I AA)**
  - ✓ **cardiac resuscitation until the effect of the aa. drug diminishes**

Management of electrical storm

WWU Münster

Therapeutic interventions

- class I aa. drugs (e.g. lidocaine, procainamide), amiodarone, and sympathetic blockade have been proposed
- with the exception of amiodarone, aa. drugs have yielded frustrating results in patients with VT clusters
- class I aa. drugs may even aggravate the situation by increasing the propensity to VT or VF
- amiodarone is effective but sufficient rhythm control may take a few days

Incessant VT / VF

WWU Münster

Acute interventions
- monomorphic VT (III)

- **treat heart failure** (catecholaminergic drugs, diuretics, hemofiltration)
- **exclude ischemia: early coronary angiography**
- **i.v. amiodarone** (5 mg / kg within 5 to 15 min)

→ **catheter ablation**

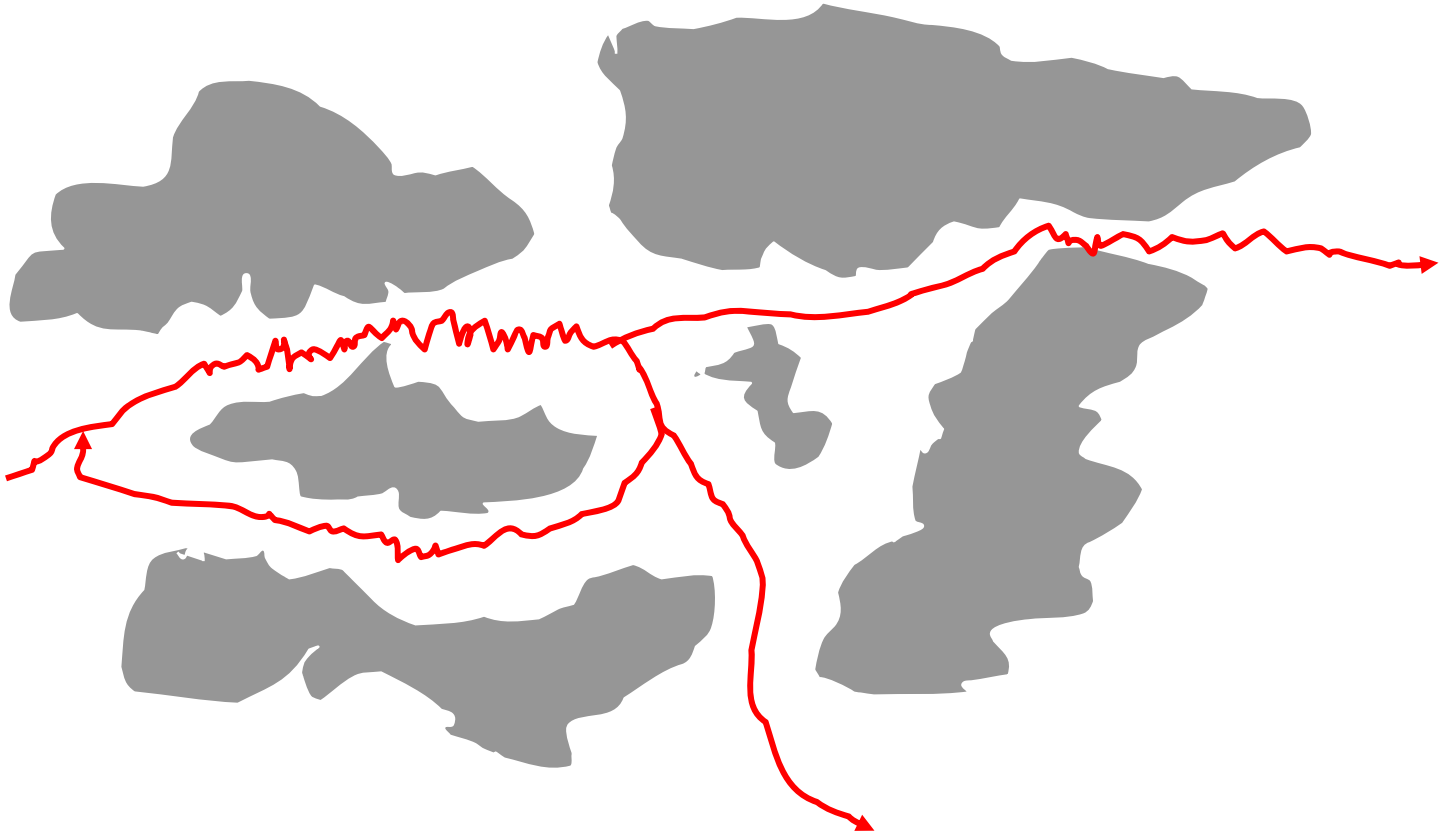
(TEE: exclude thrombus)

Management of electrical storm

WWU Münster

Catheter ablation:

areas of slow conduction and of conduction through narrow pathways

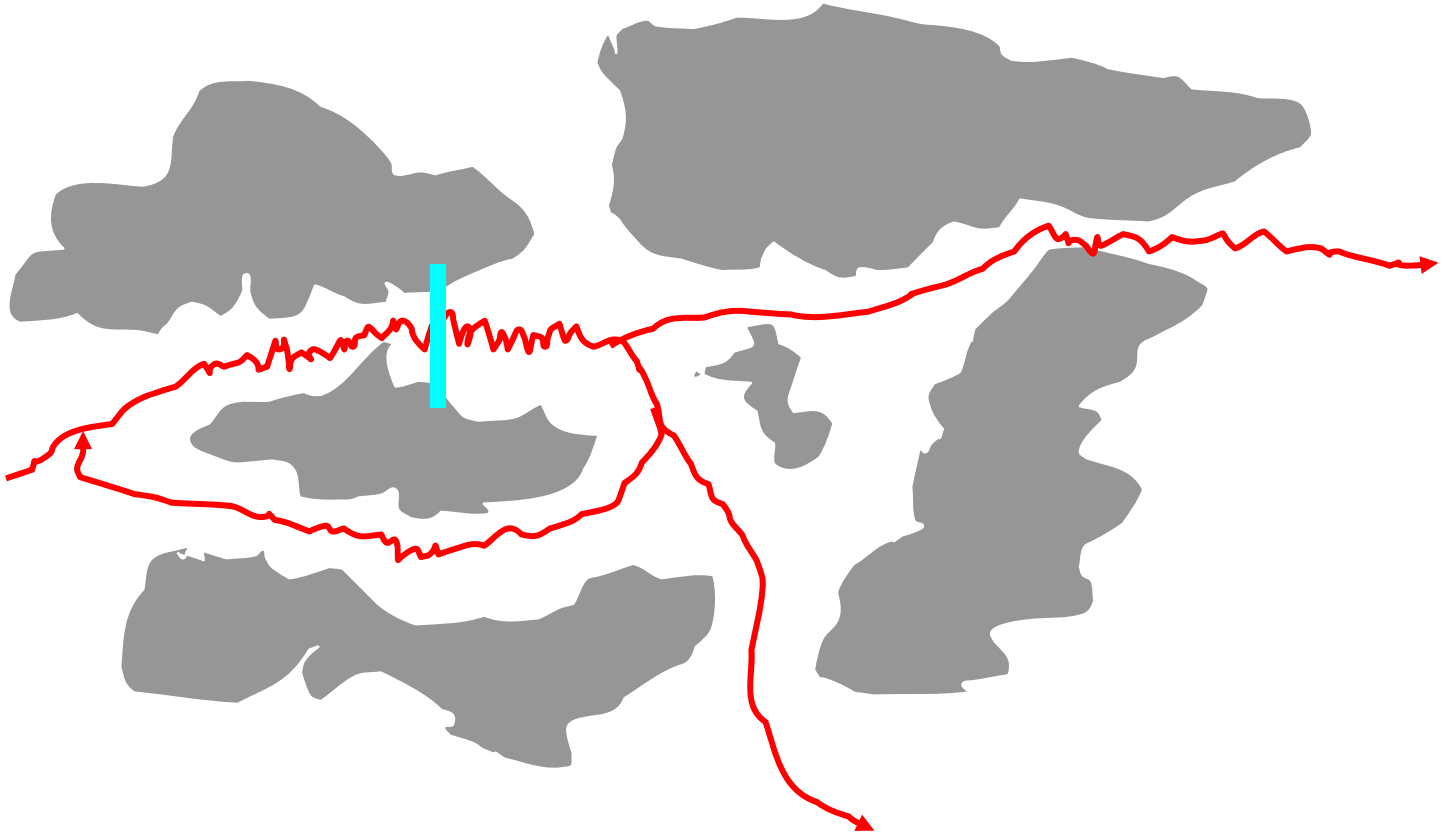


Management of electrical storm

WWU Münster

Catheter ablation:

areas of slow conduction and of conduction through narrow pathways



Management of electrical storm

WWU Münster

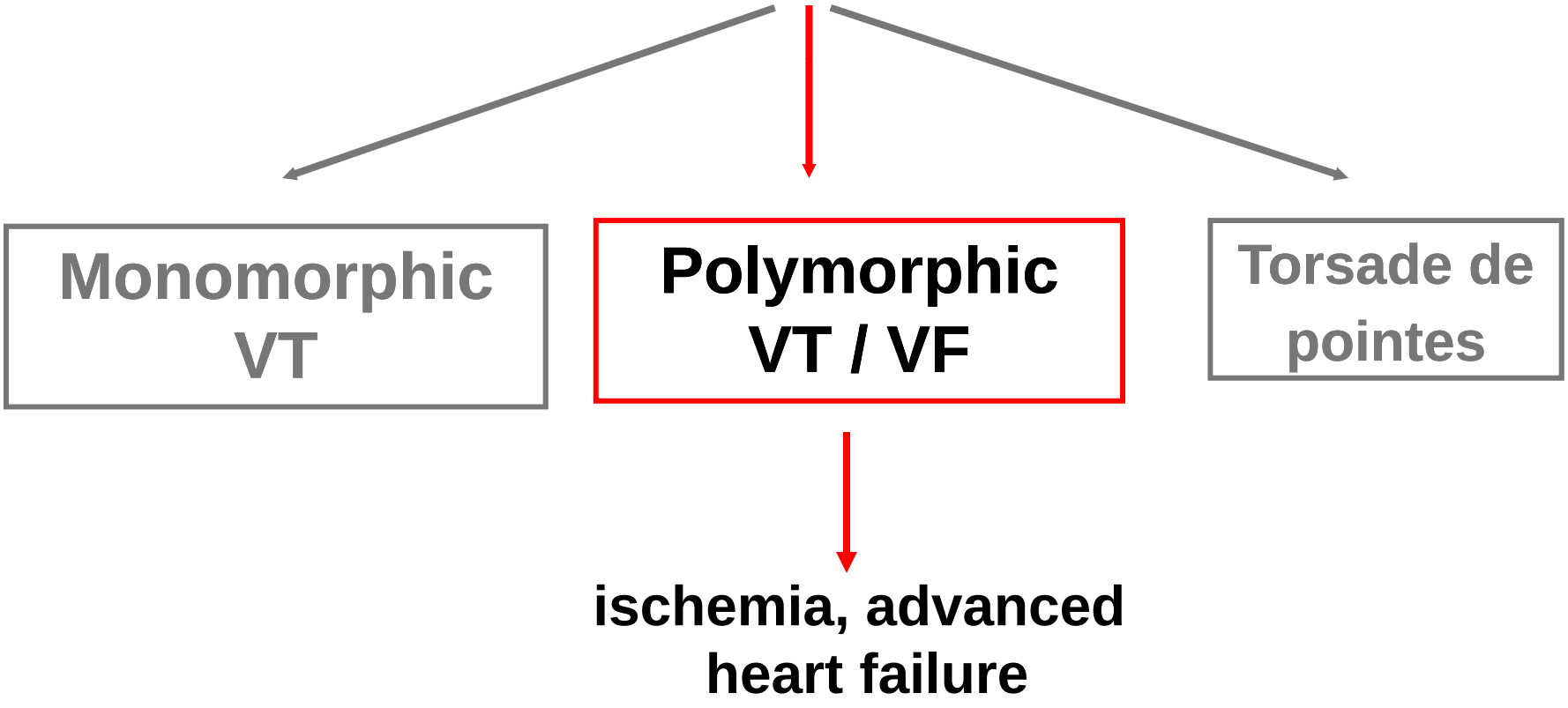
Therapeutic interventions: Catheter ablation

- acute success in eliminating the dominating type of VT is high
- also other forms of inducible VT
- aim of intervention: to get rid of incessant VT
  - ✓ additional types of VT are left behind since these pts frequently are already protected by an ICD or would receive one afterwards anyhow

Incessant VT / VF

WWU Münster

Acute interventions



Management of electrical storm

WWU Münster

Therapeutic interventions: Catheter ablation of VF

- the Purkinje system has been shown to be responsible for the initiation of VF in the absence of structural heart disease *)
- a similar mechanism has been reported in electrical storm early after MI

*) Haissaguerre et al., Mapping and ablation of idiopathic ventricular fibrillation. Circulation 2002; 106: 962-7. Haissaguerre et al., Role of Purkinje conducting system in triggering of idiopathic ventricular fibrillation. Lancet 2002; 359: 677-8

Management of electrical storm

WWU Münster

- 6 - 30 RF applications abolished all local Purkinje potentials at the site of earliest activation and/or perfect pace mapping and suppressed VPBs in all pts
  - No episode of VT or VF has recurred for 33, 14, 6, and 5 months in all pts

D Bänsch et al., Circulation 2003; 108: 3011-16

Management of electrical storm

Use of thoracic epidural anesthesia for management of electrical storm: A case report

Aman Mahajan, MD PhD,*† James Moore, MD,† David A. Cesario, MD, PhD,* Kalyanam Shivkumar, MD, PhD*

*From UCLA Cardiac Arrhythmia Center, Department of Medicine, Division of Cardiology, Los Angeles, California, and †Department of Anesthesiology, David Geffen School of Medicine at UCLA, Los Angeles, California.

Heart Rhythm 2005; 2:1359-62

Use of thoracic epidural anesthesia for management of electrical storm

ECG telemetry strips: Panels C and D show ineffective pace termination attempts by the device.

Heart Rhythm 2005; 2:1359-62

Management of electrical storm

WWU Münster

Guidelines

ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J 2006; 27: 2099–2140

Incessant ventricular tachycardia: Recommendations

WWU Münster

Class IIa

- **Catheter ablation can be useful for patients with implanted ICDs who experience incessant or frequently recurring VT. (Level of Evidence: B)**

ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J 2006; 27: 2099–2140

Incessant ventricular tachycardia: Recommendations

WWU Münster

Class I

Revascularization and beta blockade followed by intravenous antiarrhythmic drugs such as procainamide or amiodarone are recommended for patients with recurrent or incessant polymorphic VT due to acute myocardial ischemia. (Level of Evidence: C)

Class IIa

Intravenous amiodarone or procainamide followed by VT ablation can be effective in the management of patients with frequently recurring or incessant monomorphic VT. (Level of Evidence: B)

ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J 2006; 27: 2099–2140

Incessant ventricular tachycardia: Recommendations

WWU Münster

Class IIb

(1) Intravenous amiodarone and intravenous beta blockers separately or together may be reasonable in patients with VT storm. (Level of Evidence: C)

(2) Overdrive pacing or general anesthesia may be considered for patients with frequently recurring or incessant VT. (Level of Evidence: C)

(3) Spinal cord modulation may be considered for some patients with frequently recurring or incessant VT. (Level of Evidence: C)

ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J 2006; 27: 2099–2140

Management of electrical storm

WWU Münster

- Definitions and clinical significance of frequent and refractory VT/VF
- Therapeutic interventions
- **Prognosis**
- Conclusions

Management of electrical storm

WWU Münster

Prognosis

- pts with LV dysfunction after MI have an increased risk of life-threatening arrhythmia, including VT and VF
- frequent episodes of VF predict a higher risk of mortality despite the presence of an ICD

Management of electrical storm

WWU Münster

Prognosis depends on

- **the type of arrhythmia (i.e. VT or VF)**
- **the type of arrhythmia presentation (i.e. frequent episodes, clusters, storm or incessant episodes)**
- **the type and stage of underlying heart disease**
- **although rare, such episodes of VT/VF may also occur without apparent heart disease**

Management of electrical storm

WWU Münster

Prognosis

- in pts on ICD, frequent episodes have become a most demanding clinical problem during long-term follow-up
- these pts survive their arrhythmia episodes but enter into advanced stages of CHF which is linked to more frequent appearance of arrhythmias
- clusters of VTs may be an additional powerful marker, rather than the cause, of cardiac deterioration in such patients

Management of electrical storm

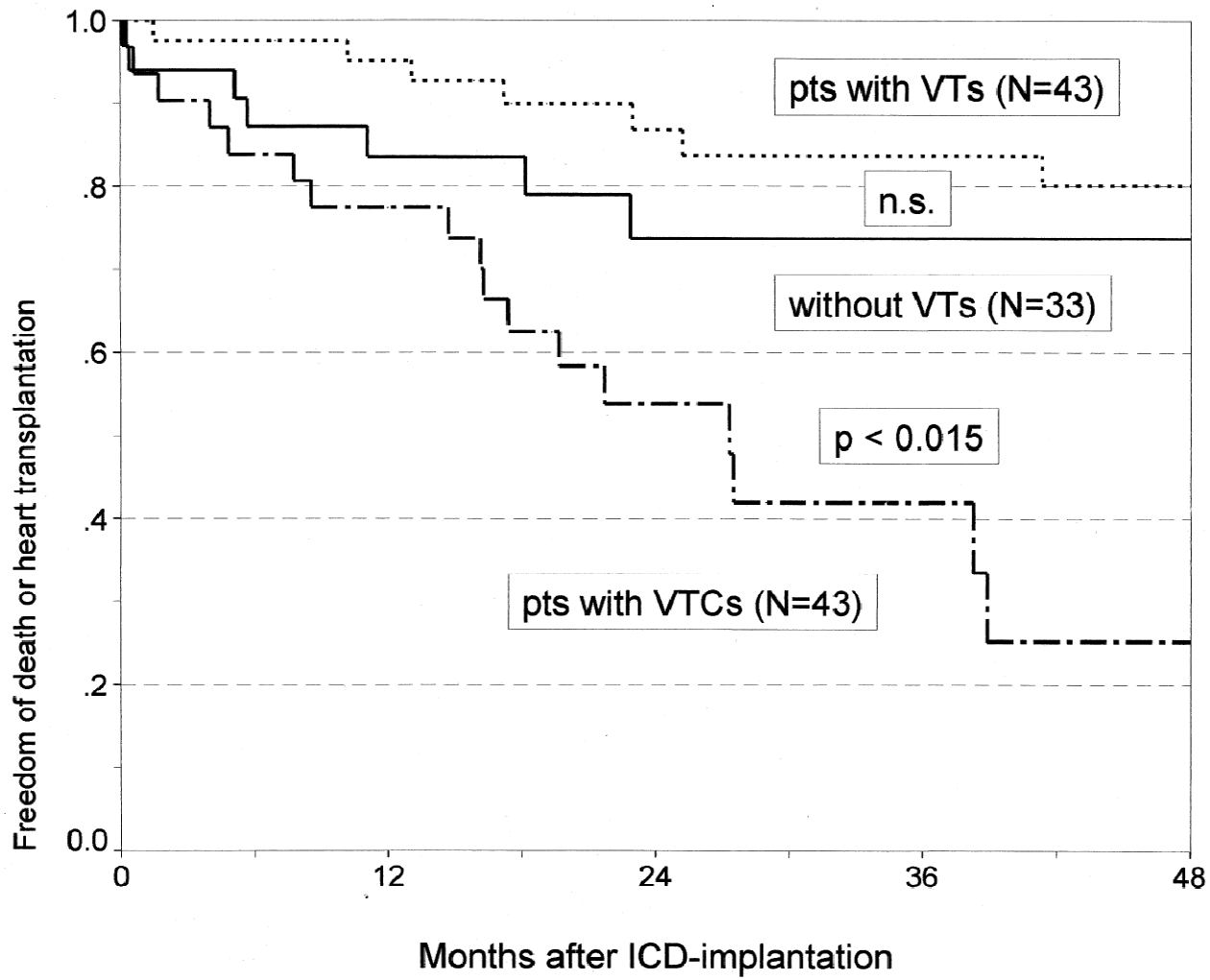
Clusters of Ventricular Tachycardias Signify Impaired Survival in Patients With Idiopathic Dilated Cardiomyopathy and Implantable Cardioverter Defibrillators

Dietmar Bänsch, MD, Dirk Böcker, MD, Jürgen Brunn, MD, Max Weber, MD, Günter Breithardt, MD, FACC, FESC, Michael Block, MD

JACC 2000; 36: 566 –73

Management of electrical storm

Survival free of Htx or death in pts with single or no VTs and VTCs after implantation.



D Bänsch et al., JACC 2000; 36: 566 –73

Management of electrical storm

European Heart Journal (2006) 27, 700–707
doi:10.1093/eurheartj/ehi726

Clinical research
Arrhythmia/electrophysiology

Clinical predictors and prognostic significance of electrical storm in patients with implantable cardioverter defibrillators

François Brigadeau[1]*, Claude Kouakam[1], Didier Klug[1], Christelle Marquié[1], Alain Duhamel[2], Frédérique Mizon-Gérard[1], Dominique Lacroix[1], and Salem Kacet[1]

[1] *Department of Cardiology A, Hôpital cardiologique de Lille, CHRU, 59037 Lille Cedex, France; and* [2] *Department of Biostatistics, Lille University Hospital, Lille, France*

Contradictorary results!!! →

Clinical predictors and prognosticc significance of electrical storm in pts with ICDs

- **Electrical storm is frequent but does not increase mortality in ICD's recipients**
- **Pts with severe systolic dysfunction, chronic renal failure and VT as initial arrhythmia are likely to experience ES**
- **Diabetics are less affected by ES**

F Brigadeau et al., Eur Heart J 2006; 27: 700-9

Management of electrical storm

WWU Münster

- Definitions and clinical significance of frequent and refractory VT/VF
- Therapeutic interventions
- Prognosis
- **Conclusions**

Management of electrical storm

WWU Münster

Conclusions

- Management of pts with frequent and even incessant VT/VF is often very difficult
- even in experienced centers, prognosis is frequently poor
- pts should be referred as early as possible to an experienced center that has all modalities for coronary, electro-physiological, and hemodynamic (e.g. assist devices) interventions

Thank you very much for your attention