Prevention of Inappropriate ICD Therapy "SVT"

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Disclosures

- Honoraria
  - Biotronik
  - Medtronic
  - St Jude

Prevention of Inappropriate ICD Rx

- Don’t put one in

Or

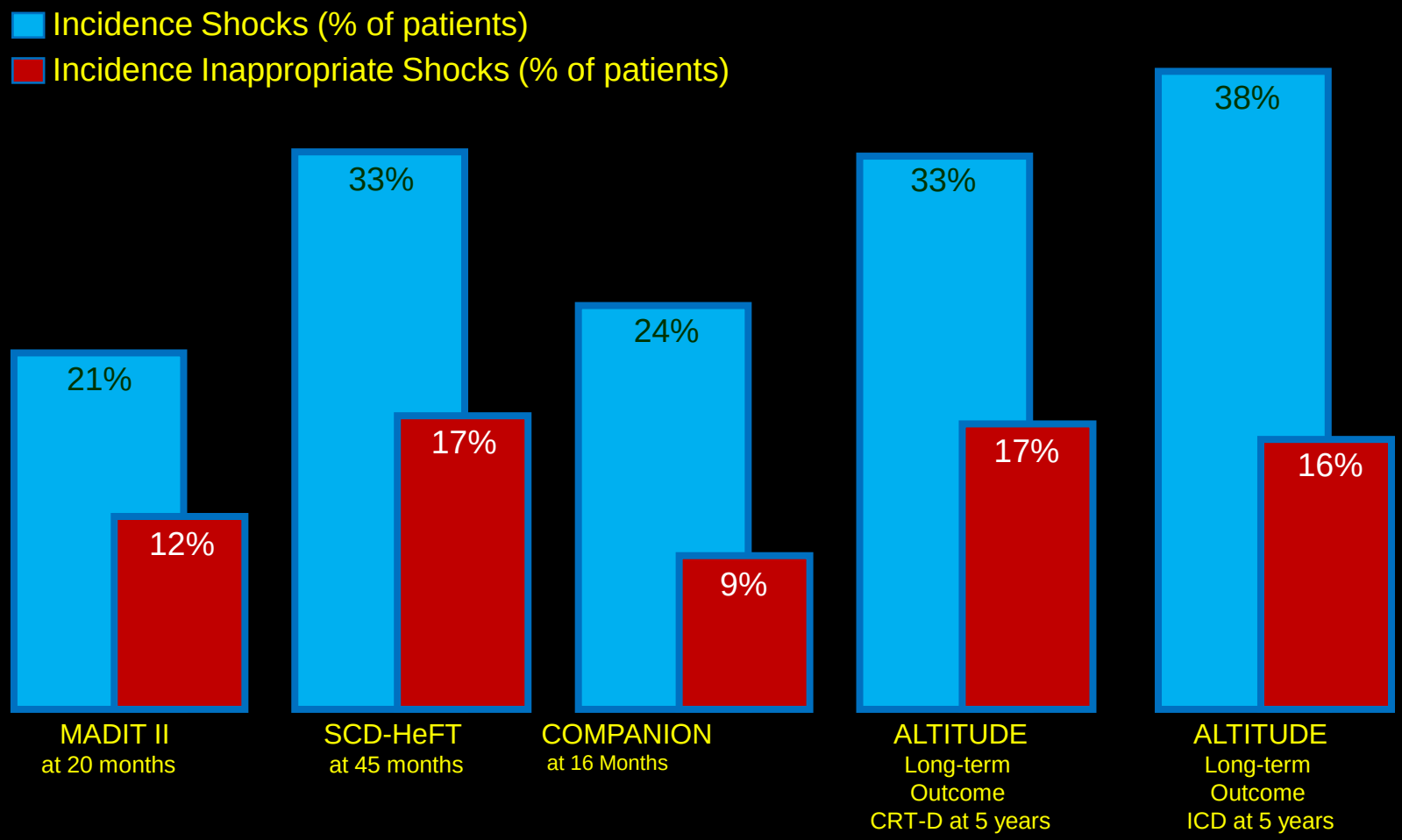
- Ablate the AV Node

Recognition of the problem

- Early trials
  - ICD therapy = life saved
- ICD advances: Electrogram storage
  - Proved that shock did not equal life saved
- AVID: Therapy analysis
  - 43% no Egram storage
  - Single chamber
  - “Concordance of expert review” 49% for AF
  - SVT 18% shocks (mix AF and SVT)
  - AF predicted VF
    - Was this AF

J Cardiovasc Electrophysiol 2003 14: 940-948

Incidence ↑Primary vs Secondary Prevention



Causes of ICD Shock

- Appropriate
- Unecessary
- Inappropriate
  - SVT (Afib/flutter/tach; “SVT”; Sinus tachy)
  - Signal Misinterpretation
  - Phantom

Frequency and Predictors

- MADIT II substudy (post MI, poor LV)
  - N=719
- Inappropriate shock
  - 11.5% patients: mean 2 shocks
  - 31.2% shocks
  - AF 44%; **SVT 36%:** Abnormal sensing 20%
  - Time course same
  - One patient had all 3 causes
- More frequent if stability programmed **off**
- DDD enhancements used less

J Am Coll Cardiol 2008 51: 1357-65

Frequency, Predictors and Mortality

- Inappropriate shock increased mortality
  - Hazards ratio: 2.3
- Predictors
  - Prior AF 18 vs 7%
  - Smoking 89 vs 78%
  - Diastolic BP
  - Prior appropriate shock
- Mortality
  - App shock HR 3.4
  - Inapp shock HR 2.3
  - Both types HR 4.0

MADIT II JACC 2008 51: 1357-65 SCD HeFT NEJM 2008 359: 1009-1017

Mortality: Questions

- Do shocks predict mortality
  - ie marker of significant clincal change
  - But ATP no ↑ mortlaity
- Do shocks worsen mortality?
- Putative Mechanisms: Myocardial damage
  - PEA after ICD test: “cardiac annihilation”
  - Alteration in elecyrophysiological and haemodynamic function, Biochemical alteration, Cell morphology changes
  - ?Electroporation
  - Pre-existant dysfunction may sensitise the myocardium

JACC 2009 54: No 9: 829-831

Morbidity

- Painful, psychologically disturbing ?arrhythmogenic

- Worse mental health
- Impaired QOL
- Decreased new activity: fear
- Depression
- Anxiety

- “TAKE IT OUT PLEASE”

SCD –HeFT Substudy NEJM 2008 359: 999-1008 JACC 2008 51: 14: 1366-1368

SVT/VT Discrimination

- As per surface ECG
  - more information: better diagnosis
- V rate
- V regularity
- Onset/offset
- Atrial rhythm
- AV timing
- QRS morphology

Detection

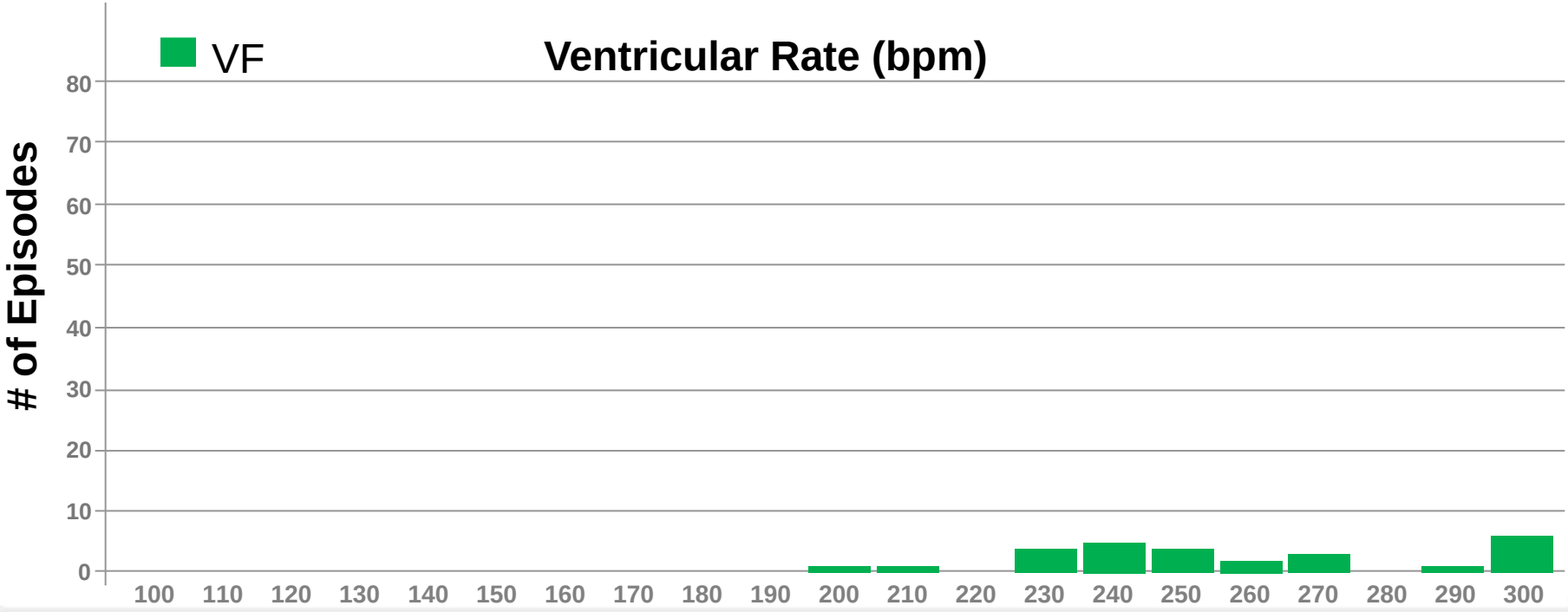
- Primary criterion: **Ventricular rate**
  - V electrograms exceeding programmed sensitivity in a sliding detection window
  - Usually consecutive in VT zone
  - Percentage of beats in VF zone (to accommodate dropout of low amplitude signals)

- Crude
  - High rates may not protect against inappropriate detection
  - 20% of “SVT” in VF zone>220 bpm

Rate Distribution of All Shocked Rhythms

INTRINSIC RV Study Adjudicated Shock Episode Data[1]

Spontaneous episodes of ventricular fibrillation (VF) shown by incidence and rate

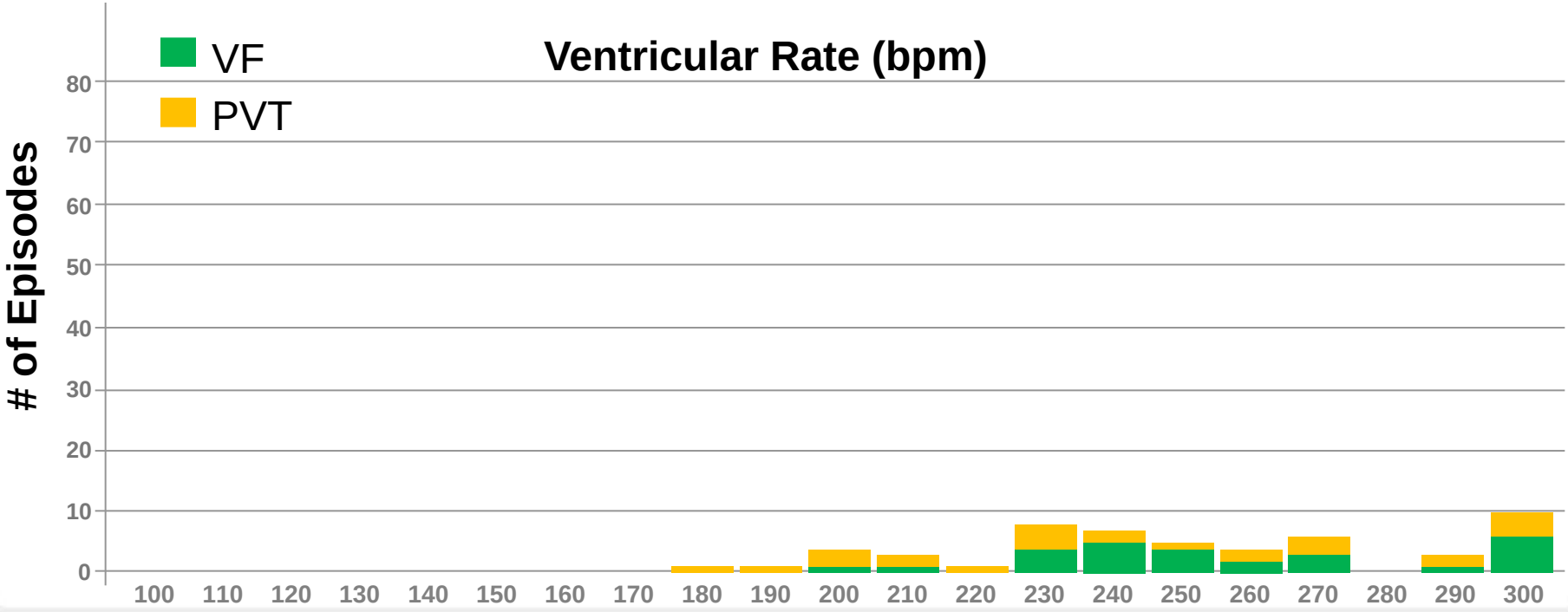


[1] B. Olshansky, et al. Heart Rhythm 2009; 6(5);Suppl1:PO01-88

Rate Distribution of All Shocked Rhythms

INTRINSIC RV Study Adjudicated Shock Episode Data[1]

Spontaneous episodes of polymorphic ventricular tachycardia (PVT) shown by incidence and rate

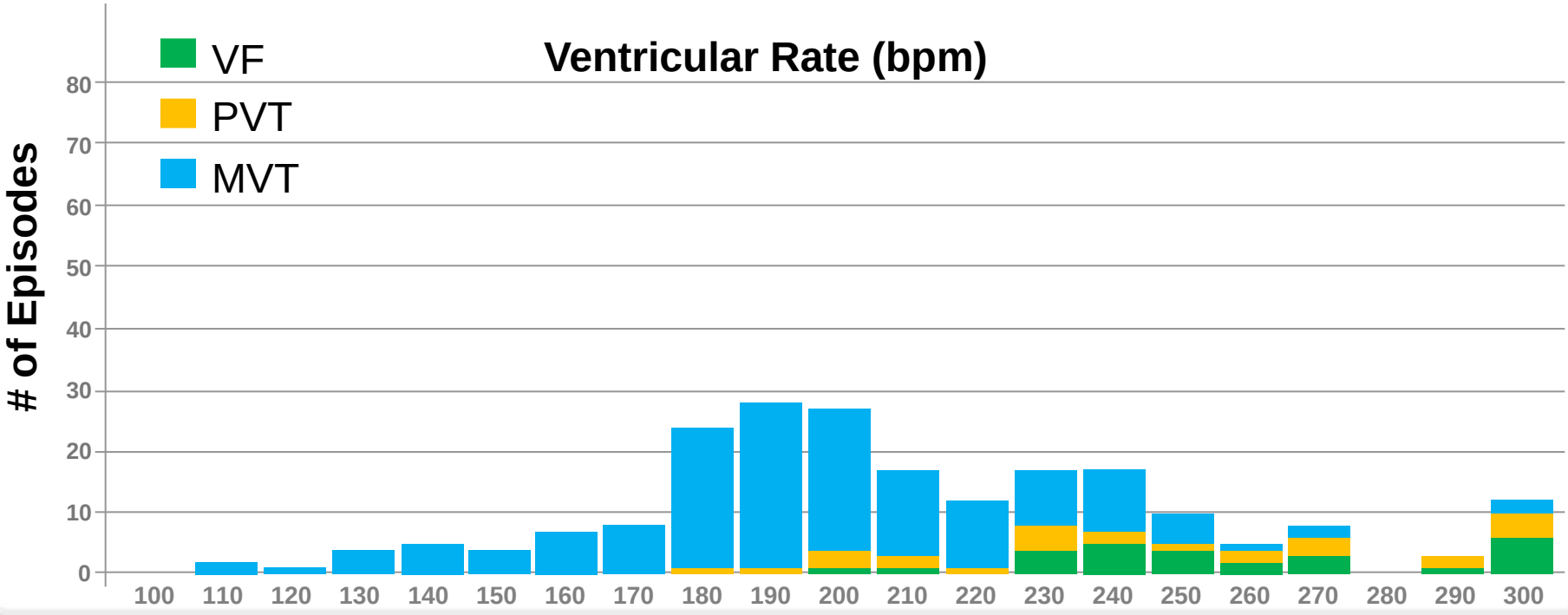


[1] B. Olshansky, et al. Heart Rhythm 2009; 6(5);Suppl1:PO01-88

Rate Distribution of All Shocked Rhythms

INTRINSIC RV Study Adjudicated Shock Episode Data[1]

Spontaneous episodes of monomorphic ventricular tachycardia (MVT) shown by incidence and rate



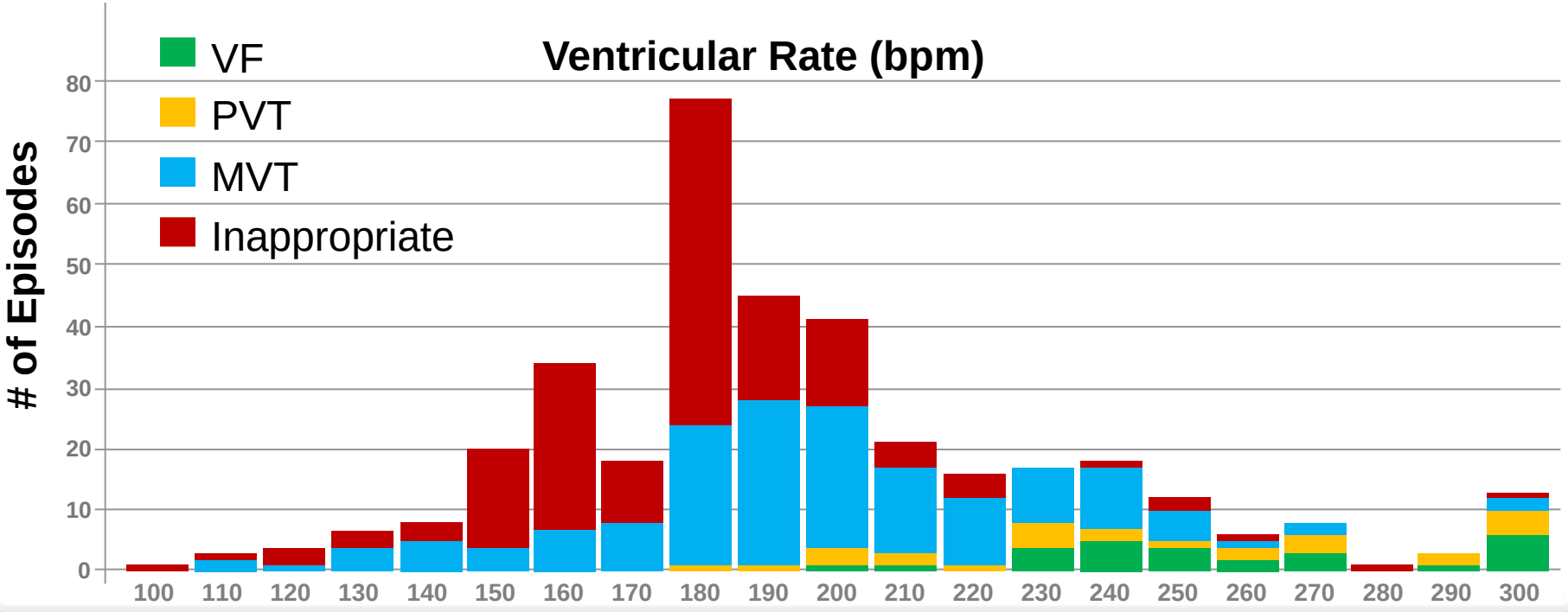
[1] B. Olshansky, et al. Heart Rhythm 2009; 6(5);Suppl1:PO01-88

Rate Distribution of All Shocked Rhythms

INTRINSIC RV Study Adjudicated Shock Episode Data[1]

Spontaneous episodes inappropriately treated with a shock shown by incidence and rate

- Single-zone programming without rhythm discriminators or ATP used in over 50% of shock episodes
- 68% of inappropriate shock episodes occurred at ventricular rates between 160 - 200 bpm



[1] B. Olshansky, et al. Heart Rhythm 2009; 6(5);Suppl1:PO01-88

SVT: Ventricular Rate During Inappropriate Rx

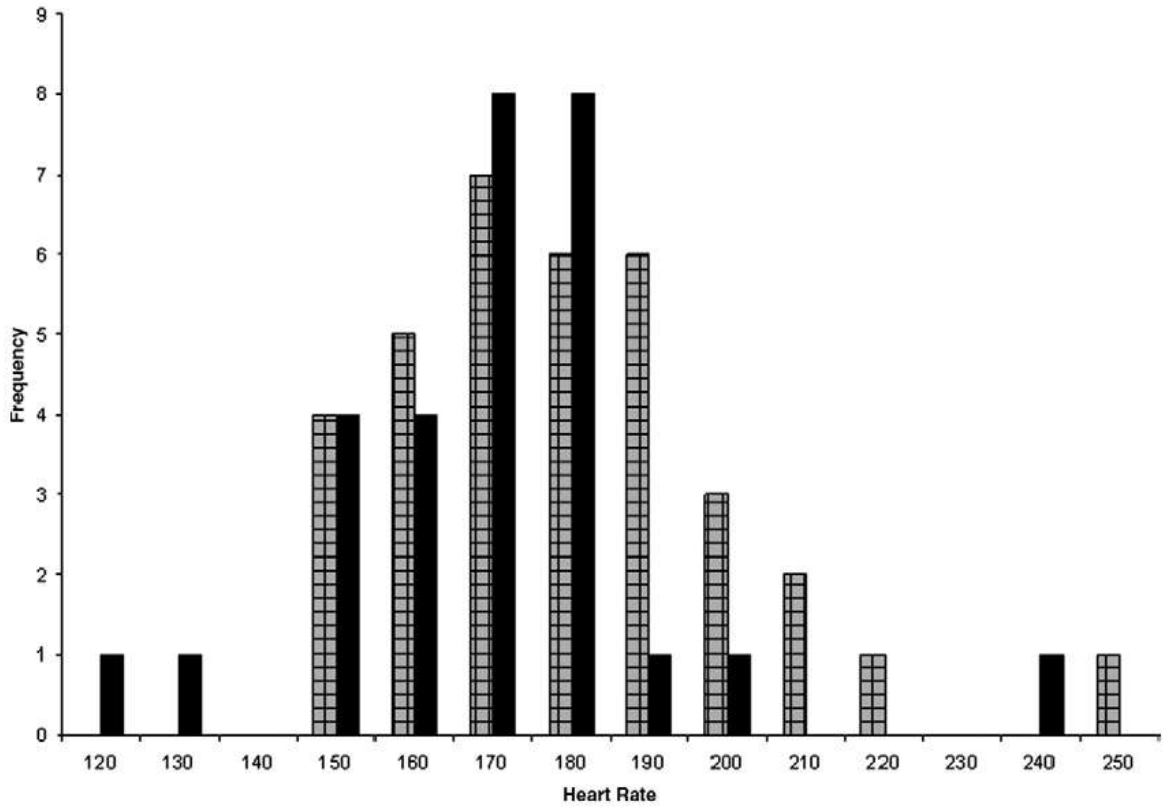


Figure 3 **Ventricular Rate Precipitating Inappropriate Shock**

The heart rate at the time of the ICD detection resulting in a patient's first inappropriate shock is shown in the bar graph in groups of 10 beats/min. Atrial fibrillation episodes are shown with **cross-hatched bars**, and SVT episodes are shown with **solid bars**. Inappropriate shocks caused by abnormal sensing are excluded because the device has by definition misconstrued the actual ventricular rate (typically normal in these cases). The events relate to shocks, not patients, in this figure. Abbreviations as in figure 2.

J Am Coll Cardiol 2008 51: 1357-65

Prevention Strategies: Detection

- Rate
- Stability
- Onset
- Morphology

- Available in single and dual lead devices

- Concern: enhancements that increase specificity may degrade sensitivity

Prevention Strategies: Detection

Table 1 Single-chamber implantable cardioverter defibrillator detection algorithms from different manufacturers (manufacturers presented in alphabetical order)

Diagnostic algorithm	Biotronik	ELA	Guidant	Medtronic	St Jude
	Criterion is met and SVT is diagnosed when				
Onset	Average of recent four VIs minus average of current four VIs < programmable value (also as % value)	Current RR interval >75% of the preceding RR interval	Cycle length decrease in adjacent VIs prior episode start < programmable value (also as % value)	Average of four recent VIs divided by average of four previous VIs > programmable % value	PreVT (sinus) average VI minus first average VI within VT zone < programmable value (also % value)
Stability	Fluctuation in duration of the last four tachycardic VIs > programmable value	Ratio of intervals within a programmable stability range < programmable ratio	Average of RR interval differences > programmable value	VI—any of previous three VIs > programmable interval	Second longest–2nd shortest VI in a detection window > programmed value
Morphology	Not available	Not available	≥3 out of 10 beats match with stored template (match percentage > non-programmable value)	≥3 out of last 8 beats match with stored template (match percentage > programmable value)	≥5 out of last 8 beats match with stored template (match percentage > programmable value)

SVT, supraventricular tachycardia; VT, ventricular tachycardia; VI, ventricular interval.

Europace 2008 10: 1256-1265

Prevention Strategies: Onset

- Premise
  - Sinus tachy: gradual rate change
  - VT (reentrant) sudden rate change

- Advantage
  - Excludes sinus tachy well
- Disadvantage/Limitation
  - Fails to exclude AF/Flutter, SVT
  - May under-detect VT during sinus tachy or exercise

JACC 1994 23: 1342-1355

Prevention Strategies: Stability

- Premise
  - AF: irregular/unstable cycle length
  - VT: regular/stable cycle length
- Advantage
  - Excludes AF well below 190/min
- Disadvantage/Limitation
  - AF regularisation at high rates: false diagnose VT
  - May under-detect irregular VT
- However
  - combination onset/stability sensitivity 100% specificity 80%

PACE 2001 24: 1325-1333

Prevention Strategies: Morphology

- Premise
  - SVT QRS complex morphology = sinus complex morphology
  - VT QRS complex morphology ≠ sinus complex morphology
- Function
  - Acquire sinus template
  - Match arrhythmia
  - Examine discordance/similarity
  - Wavelet/polygon/vector time and correlation
  - Computationally heavy
- NB
  - Only available in some manufacturers
  - Usually single Egram used (Medtronic Can-Coil, StJude RV bipole, Boston both)

Europace 2008 10: 1256-1265

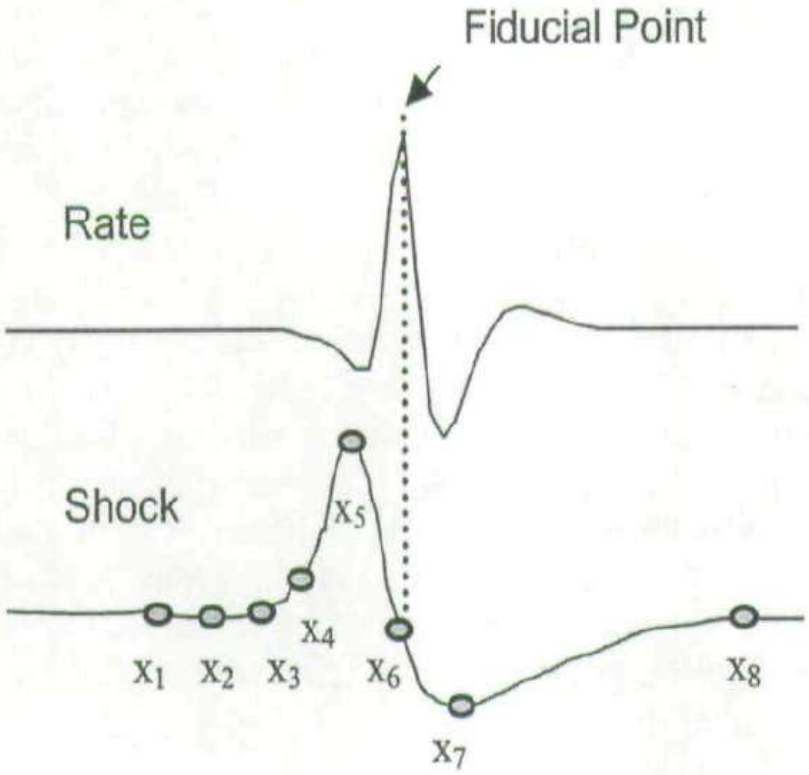
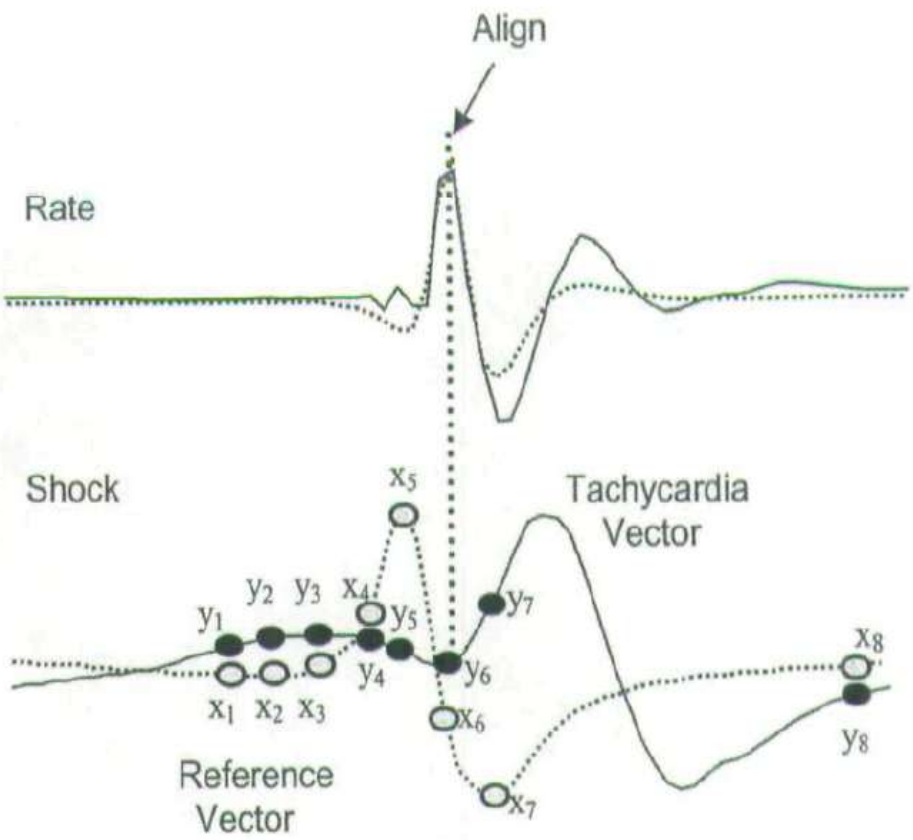


Figure 2. *Reference vectors. Fiducial point and features are noted.*



$$FCC = \frac{(8\sum_{i=1}^{8} x_i y_i - (\sum_{i=1}^{8} x_i)(\sum_{i=1}^{8} y_i))^2}{(8\sum_{i=1}^{8} x_i^2 - (\sum_{i=1}^{8} x_i)^2)(8\sum_{i=1}^{8} y_i^2 - (\sum_{i=1}^{8} y_i)^2)}$$

Figure 3. *Feature correlation coefficient (FCC) calculation. x_i indicate reference feature amplitudes and y_i indicate arrhythmia feature amplitudes.*

J Cardiovasc Electrophysiol 2002 13 1092-1097

Prevention Strategies: Morphology

- Limitations
  - Template misalignment
  - Rate dependent aberration
  - Septal VT (similar sinus)

  - Ischaemia may alter morphology
  - Exercise myopatentials degrade egram
  - Post shock Egram distortion

Prevention Strategies: DDD

- Premise
  - A Fib A>V
  - SVT A=V
  - VT V>A (90% of VT's)
- Function
  - analyse AV relationship
- Advantage
  - Integrate atrial events: improved specificity
- Limitations
  - AF and VT
  - SVT with 1:1
  - Critically dependent on A sensing: now improved with programmable blanking

Prevention Strategies: DDD Manufacturers

Table 2. Performance of Integrated Programming in Dual-Chamber Implantable Cardioverter-Defibrillators From Major Manufacturers to Distinguish Ventricular Tachycardia from Supraventricular Tachycardia

	Manufacturer				
	Biotronik	ELA Medical	Guidant	Medtronic	St Jude Medical
Source	Sinha et al[38] 2004	Sadoul et al[39] 2002	Kouakam et al[40] 2004	Wilkoff et al[32] 2001	Bailin et al[41] 2003
No. of patients	209	95	51	933	107
Study duration	10 mo	15 mo	12 mo	3.9 mo	68 d
Ventricular tachycardia					
Sensitivity, %	100	99.3	99	99.9	100
Specificity, %	89	89.2	89	66.6	84

From JAMA 2006 296; 23: 2839- 2847

Are more leads better? Probably

TABLE 1
Summary of Main Studies Comparing Single- versus Dual-Chamber ICDs or Detection Algorithms

Study	Year	Population	Randomization	n	Primary Endpoint	Follow-Up (months)	Main Findings
DATA study (23)	2008	Patients with Sc-ICD indication	Sc-ICD vs Dc-ICD vs Sc-simulated ICD	334	All-cause mortality, invasive intervention, hospitalization for CV causes, inappropriate shocks, and sustained symptomatic atrial tachyarrhythmias lasting >48 h (Clinical Significant Adverse Events, CSAE)	16	Dual-chamber ICD is associated with less CSAE
Detect Supraventricular Tachycardia study (19)	2006	Dc-ICD recipients	Sc vs Dc mode detection	400	Inappropriately detected SVT arrhythmias	6	Reduction of inappropriately detected SVT arrhythmias with Dc-ICD (32.3% vs 46.5%) No reduction of the proportion of inappropriate shocks
PINAPP (20)	2004	Dc-ICD recipients	Sc vs Dc mode detection	60	Delivery of inappropriate ICD therapies for atrial arrhythmias	12	No differences in the absolute number of misclassified episodes of SVT and inappropriate therapies
1 + 1 Trial (21)	2004	Dc-ICD recipients with slow VTs	Sc vs Dc mode detection	100	Inappropriate ICD therapies. VTs above the TDI, and VTs with a therapy delay >2 minutes	12 (6 + 6 crossover)	Moderate superiority of Dc-ICD for the combined primary end-point No significant differences in the rate of inappropriate therapies Low sensitivity of Dc-ICDs for true VTs (94%)
Deisenhofer *et al.* (22)	2001	Sc and Dc-ICD recipients	True Sc vs Dc ICDs	92	Inappropriate ICD therapies and complications	7.6	No significant differences in the proportion of inappropriate therapies Dc- and Sc-ICDs are equally safe during implantation and follow-up

Prevention Strategy: DDD

- DETECT SVT Study
  - N=400 mix primary/secondary
  - DDD in all ramdomised DDD vs VVI but egrams stored
  - Rate enhancements programmed on: ATP discretional
- Results
  - Per episodes 42 % ScICD VT/VF was SVT, DcICD 69%
  - Per patient inapp detection (not shock) 46% Sc vs 32% Dc
  - 50% reduction inapp therapy
  - No diff shocks: much more aggressive ATP ScICD

CIRC 2006 113: 2871-2879

Prevention Strategies: Detection

- Should enhancements be used
  - YES
- Whose enhancement
  - Doesn’t matter
- Which enhancement
  - All

Avoidance Strategies: Time to Rx

- Best enhancement!
  - Allows spontaneous termination
- PREPARE study
  - Programme VT/VF to 30/40 beats
  - Corresponds to 12-13 secs VT <200 bpm
  - Substantial reduction in all shocks/therapies

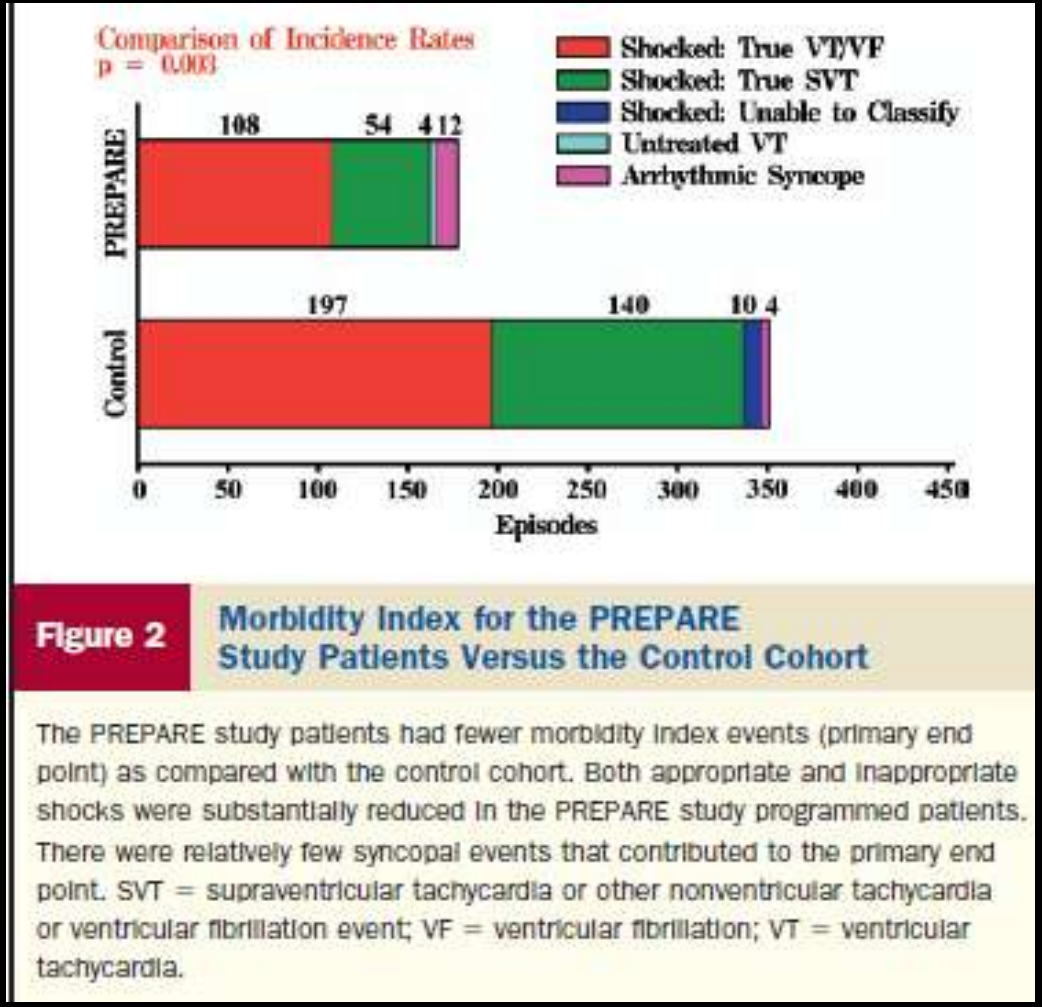


Figure 2 **Morbidity Index for the PREPARE Study Patients Versus the Control Cohort**

The PREPARE study patients had fewer morbidity index events (primary end point) as compared with the control cohort. Both appropriate and inappropriate shocks were substantially reduced in the PREPARE study programmed patients. There were relatively few syncopal events that contributed to the primary end point. SVT = supraventricular tachycardia or other nonventricular tachycardia or ventricular fibrillation event; VF = ventricular fibrillation; VT = ventricular tachycardia.

Avoidance Strategies: ATP

- Painfree II Rx Trial
  - N=634, ATP for rapid VT
  - 18/24 cycles 188-250 bpm
  - 75% of “VF” was Fast VT and terminated with 8 pulse burst
- Empiric Trial
  - N=900 standard vs tailored programme
  - More VT/VF shock in tailored
  - More SVT empiric but no more shocks
- Advance D Trial
  - Compare 15 pulse ATP vs 8 pulse ATP
  - 15 better if no CHF or LVD otherwise no difference
- PITA-GORA
  - Ramp vs burst : no difference

ATP Strategies

- Long detetction
  - Avoid detection non sustained tachycardia
- Programme on rate enhancements
  - Avoid treating SVT
- Empirical ATP
  - >150/min
- ATP in VF zone
  - Treat rapid VT

Modification Strategies: Drugs

- Assess total shock risk
  - Secondary prevention (↑ %age inapp I^0 vs 2^0)
  - VT as index HR 2.5
  - Recent first app shock ?inapp shock
  - Hospitisation CHF/CAD
  - Poor LV < 25%
  - Prior SVT/AF
- Drugs may
  - ↓shocks and ↓mortality: beta blockers
  - ↓shocks and no effect mortality sotalol/azimolide/amio
  - ?↓shocks and ↑mortality class Ic

Modification Strategies: Drugs

- Sotalol: NEJM1999 340 :1855-1862
  - Beta blocker low dose, Class III higher dose
  - Double blind randomised trial
  - N=300 stratified by LVEF at 30%
  - Inapp Shock decreased 64%

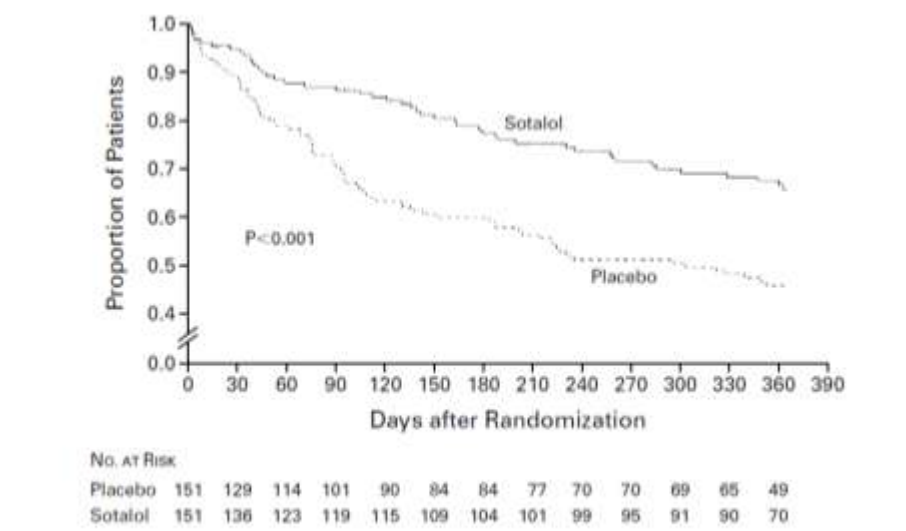


Figure 1. Time to Death from Any Cause or the Delivery of a First Shock for Any Reason, According t the Intention to Treat.
The log-rank test was used to calculate the P value.

TABLE 3. OUTCOME ACCORDING TO THE INTENTION-TO-TREAT ANALYSIS.

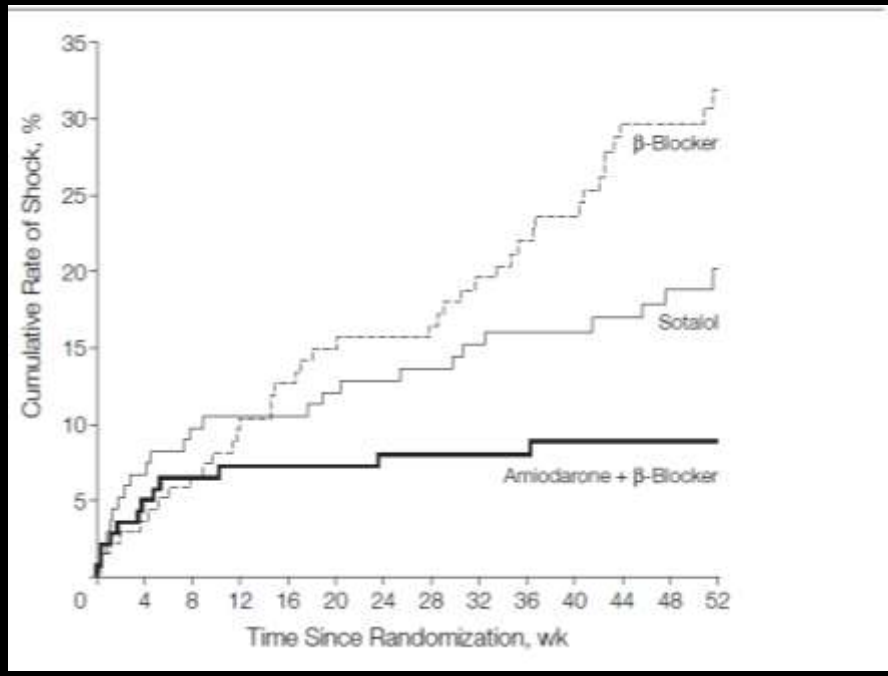
VARIABLE	PLACEBO (N=151)	SOTALOL (N=151)
	number (percent)	
Death from any cause	7 (5)	4 (3)
Delivery of a first shock for any reason*	73 (48)	45 (30)
Kaplan–Meier estimate of survival free of shock for any reason	74 (46)	104 (66)†

*Three patients in the placebo group and two in the sotalol group received a first shock for any reason before they died.

†P<0.001 by the log-rank test.

Modification Strategies: Drugs

- OPTIC study: JAMA 2006 295: 165-171
  - Randomised N=412
  - Amio+BB, Sotalol alone, BB alone
  - Standardised programming
- Results
  - Annual risk inapp shock
    - BB alone: 15.4%
    - Sotalol: 9.4%
    - Amio+BB: 3.3%



- NNT: Amio+BB 35 patients to prevent 10 total shocks

Modification Strategies: Drugs

- Azimolide: SHIELD JACC 2008 52: 1076-1083
  - Randomised placebo controlled n= 633 2^0 (70%VT)
  - Azimilide 75 mg or 125 mg/day class III
- Results
  - Reduced all shocks
  - No effect inapp shocks

Initial Rhythm	Placebo (Total=257 Events, 57 pts)	Azimilide 75 mg (Total=283 Events, 50 pts)	Azimilide 125 mg (Total=130 Events, 42 pts)
Sinus tachycardia	13 (5%)	17 (6%)	20 (15%)
No. of patients with this rhythm	9	11	13
Atrial fibrillation	83 (32%)	108 (38%)	26 (20%)
No. of patients with this rhythm	20	17	9
Atrial flutter	30 (12%)	32 (11%)	4 (3%)
No. of patients with this rhythm	2	6	1
Atrial tachycardia or SVT	85 (33%)	82 (29%)	38 (29%)
No. of patients with this rhythm	19	16	13
Other	46 (18%)	44 (16%)	42 (32%)
No. of patients with other rhythms	27	21	19

Modification Strategies: Drugs

- ?Mexilitine

Modification Strategies: Drugs: AF

- Statins
  - N=1445 primary/secondary non-randomised observational
  - Statins reduced AF+shock HR 0.47 **AF alone 0.63**
  - Other predictors: primary implant/COPD/prior AF
  - But Statin group less prior AF
    - Europace (2008) 10, 854–859
- Meta analysis in CHF
  - **47% reduction in AF**
    - Heart Rhythm 2006;3:881–6
- Fish Oils
  - Probably no effect

Modification Strategies: Ischaemia

- CABG Patch
  - No benefit ICD
- MUSTT
  - Recent prior CABG: No benefit ICD

NEJM 1997 337: 1569 J Cardiovasc Electrophysiol 2002 13: 757 JACC 2005 46: 1721

Modification Strategies: CRT

- MADIT-CRT substudy
  - N=1820, IHD/DCM, EF <30%, QRSd>130 msec
  - CRT ICD Responder vs CRT Non responder vs ICD
  - Responder = at least 25% reduction LVESV at 1 year
  - Assessed **appropriate Rx**

- VT at 2 years
  - 28% Non responder vs 21% ICD vs 12% responder
  - ?would inapp shock be the same
  - Is CRT arrhythmogenic

JACC 2011 57: 2416-23 and 2424-2425

Curative Strategies

- Ablate substrate
  - Avoids pacing dependence
  - Recurrence
- Ablate AV Node
  - Produces pacing dependence
  - RV pacing deleterious in LV dysfunction
  - May be advantageous in Atrial Fibrillation with CRT

New Techniques: Atrial Ventricular Pacing

- Treatment upstream enhancement
  - Treat first diagnose what is left
- ATP burst with simultaneous AV or convergent AV

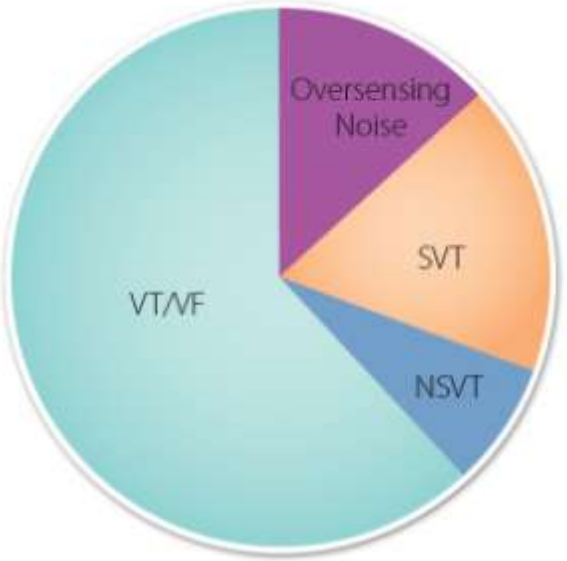
- If tachycardia has 1:1 relationship
- DD Pace
  - If terminated: Good: who cares!
  - If first sensed event is A: SVT
  - If first sensed event is V: VT
  - If equal : SVT
  - If no termination further 3 bursts: then move onto other enhancements

New Techniques: Atrial Ventricular Pacing

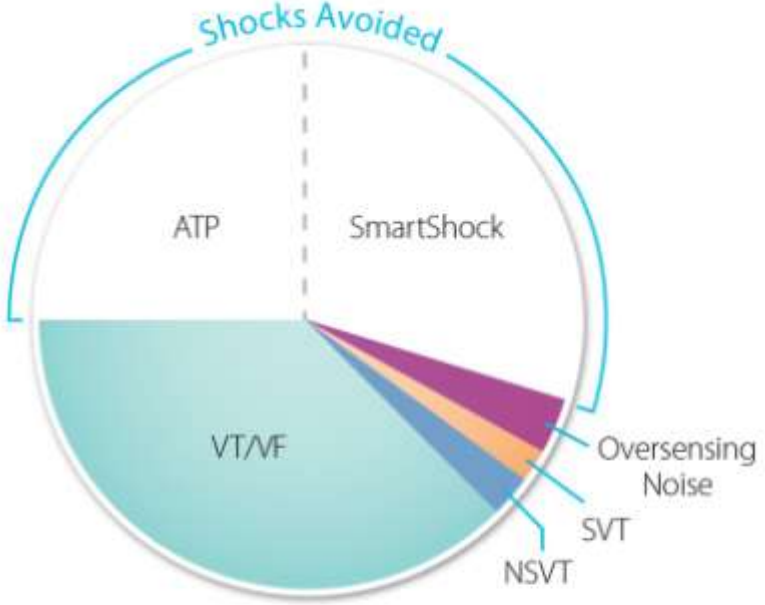
- Result
  - **6% SVT terminate**: exclude sinus tachy: 70%
  - 70% VT terminate
  - Sensitivity increased to 94% from 82% PR logic
  - Specificity unchanged
- Problems
  - VPBs: diagnose VT
  - Failure A capture: diagnose SVT
  - Small numbers: 64 patients
  - 1381 SVT 26 VT
  - 1324 sinus detection 150 bpm

New Techniques: Default combination

Cause for Shocked Episodes[1,3]



SCD-HeFT Sample Episodes[†,*]
Shock Only Programming
(n = 736, > 188 bpm)



Protecta XT™ Predicted Performance
at Nominal Settings
(SmartShock Technology, ATP During Charging™, NID 18/24)

† All shocked episodes from SCD-HeFT that had protocol defined programming and were determined not to be continuations of previous true VT/VF were included for these calculations (736/1,233, 59.7% of total SCD-HeFT treated episodes).

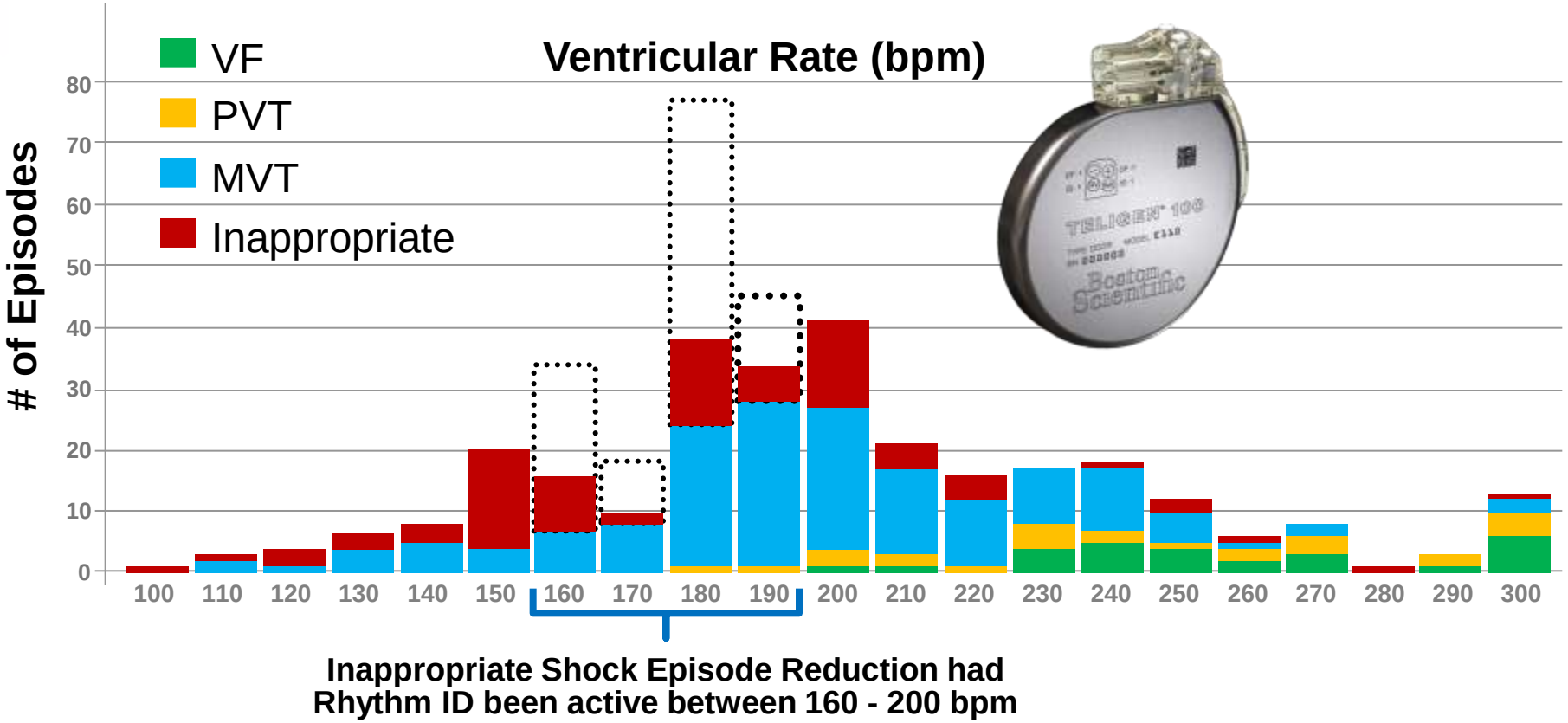
* A sample of save to disk episodes from the SCD-HeFT study was used. The analysis presented here does NOT represent the actual or official results of the SCD-HeFT trial.

[1] Predicted from *Virtual ICD: A Model to Evaluate Shock Reduction Strategies*. Presented at HRS 2010 (P03-125).
[2] Protecta Clinical Study, Medtronic data on file.
[3] Poole JE, Johnson GW, Hellkamp AS, et al. Prognostic importance of defibrillator shocks in patients with heart failure. N Engl J Med 2008 359:1009-1017

Mathematical Simulation

Rate Distribution of All Shocked Rhythms

Simulation Results: 21% decrease in shock episodes*



***Note**: Simulation results may not be indicative of clinical performance. Individual results may vary. These values are for demonstration purposes only and must not to be quoted as actual clinical results.

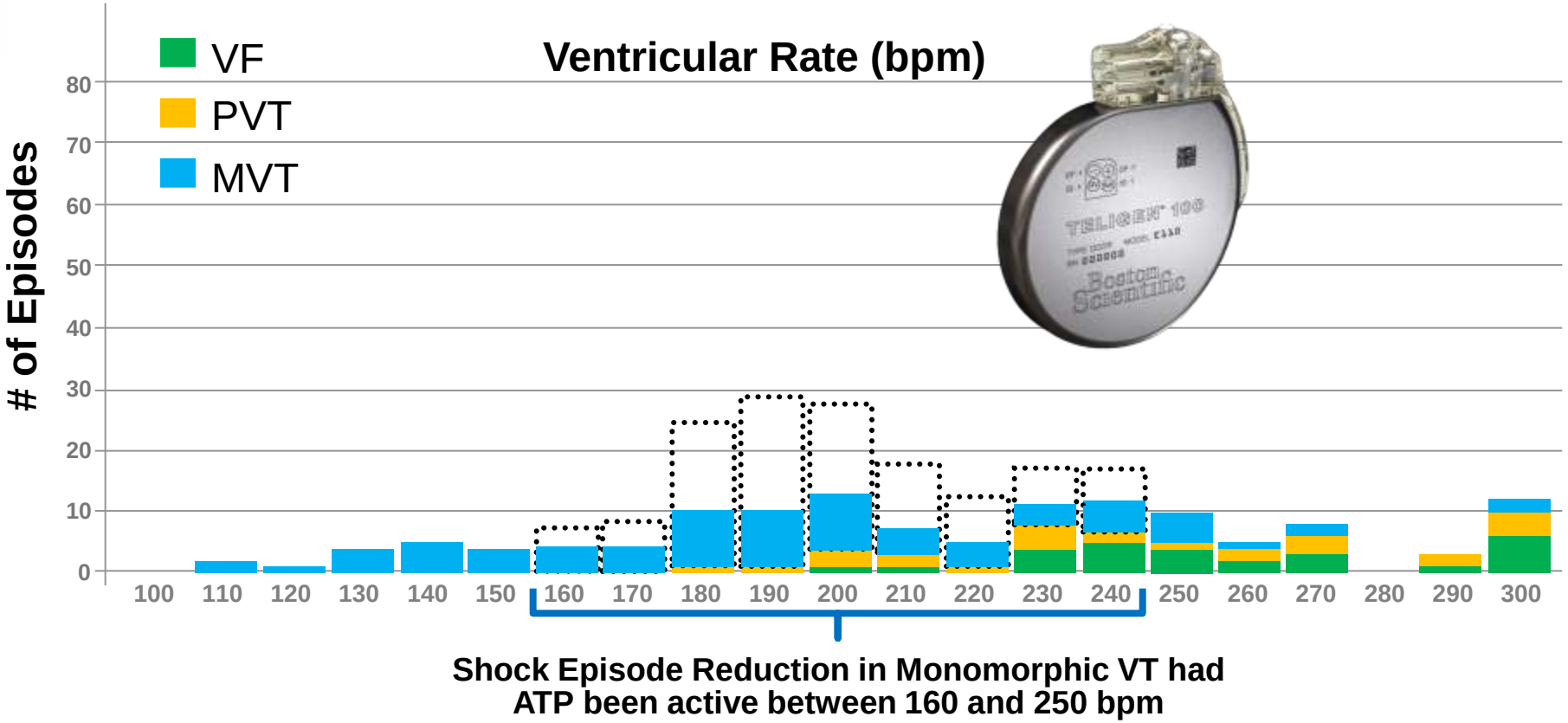
Data on File @ Boston Scientific

CRM1-6603-0311

Mathematical Simulation

Rate Distribution of All Shocked Rhythms

Simulation Results: 22% decrease in shock episodes*



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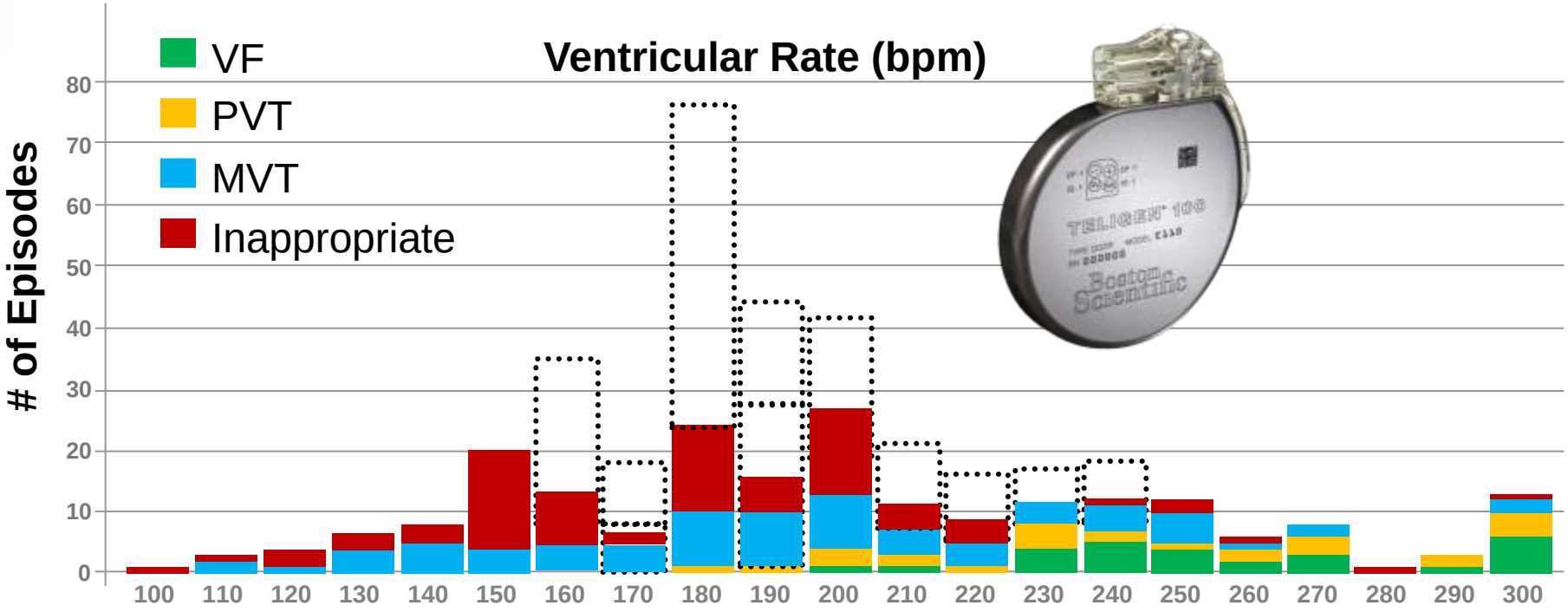
CRM1-6603-0311

Mathematical Simulation

Rate Distribution of All Shocked Rhythms

43% Shock Episode Reduction Using TELIGEN® Nominals for Rhythm ID and ATP



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Data on File @ Boston Scientific

CRM1-6603-0311

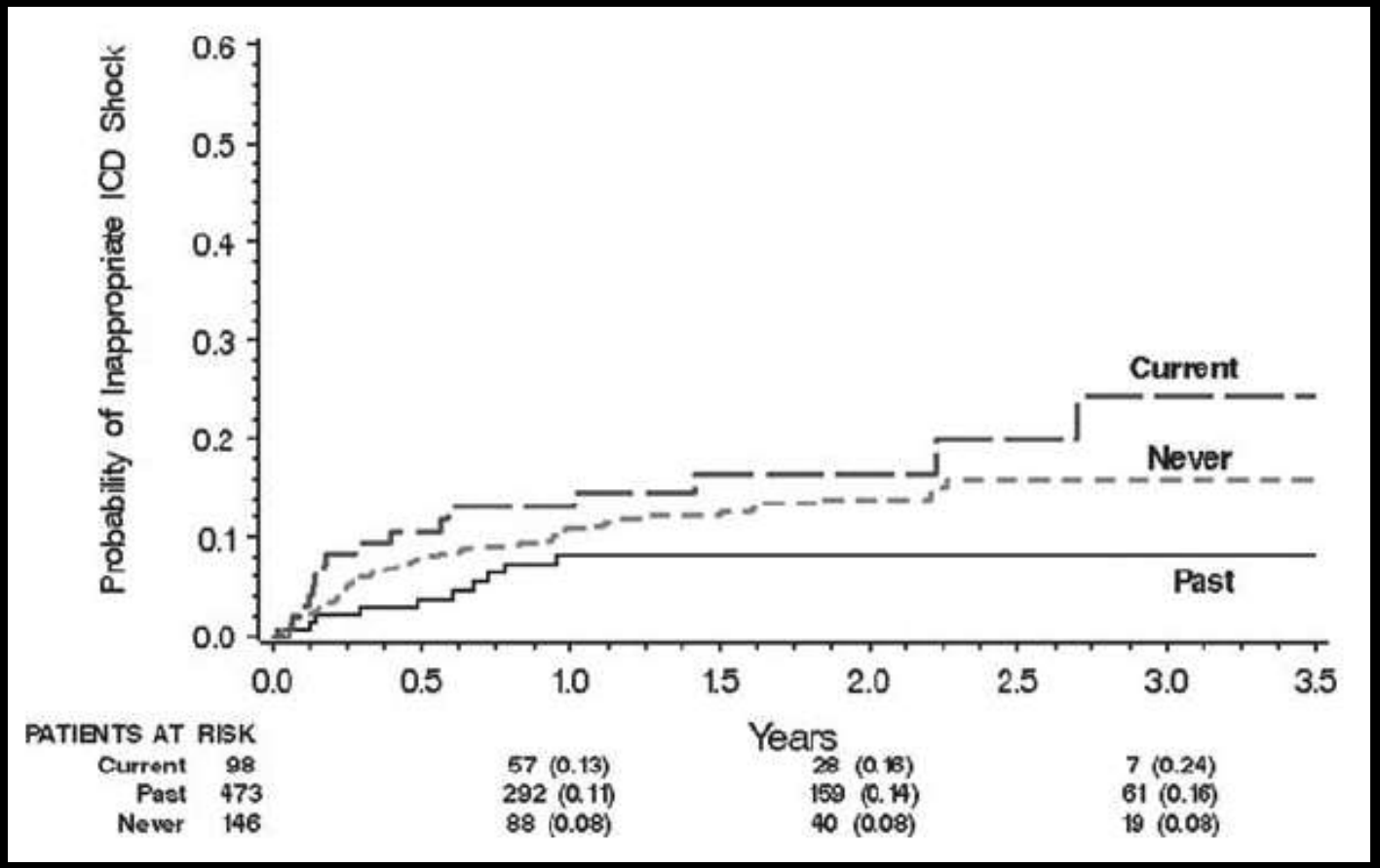
Summary

- Programme morphology **ON**
- Programme rate enhancements **ON**
- Implant dual chamber ?
- Programme NID long
- Programme ATP **ON**
- Programme ATP during charge **ON**

- **DRUGS**
- **ABLATE**

- **Treat hypertension, lipids, ischaemia, SMOKING**

Smoking: MADIT II Substudy



- STOP SMOKING

J Cardiovasc Electrophysiol, 2006 17 :931-936

Finally

On those days, the highest average incidence of events was observed during the first 2 hours after the beginning of each match. A subanalysis of serious events during that period, as compared with the control period, showed an increase in the incidence of myocardial infarction with ST-segment elevation by a factor of 2.49 (95% CI, 1.47 to 4.23), of myocardial infarction without ST-segment elevation or unstable angina by a factor of 2.61 (95% CI, 2.22 to 3.08), and of cardiac arrhythmia causing major symptoms by a factor of 3.07 (95% CI, 2.32 to 4.06) ($P<0.001$ for all comparisons).

CONCLUSIONS

Viewing a stressful soccer match more than doubles the risk of an acute cardiovascular event. In view of this excess risk, particularly in men with known coronary heart disease, preventive measures are urgently needed.


FIRST AID