HCM: Optimal ICD Programming

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Risk prediction model for SCD in HCM

- The cohort consisted of **3,675 consecutive patients** from six centres (UK, Spain, Greece, Italy).
- During a follow-up period of 24,313 patient-years (**median 5.7 years**), 198 patients (5%) died suddenly or had an appropriate implantable cardioverter defibrillator (ICD) shock.

Predictor variable	SCD group characteristics (n=198)	Hazard ratio	95% CI	*P*-value
Age (years)	42.5±15	0.988	0.979-0.997	0.007
Maximal wall thickness (mm)	21.5±6	1.048	1.025-1.071	<0.001
Fractional shortening (%)	41.0±10	0.992	0.977-1.008	0.344
LA diameter (mm)	46.2±9	1.035	1.018-1.052	<0.001
LV outflow gradient (mmHg)	18 (6-58)	1.005	1.001-1.008	0.005
Family history of SCD	73 (37%)	1.760	1.318-2.350	<0.001
Non-sustained VT	62 (31%)	2.533	1.849-3.469	<0.001
Unexplained syncope	52 (26%)	2.326	1.693-3.195	<0.001

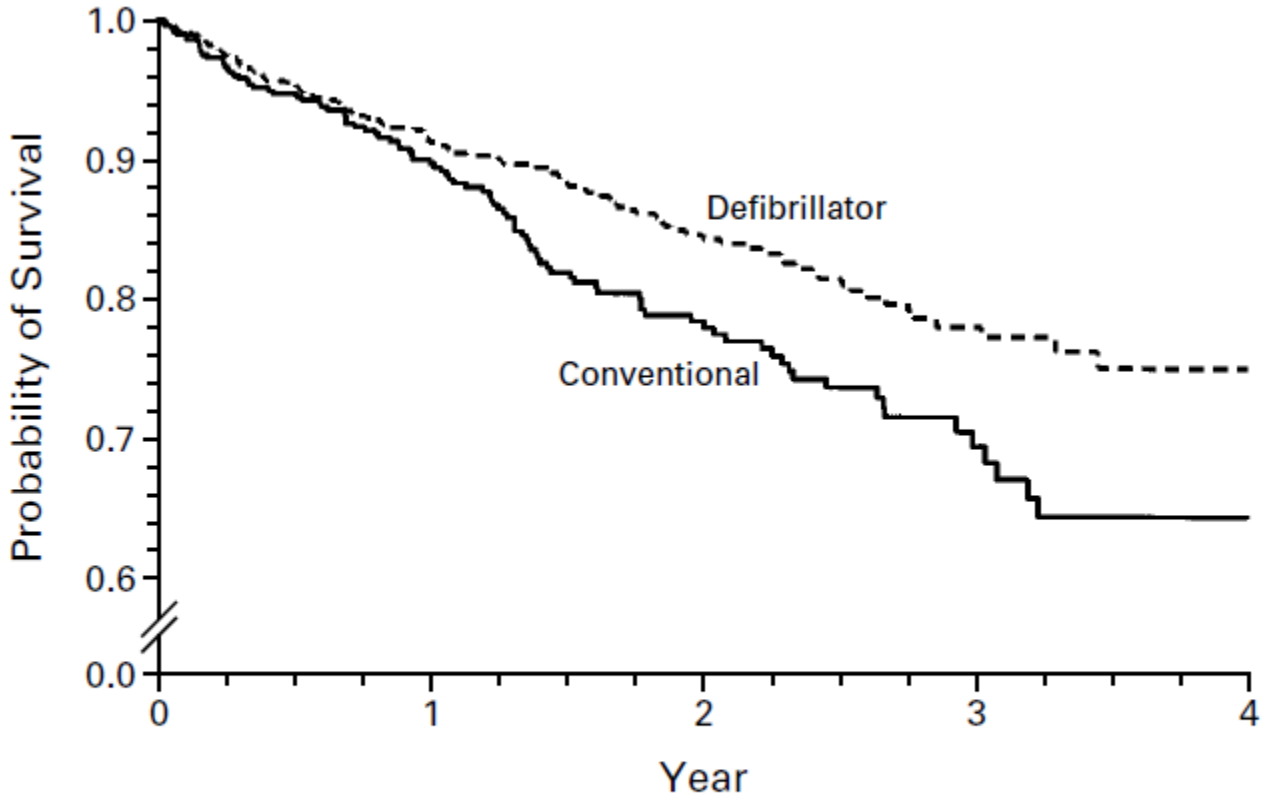
Eur Heart J. 2014;35:2010-20.

심율동전환제세동기(ICD) 거치술 인정기준

- **비후성 심근병증** 환자로서 아래의 ① ~ ⑤ 중 두 가지 이상에 해당되는 경우
  - ① 실신의 증상
  - ② 급사의 가족력
  - ③ 좌심실중격의 과도한 비후(>30mm)
  - ④ 24시간 활동 중 심전도에서 나타난 비지속성 심실빈맥
  - ⑤ 운동부하검사 상 이상 혈압증가 반응이 없는 경우 (충분한 운동부하에도 혈압상승이 < 20mmHg 인 경우)

Prophylactic implantation of a defibrillator in patients with MI and reduced EF

1232 patients with a prior MI (one month or more before entry) & a **LVEF <30%**



No. at Risk					
Defibrillator	742	503 (0.91)	274 (0.84)	110 (0.78)	9
Conventional	490	329 (0.90)	170 (0.78)	65 (0.69)	3

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MADIT-II. *N Engl J Med*. 2002;346:877-83.

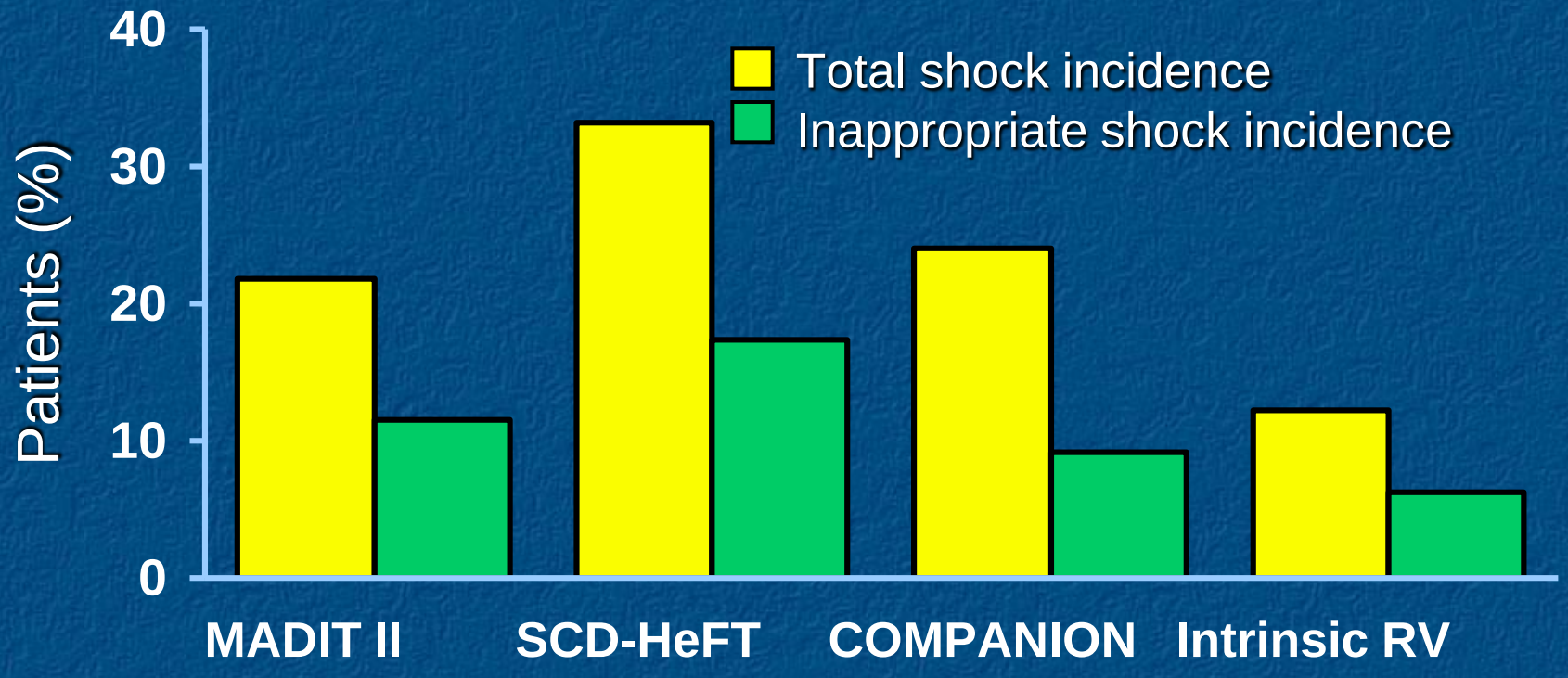
ICD Programmed Settings

- VF zone >200 bpm with 1 sec detection
- VT zone 170-200 bpm with 2.5 sec detection

- Is this optimal programming for a primary prevention ICD?

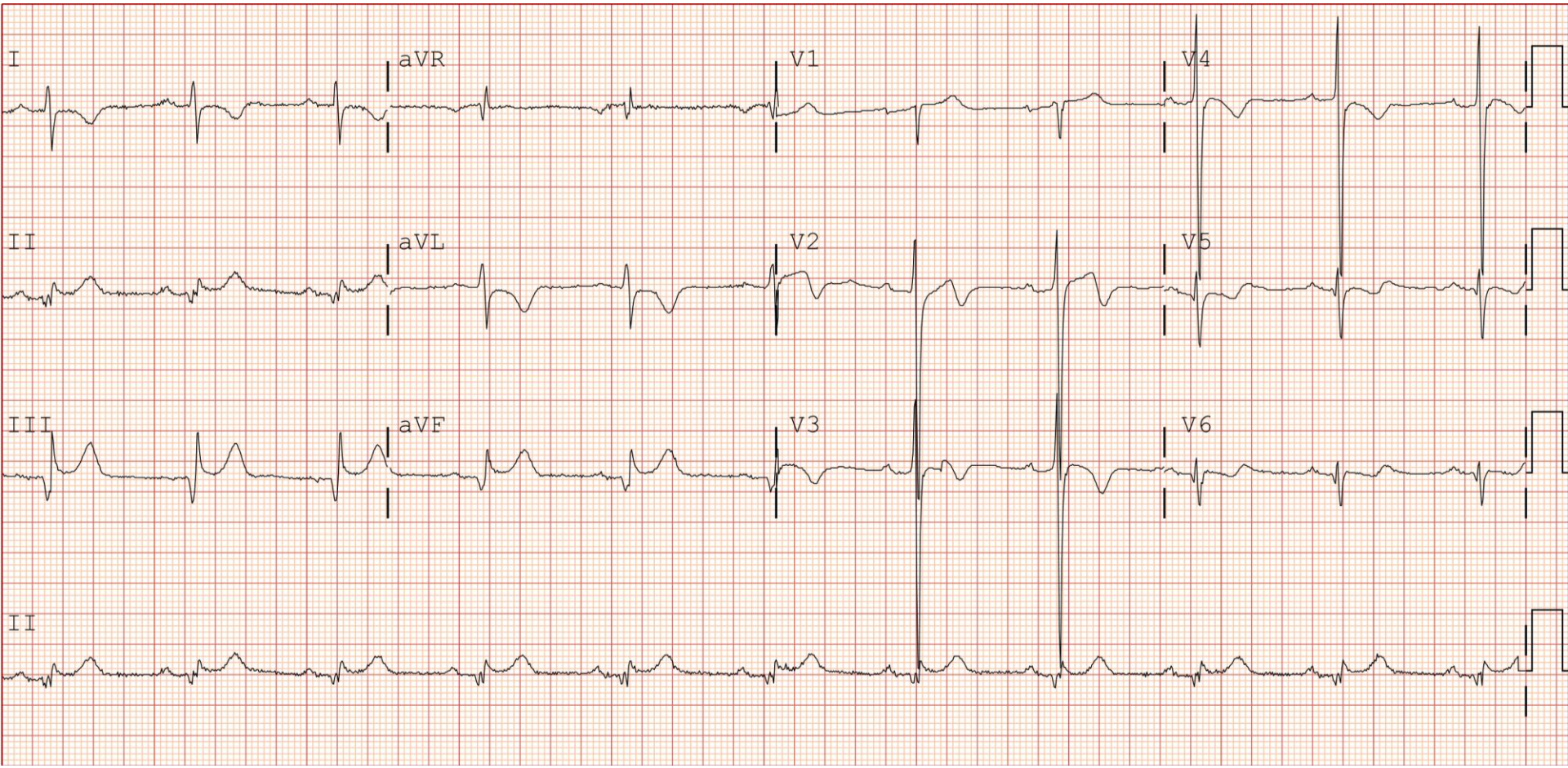
Incidence of ICD and CRT-D shocks in primary prevention trials

- **Up to 17% patients receive inappropriate shocks over 2-4 years**



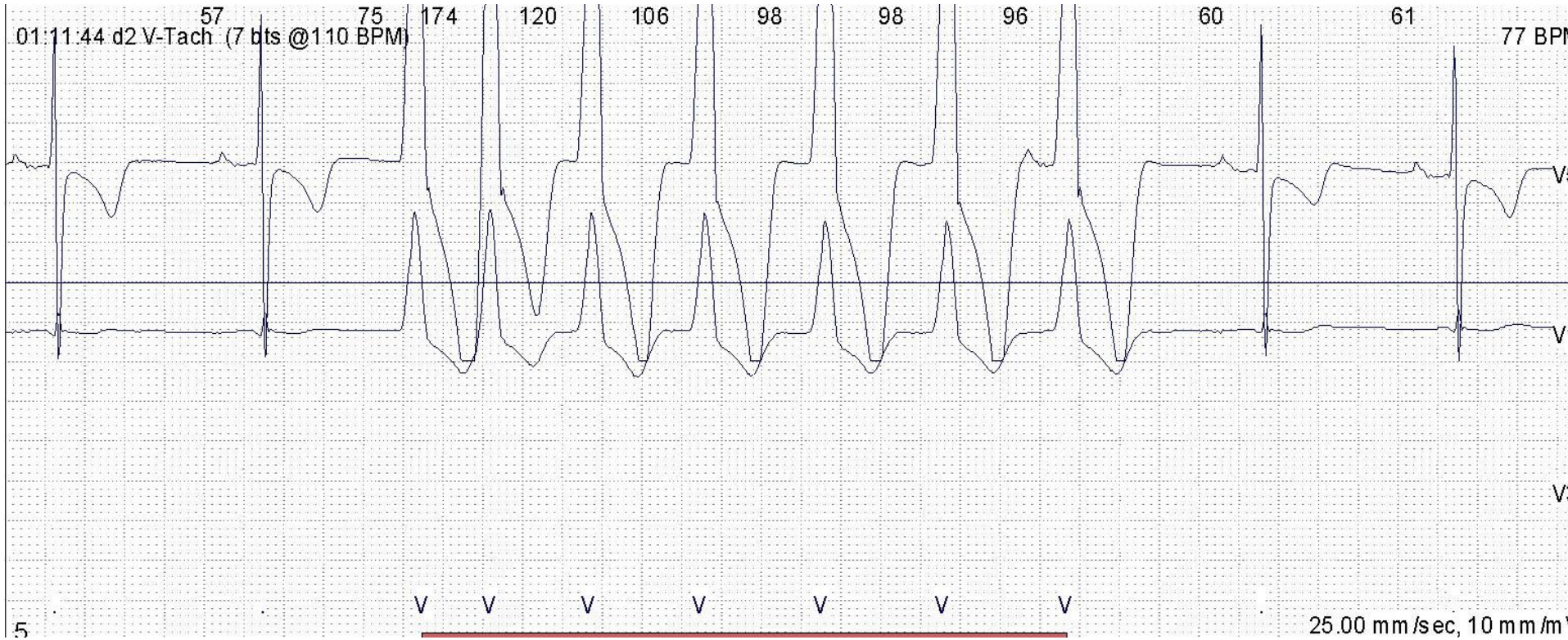
[1]Daubert JP et al: 51:1357, [2]Bardy GH et al: NEJM 352(3):225, 2005;
[3]Saxon et al: Circ 114:2766, 2006; *Data are for 1st shock only

M/38 Chest discomfort
Family history – Father died from sudden cardiac death at age 45.

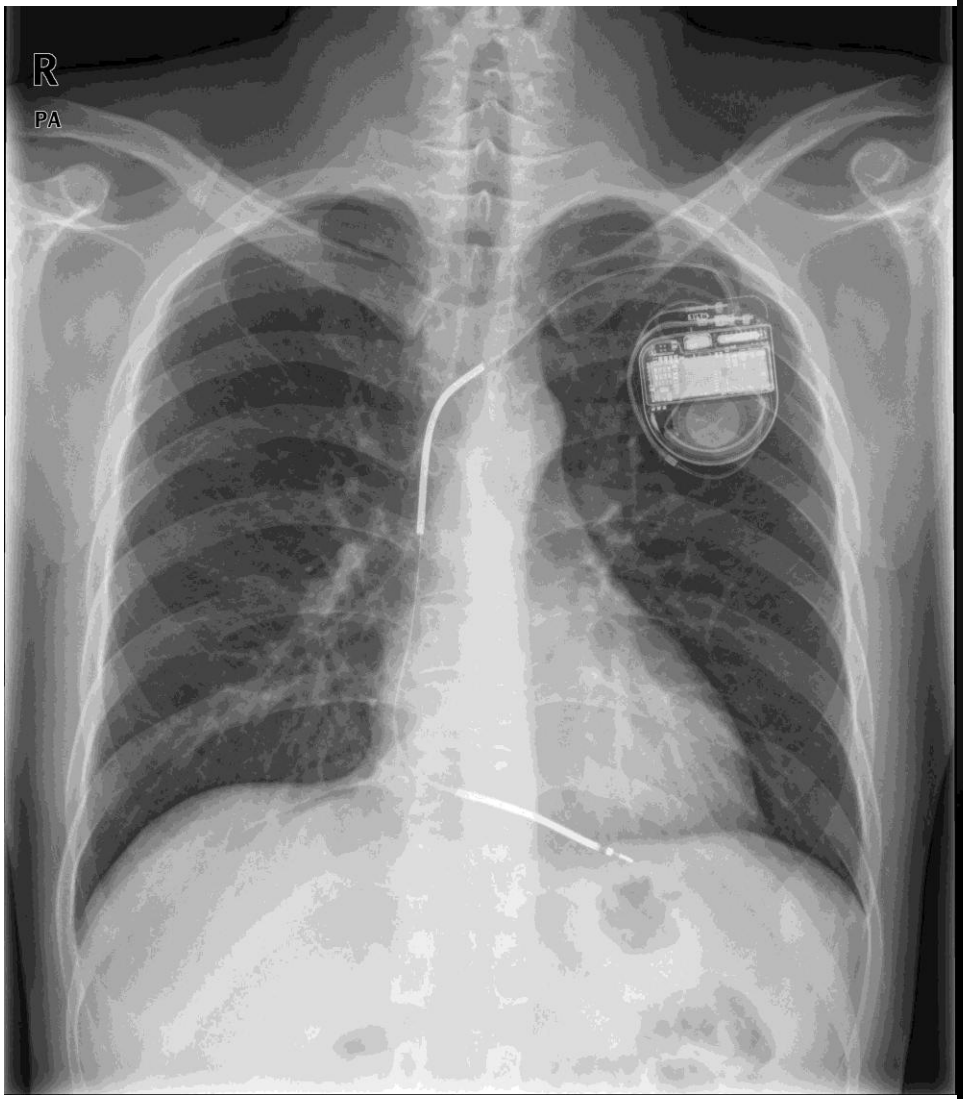


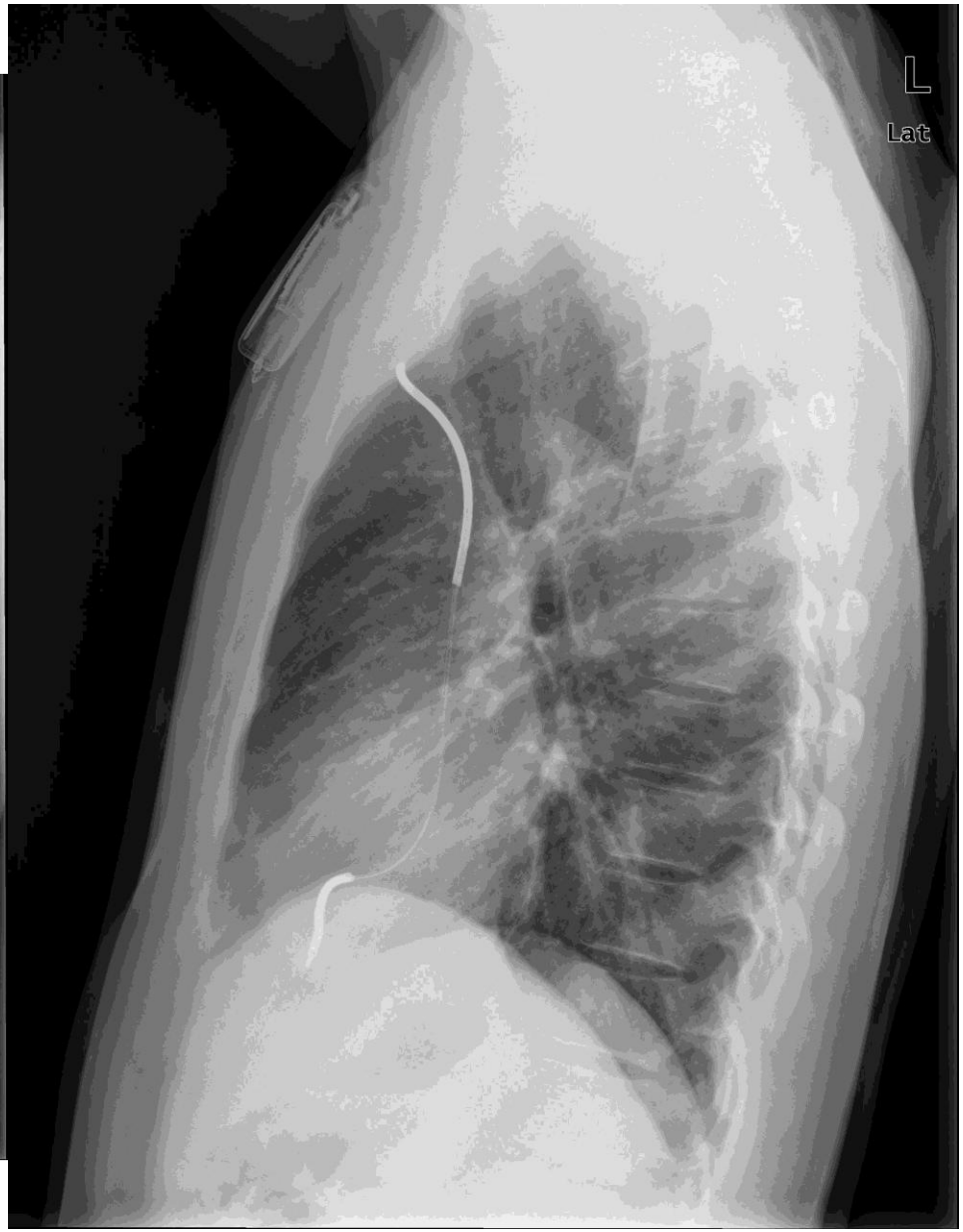
- Maximal wall thickness 20.9 mm
- LV mass index 143 g/m^2

Holter


57
75
174
120
106
98
98
96
60
61
01:11:44 d2 V-Tach (7 bts @110 BPM)
77 BPM
V
V
V
V
V
V
V
V
25.00 mm/sec, 10 mm/mV

ICD implantation





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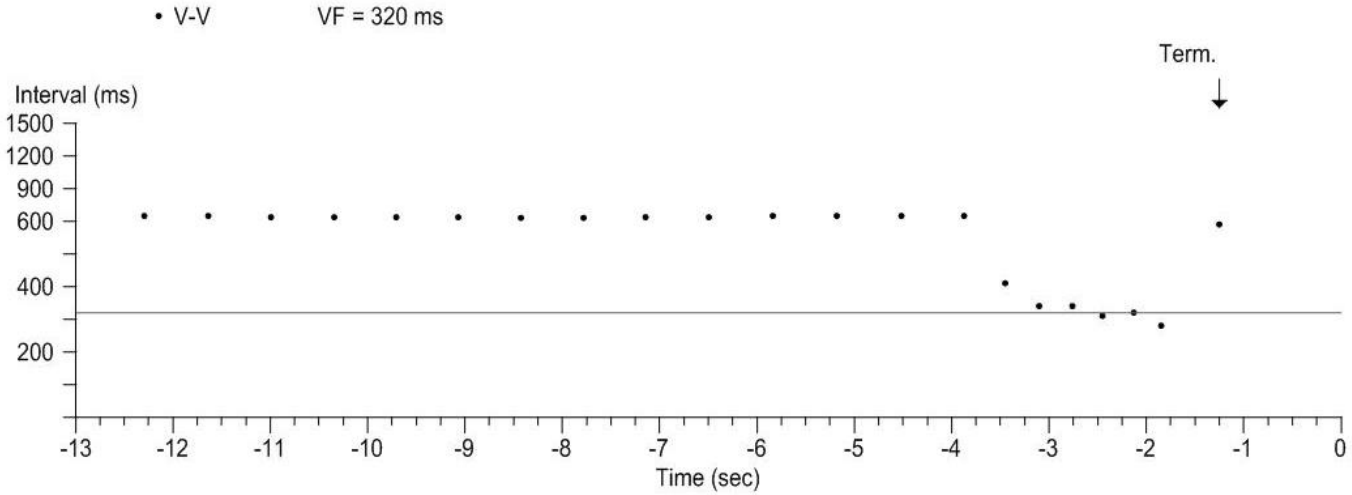
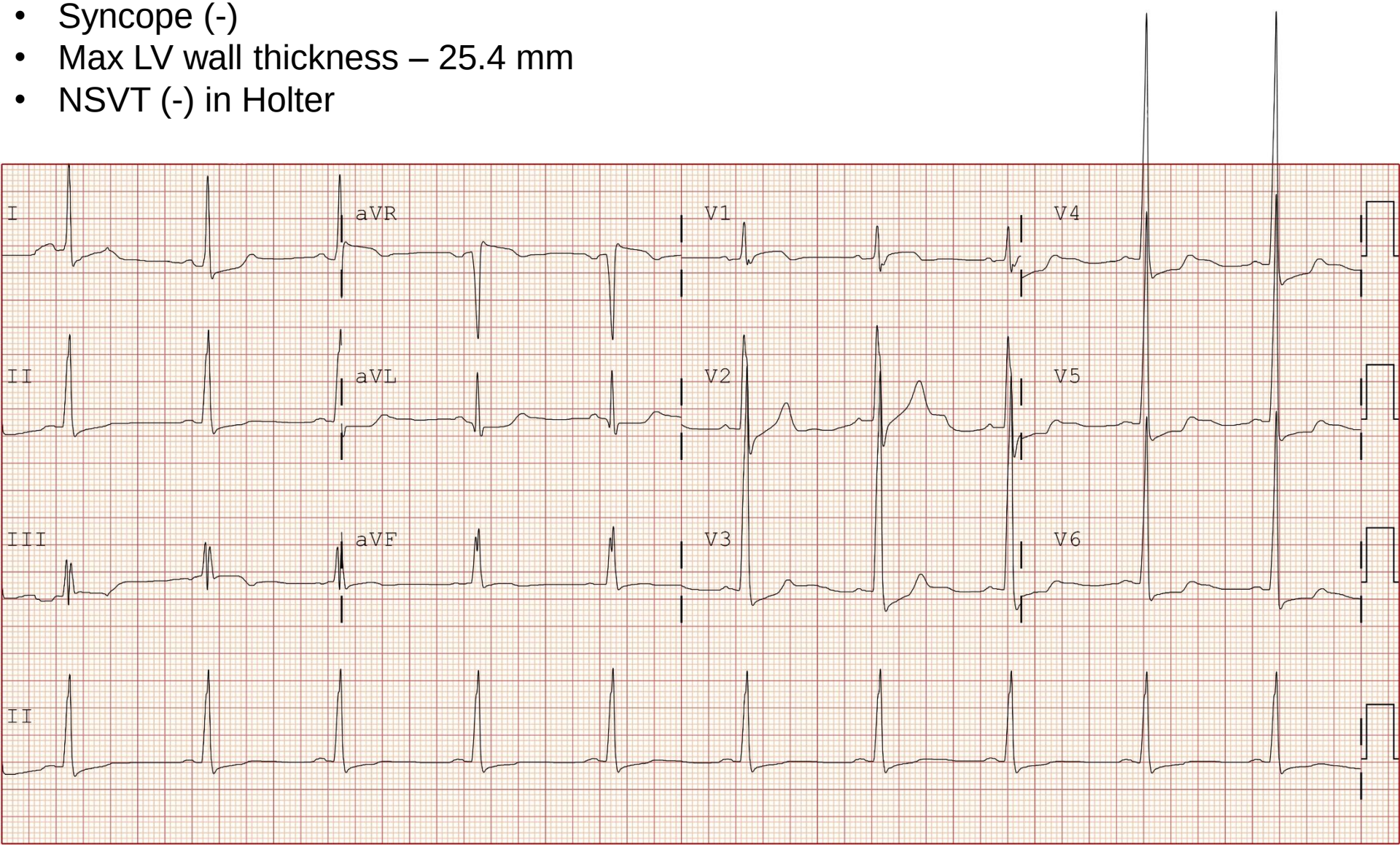
ICD analysis

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm V	Max bpm V	Activity at Onset
VT-NS				4	23-Feb-2011	21:20	<:01	214		Rest



F/29 Exertional discomfort

- Family history – SCD (mother's two brothers, 27, 41YO), Heart TPL (mother)
- Syncope (-)
- Max LV wall thickness – 25.4 mm
- NSVT (-) in Holter



- Maximal wall thickness 25.4 mm
- LV mass index 182.59 g/m^2

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Exercise ECG

1st TMT

Test Result Detail

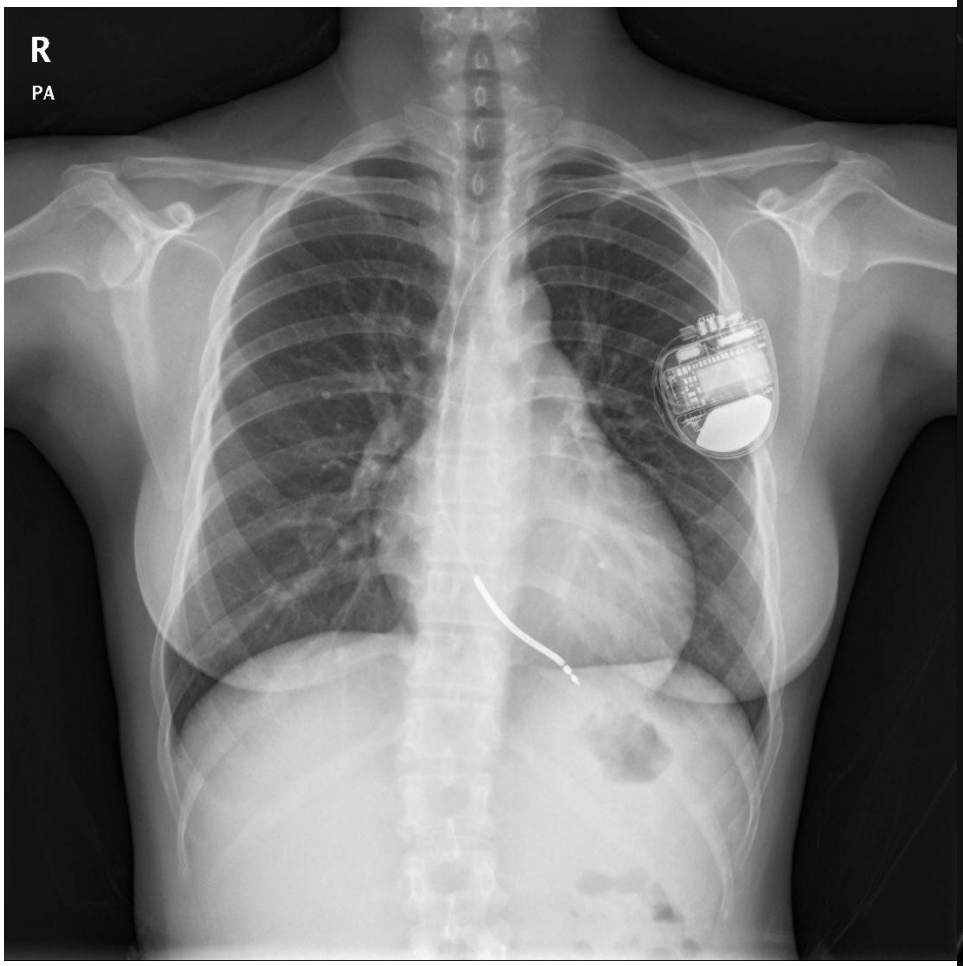
Stage	Stage Time	Exer. Time	Speed: (MPH)	Grade (%)	METS	HR	BP	RPP	ST Level III (mm)	Comments
Sitting	00:01		0.0	0.0	1.0	60			-1.1	
Stand	01:12		0.5	0.0	1.0	63	113/ 61	71	-0.7	
Stage 1	03:00	03:00	1.7	10.0	4.6	100	76/ 49	76	-1.2	116/54 no dizziness
Stage 2	03:00	06:00	2.5	12.0	7.0	118	124/ 54	146	-2.0	
Stage 3	03:00	09:00	3.4	14.0	10.2	139	131/53	206	-2.5	
Stage 4	01:00	10:00	4.2	16.0	11.8	152	148/51		-4.3	
Recov1	00:55	10:00	0.0	0.0	7.5	117	161/ 48	188	-1.8	
Recov3	01:55	10:00	0.0	0.0	1.0	70			-1.1	
Recov5	01:55	10:00	0.0	0.0	1.0	65	133/ 56	86	-1.3	
Recov7	01:55	10:00	0.0	0.0	1.0	68	124/ 60	84	-1.3	
Recovery	00:51	10:00	0.0	0.0	1.0	65			-1.2	
Recovery	01:55	10:00	0.0	0.0	1.0	66	122/ 64	81	-1.2	

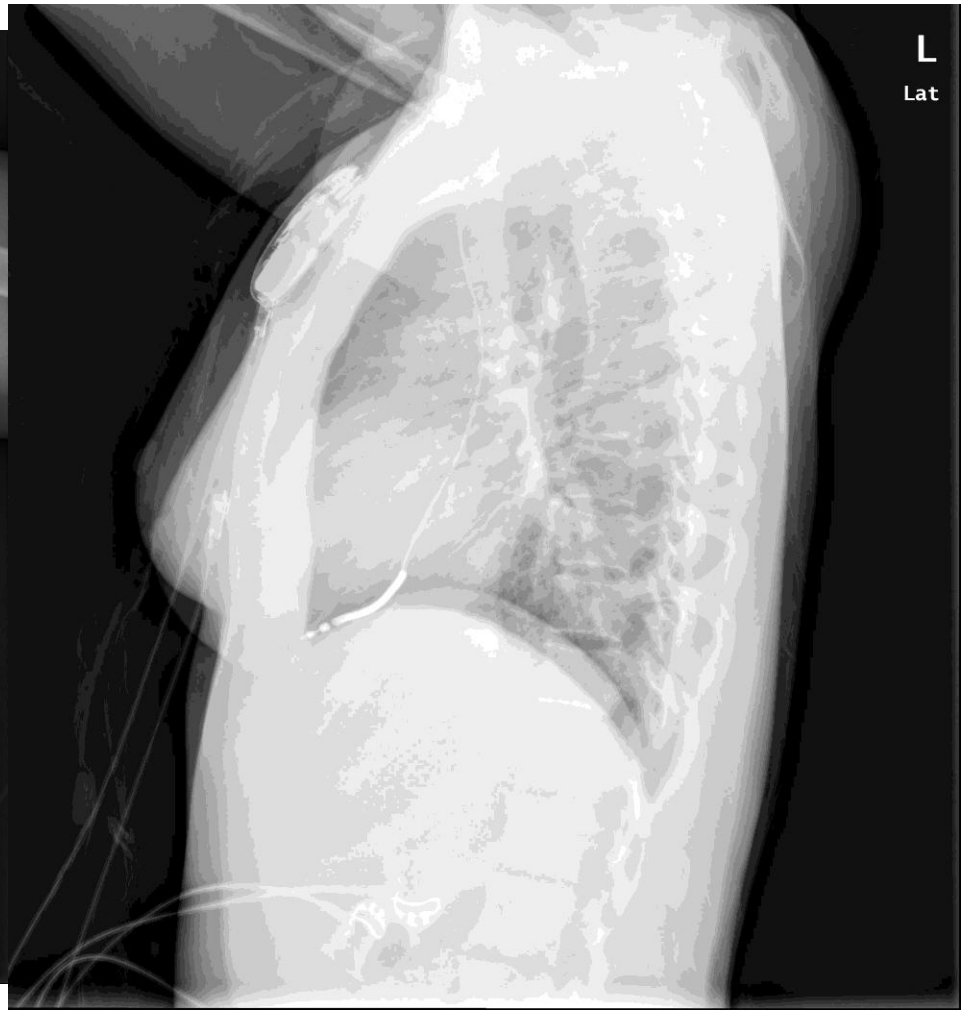
2nd TMT

Exercise Test Summary

Phase Name	Stage Name	Time in Stage	Speed (mph)	Grade (%)	HR (bpm)	BP (mmHg)	Comment
PRETEST	SUPINE	00:02	0.00	0.00	67		
	STANDING	00:57	0.60	0.00	62	115/59	
EXERCISE	STAGE 1	03:00	1.70	10.00	105	116/58	
	STAGE 2	03:00	2.50	12.00	126	148/60	
	STAGE 3	03:00	3.40	14.00	144	181/59	
	STAGE 4	00:46	4.20	16.00	153	124/63	
RECOVERY	recovery	01:00	0.00	0.00	112	160/63	
		02:00	0.00	0.00	68	150/57	
		02:00	0.00	0.00	66	124/71	
		00:20	0.00	0.00	64		

ICD implantation

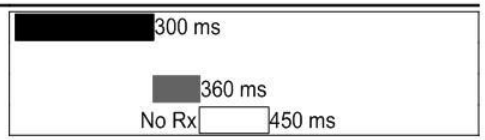




ICD setting

VT/VF Detection

		V. Interval (Rate)	Initial	Redetect
VF	On	300 ms (200 bpm)	30/40	12/16
FVT	OFF			
VT	On	360 ms (167 bpm)	24	12
Monitor	Monitor	450 ms (133 bpm)	32	



Wavelet		Other Enhancements		Sensitivity
Wavelet	On	Stability	Off	RV 0.30 mV
Template	17-Dec-2014	Onset	Off	
Match Threshold	70 %	High Rate Timeout		
Auto Collection	On	VF Zone Only	0.75 min	
SVT V. Limit	260 ms	All Zones	Off	
		TWave	On	
		RV Lead Noise	On+Timeout	
		Timeout	0.75 min	

VF Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
VF Therapy Status	On	On	On	On	On	On
Energy	35 J	35 J	35 J	35 J	35 J	35 J
Pathway	B>AX	B>AX	B>AX	AX>B	B>AX	AX>B

ATP During Charging
Deliver ATP if last 8 R-R >= 240 ms,Burst, Pulses = 8, R-S1 = 88 %, Decrement = 10 ms
ChargeSaver = On(1 episodes), SmartMode = On

FVT Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
FVT Therapy Status	Off	Off	Off	Off	Off	Off

VT Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
VT Therapy Status	On	On	On	On	On	On
Therapy Type	Burst	CV	CV	CV	CV	CV
Energy		20 J	35 J	35 J	35 J	35 J
Pathway		B>AX	B>AX	B>AX	AX>B	AX>B
Initial # Pulses	8					
R-S1 Interval=(%RR)	88 %					
S1S2(Ramp+)=(%RR)						
S2SN(Ramp+)=(%RR)						
Interval Dec	10 ms					
# Sequences	3					
Smart Mode	Off					

Shared V. ATP	
V-V Minimum ATP Interval	200 ms
V. Amplitude	8 V
V. Pulse Width	1.5 ms
V. Pace Blanking	240 ms

Shared V. Therapies	
Active Can/SVC Coil	Can+SVC On
Progressive Episode Therapies	Off
Confirmation+	On

Shock episode developed 15 months after implantation

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm V	Max bpm V	Activity at Onset
VT-Mon				273	06-Mar-2016	14:20	:01:45	147	158	Active
VT-Mon				272	05-Mar-2016	12:31	:01:31	144	150	Active
VT-Mon				271	05-Mar-2016	12:28	:01:48	146	150	Active
VT-Mon				270	05-Mar-2016	12:21	:04:44	150	154	Active
VT-Mon				269	03-Mar-2016	18:50	:08:10	146	167	Active
VT-Mon				268	02-Mar-2016	12:22	:14:53	153	162	Active
VT-Mon				267	27-Feb-2016	09:39	:38	138	150	Active
VT-Mon				266	26-Feb-2016	09:04	:27	141	146	Active
VT-Mon				265	22-Feb-2016	20:06	:01:01	149	167	Active
VT	3	20J	Yes	264	22-Feb-2016	20:05	:42	176	176	Active
SVT-Wavelet				263	22-Feb-2016	20:05	:12	176	---	Active
VT-Mon				262	22-Feb-2016	18:49	:05:06	158	167	Active
VT-Mon				261	17-Feb-2016	18:55	:01:20	149	154	Active
VT-Mon				260	17-Feb-2016	18:51	:01:23	149	154	Active
VT-Mon				259	17-Feb-2016	18:48	:01:21	148	154	Active
VT-Mon				258	17-Feb-2016	18:45	:01:48	147	154	Active
VT-Mon				257	17-Feb-2016	18:38	:05:37	154	158	Active
SVT-Wavelet				248	12-Jan-2016	19:47	:01:16	171	171	Active
SVT-Wavelet				247	12-Jan-2016	19:45	:42	171	171	Active
SVT-Wavelet				246	12-Jan-2016	19:11	:48	171	171	Active
SVT-Wavelet				241	07-Jan-2016	19:42	:32	171	171	Active
VT	2		Yes	189	20-Oct-2015	12:32	:23	171	171	Active
SVT-Wavelet				115	17-Jul-2015	12:08	:41	176	176	Active

---------- Last Programmer Session 12-Jun-2015 ----------

(Data prior to last session has not been interrogated.)

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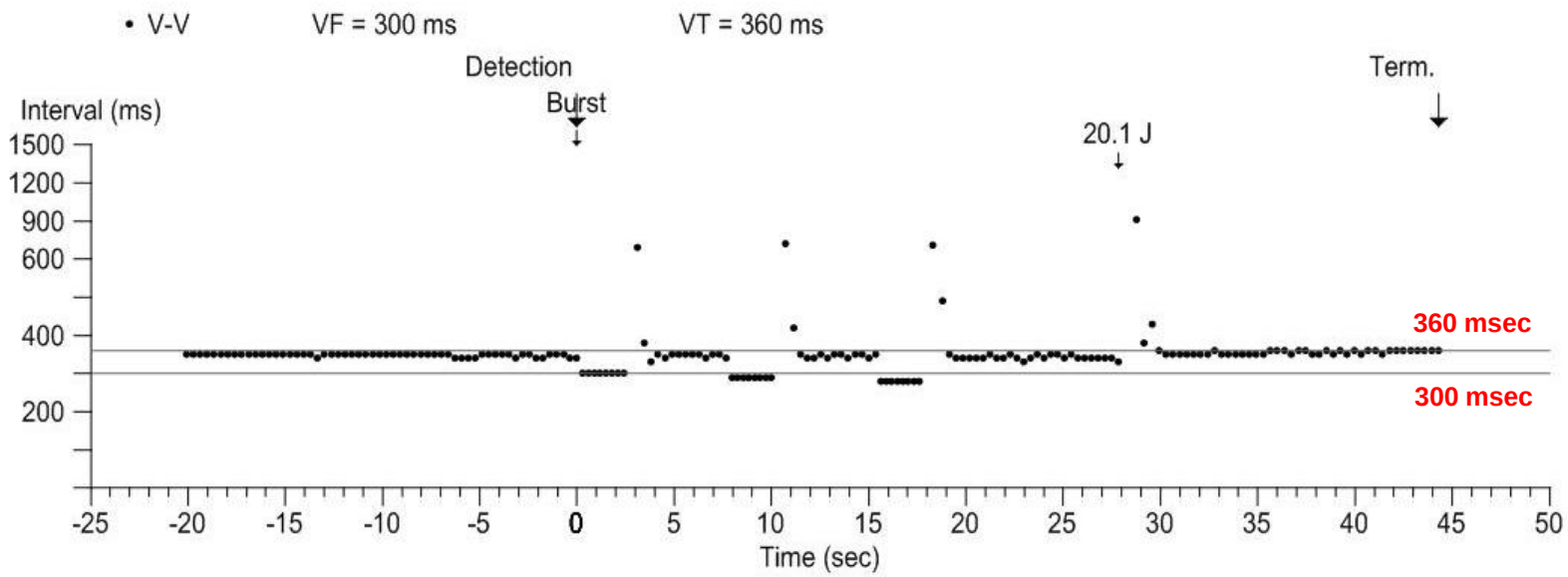
Shock episode

Detection		Rates	Therapies
VF	On	>200 bpm	ATP During Charging, 35J x 6
FVT	OFF		All Rx Off
VT	On	167-200 bpm	Burst(3), 20J, 35J x 4

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm V	Max bpm V	Activity at Onset
VT	3	20J	Yes	264	22-Feb-2016	20:05	:42	176	176	Active



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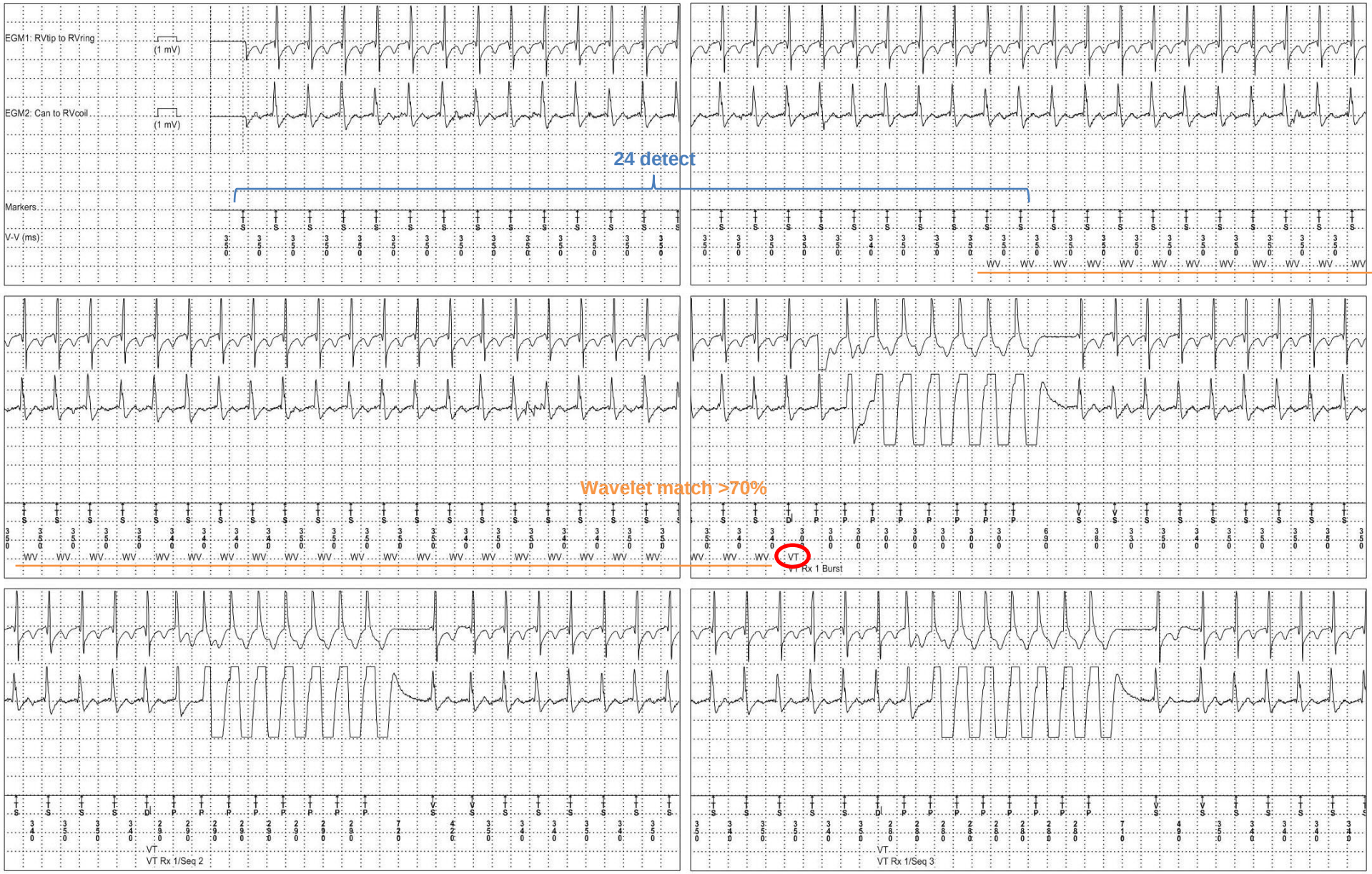

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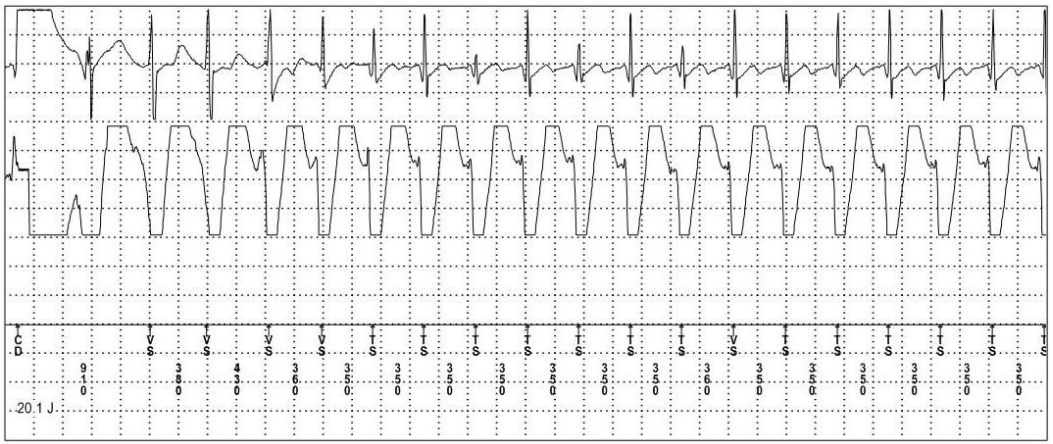

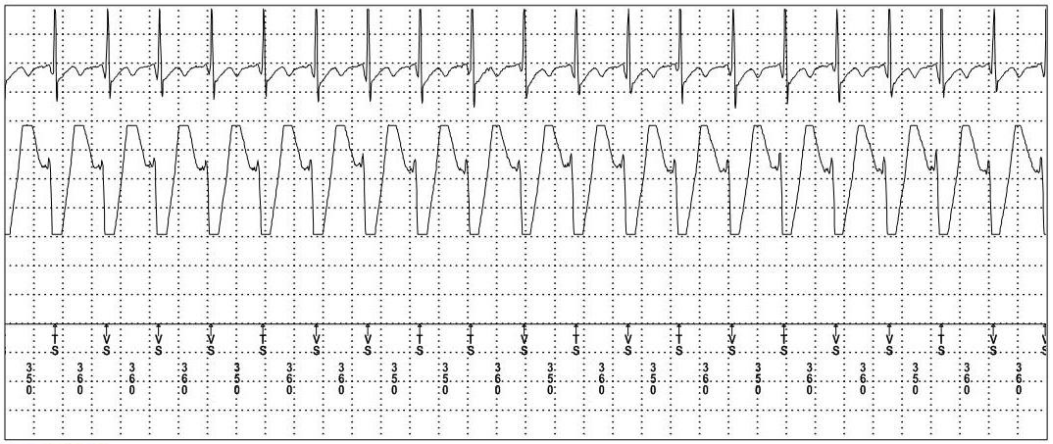

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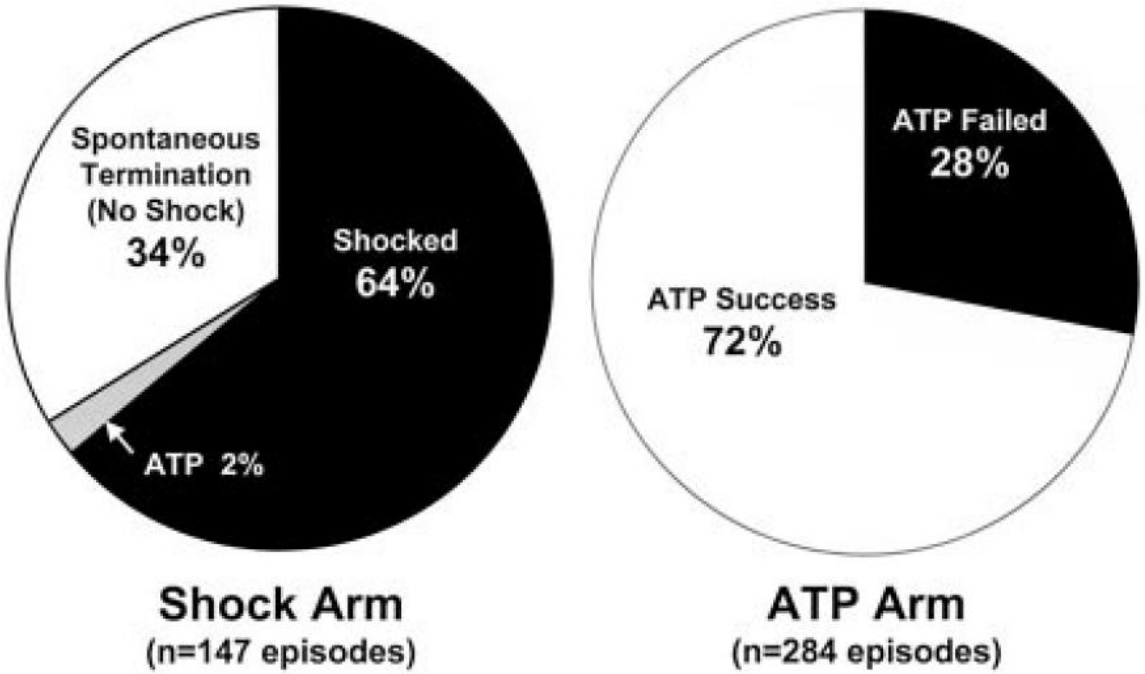
- What is optimal programming for a primary prevention ICD?

ATP Versus Shock for Rapid Ventricular Tachycardia

- We randomized 634 ICD patients to 2 arms—standardized empirical ATP (n=313) or shock (n=321)—for initial therapy of spontaneous FVT.
- ICDs were programmed to detect FVT when 18 of 24 intervals were 188 to 250 bpm and 0 of the last 8 intervals were >250 bpm. Initial FVT therapy was ATP (8 pulses, 88% of FVT cycle length) or shock at 10 J above the defibrillation threshold.



Shock termination of FVT episodes
- 67% in shock arm
- 17% in ATP arm

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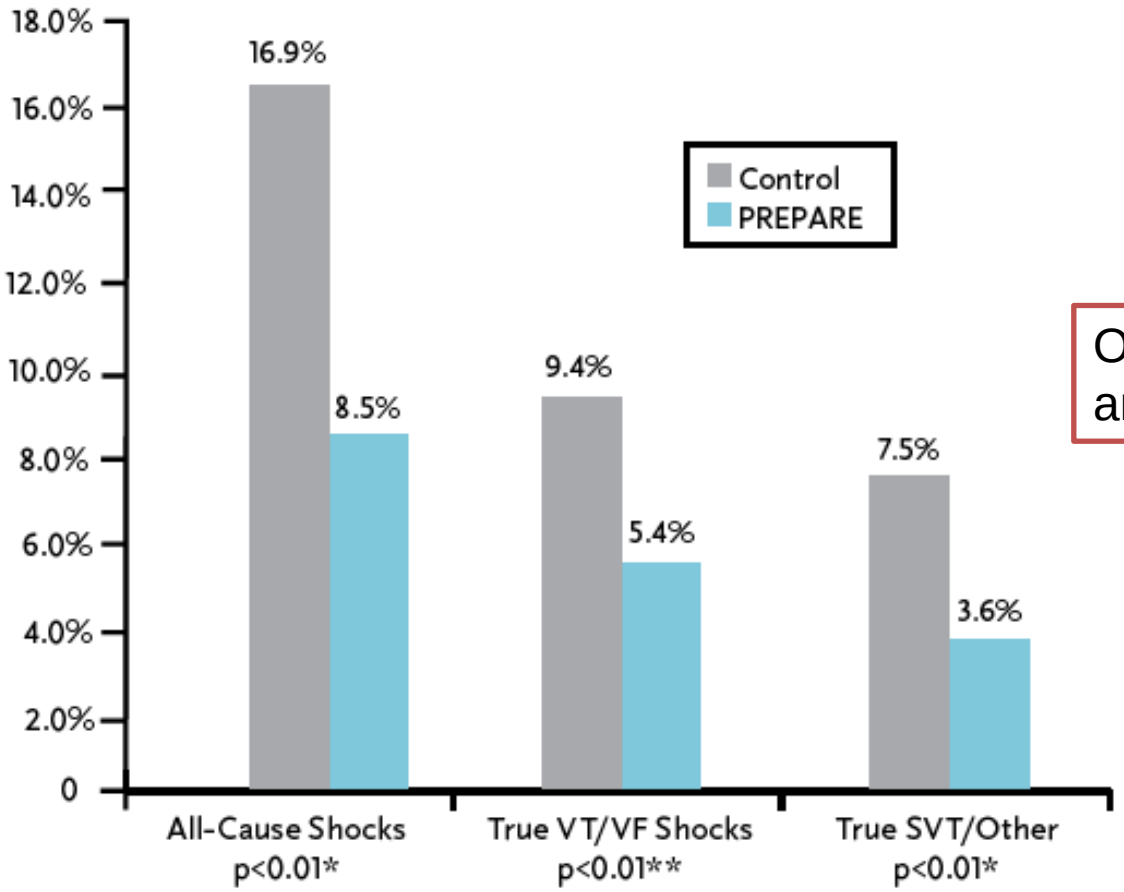
PainFREE Rx II. *Circulation*. 2004;110:2591-6.

The PREPARE Study Versus Physician-Tailored Programming of ICDs

- The PREPARE study was a prospective, cohort-controlled study that analyzed 700 patients with primary prevention indications for an ICD from 38 centers followed for 1 year.
- VT/VF was detected for rates ≥182 bpm that were maintained for at least 30 of 40 beats.
- **Antitachycardia pacing** was programmed as the first therapy for regular rhythms with rates of 182 to 250 beats/min, and supraventricular tachycardia discriminators were used for rhythms ≤200 bpm.1



Only 3.6% patients received an inappropriate shock

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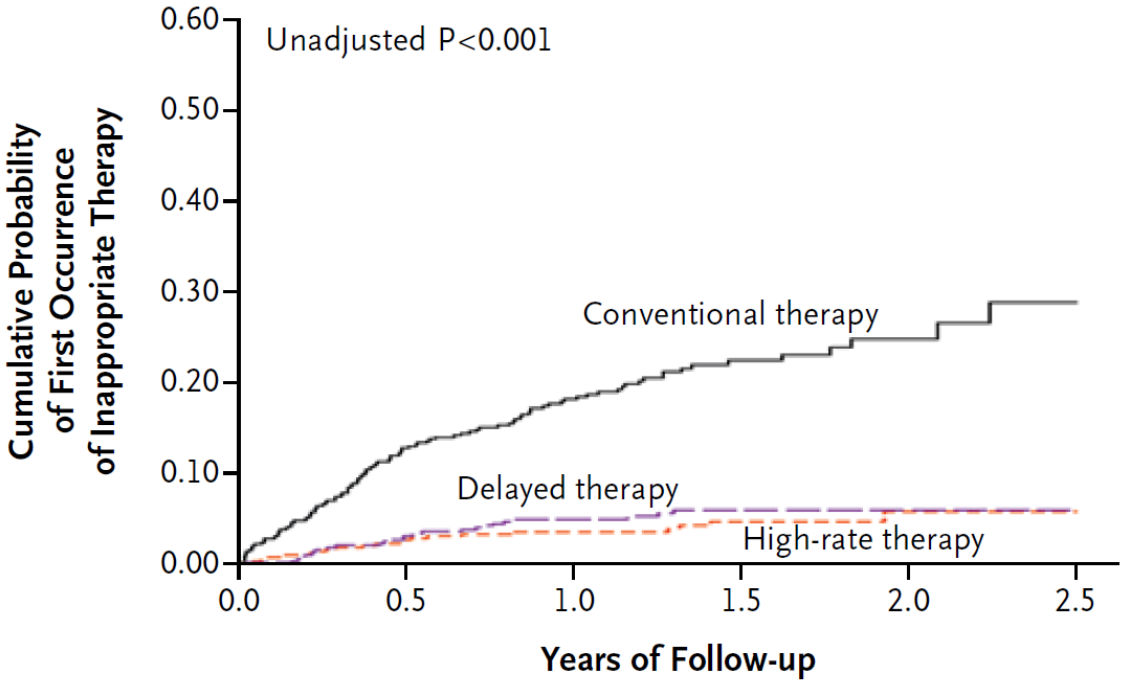
PREPARE. *J Am Coll Cardiol*. 2008;52:541-50.

Reduction in inappropriate therapy and mortality through ICD programming

- 1,500 patients had ischemic or nonischemic heart disease, were in sinus rhythm, and met approved guidelines for primary prevention with an ICD or CRT-D.
- 1:1:1 ration to **high-rate therapy** (with a **2.5-second delay** before the initiation of therapy at a HR of ≥200 bpm) or **delayed therapy** (with **a 60-second delay** at 170-199 bpm, a **12-second delay** at 200-249 bpm, and a **2.5-second delay** at ≥250 bpm), or **conventional programming** (with a **2.5-second delay** at 170-199 bpm and a **1.0-second delay** at ≥200 bpm).



No. at Risk						
Conventional therapy	514	420 (0.13)	305 (0.18)	149 (0.22)	56 (0.25)	8 (0.29)
High-rate therapy	500	454 (0.03)	339 (0.04)	191 (0.05)	70 (0.06)	17 (0.06)
Delayed therapy	486	445 (0.03)	342 (0.05)	177 (0.06)	82 (0.06)	13 (0.06)

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MADIT-RIT. *N Engl J Med*. 2012;367:2275-83.

Company-specific programme parameters to minimize shock risk in primary prevention

Manufacturer	Detection	Rate	Beats to detection duration	Enhancement	Therapy
Medtronic©	VT (monitor)	167 b.p.m.	32 intervals	AF/AFL on	Off
	FVT via VF	182 b.p.m.	**9.9 s**	ST (1 : 1 VT/ST = 66%) on wavelet (match = 70%) SVT Limit = 300 ms	Burst ×1, 30–35 J ×5
	VF	250 b.p.m.	**7.2 s**		30–35 J ×6
Boston Scientific©	VT-1 (monitor)	165 b.p.m.	9.0 s	Monitor only	Off
	VT	180 b.p.m.	**7.0 s**	Rhythm ID on	Burst ×1, 41 J ×6
	VF	200 b.p.m.	**7.0 s**	Not applicable	41 J shocks ×8[a]
St Jude©	VT-1 (monitor)	166 b.p.m.	30 intervals	–	Off (monitor)
	VT-2	181 b.p.m.	**9.9 s**	V < A if ALL[b] Morphology Internal stability V = A if ANY morphology SVT limit = 300 ms	ATP, 30 J, 40 J ×3
	VF	240 b.p.m.	**7.5 s**		30 J, 40 J ×5[a]
Biotronik©	VT1	171 b.p.m.	32 intervals	SMART ON	off
	VT2	190	**9.5 s**	SMART ON	Burst ×2, 40 J ×8
	VF	240	9 of 13 intervals	Not applicable	40 J ×8

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Europace. 2014;16:227-34.

Applying to Clinical Practice: Primary Prevention ICDs

- Don’t detect “slow” tachycardias (< 180 bpm)
  - Generally not life threatening
  - Increase risk of inappropriate shocks for sinus tachycardia or AF
- Don’t detect NON-SUSTAINED arrhythmias
  - They stop on their own
  - How long do you wait? 7-9 seconds
- Use ATP
  - Painless termination of arrhythmais
- Discriminate slower arrhythmias (<240 bpm)