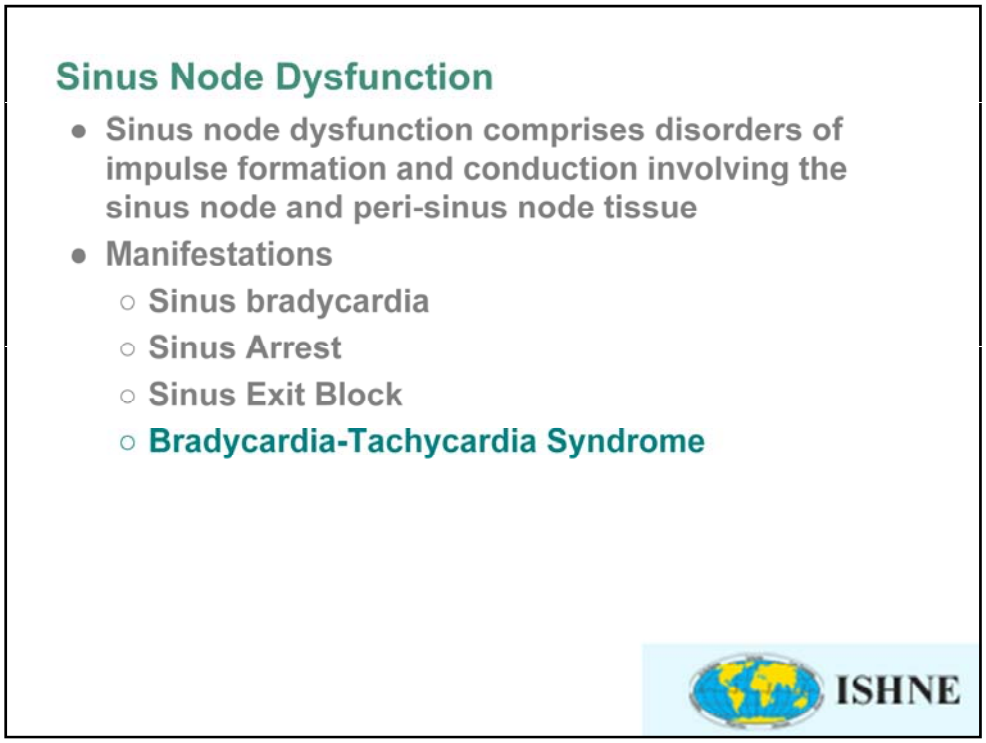
Today, I'd like to talk to you about…



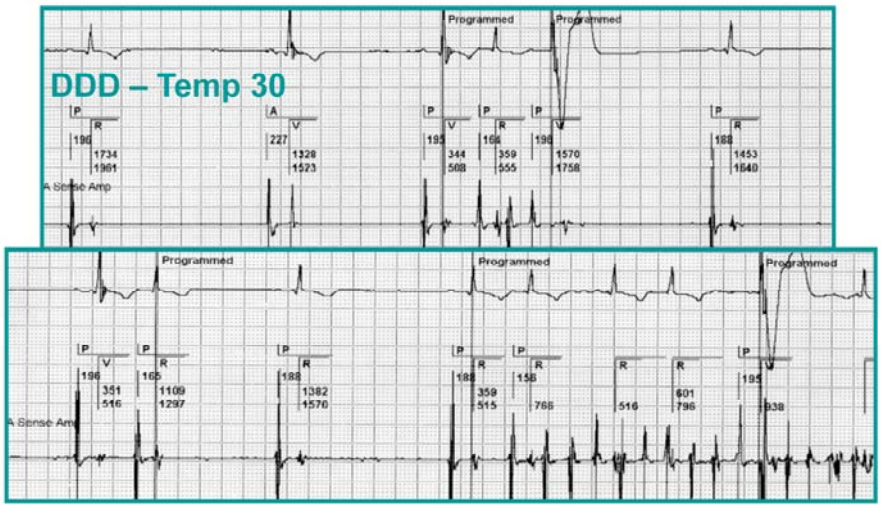
Sinus Node Dysfunction or sick sinus syndrome

A common manifestation of SND is paroxysmal atrial fibrillation alternating with marked symptomatic bradycardias. This is termed the Bradycardia-Tachycardia Syndrome. Atrial based pacing appears to be very effective in reducing or delaying the incidence of chronic atrial fibrillation in this subgroup of patients.

SND commonly involves more than disease of the sino-atrial node. It is usually a pan atrial and even a pan-conduction system disease with the sinus node abnormalities being the first manifestation.

This is the entity which generated all the excitement about the use of pacing in an effort to stabilize the atrial rhythm. The first studies, however, were retrospective and while exciting were marred by methodologic flaws.

Brady-Tachy Syndrome



Pause-dependent tachyarrhythmias

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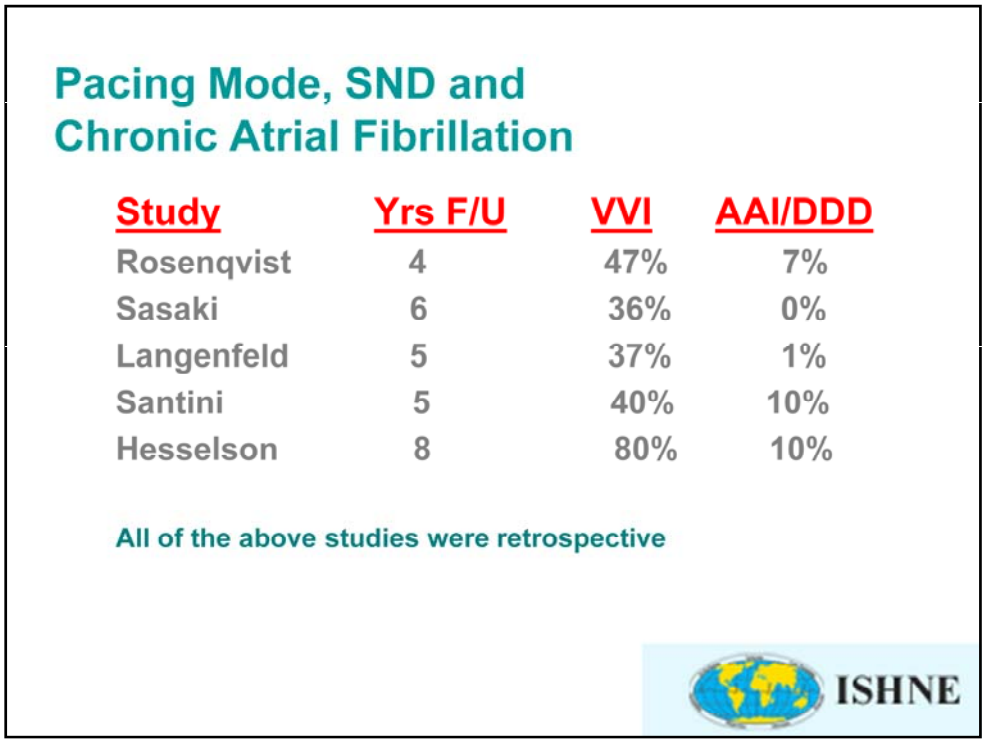


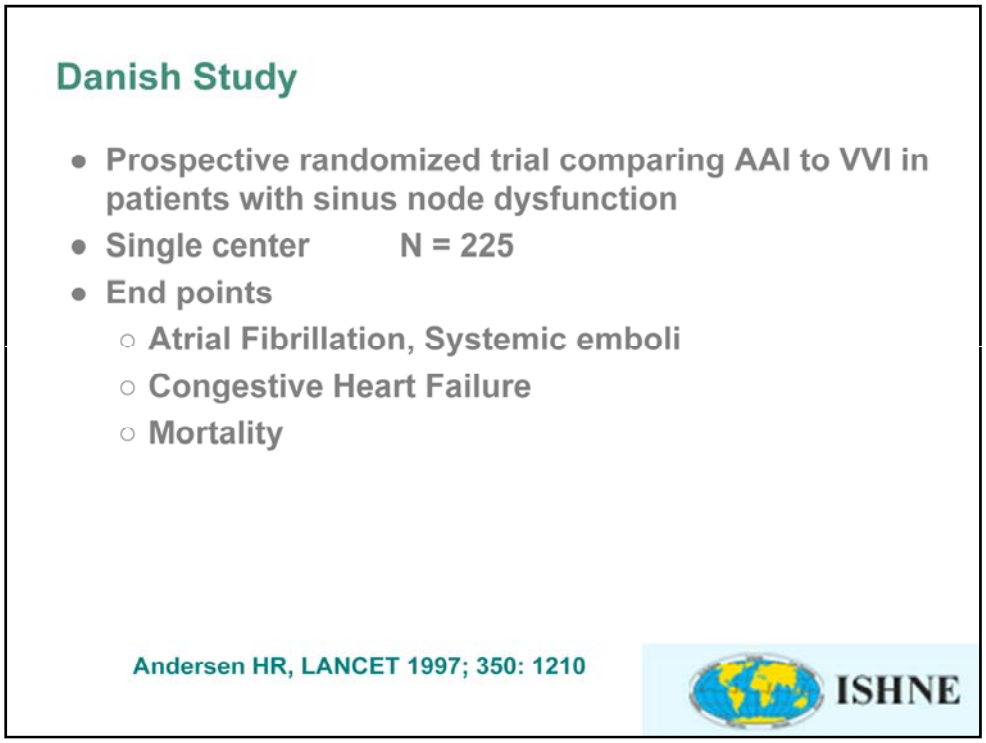
Pacing Mode, SND and Chronic Atrial Fibrillation

This slide is a summary of just 5 of the many published studies on this topic. The Rosenqvist study compared the results of AAI pacing to VVI pacing in similar patient groups but at two different hospitals. One hospital implanted only VVI devices. The other implanted both and there may have been a subtle bias in selecting the healthier patients for AAI.

Sasaki, Langenfeld and Santini presented single center studies but the analysis was performed retrospectively. There may have been significant differences between patient groups that impacted the results.

Hesselson (Dr. Parsonnet's group) reported their experience with over 8 years of follow-up. In the early years, they only used VVI while in the later years prior to the study conclusion, they were using a significant incidence of DDD devices. Pharmacologic therapies also changed in this time period.

Still, virtually every study reporting on virtually hundreds of patients came up with very similar results. The incidence of chronic atrial fibrillation was significantly higher in the group who were paced using the VVI mode as compared to the group paced either AAI or DDD (atrial based pacing).

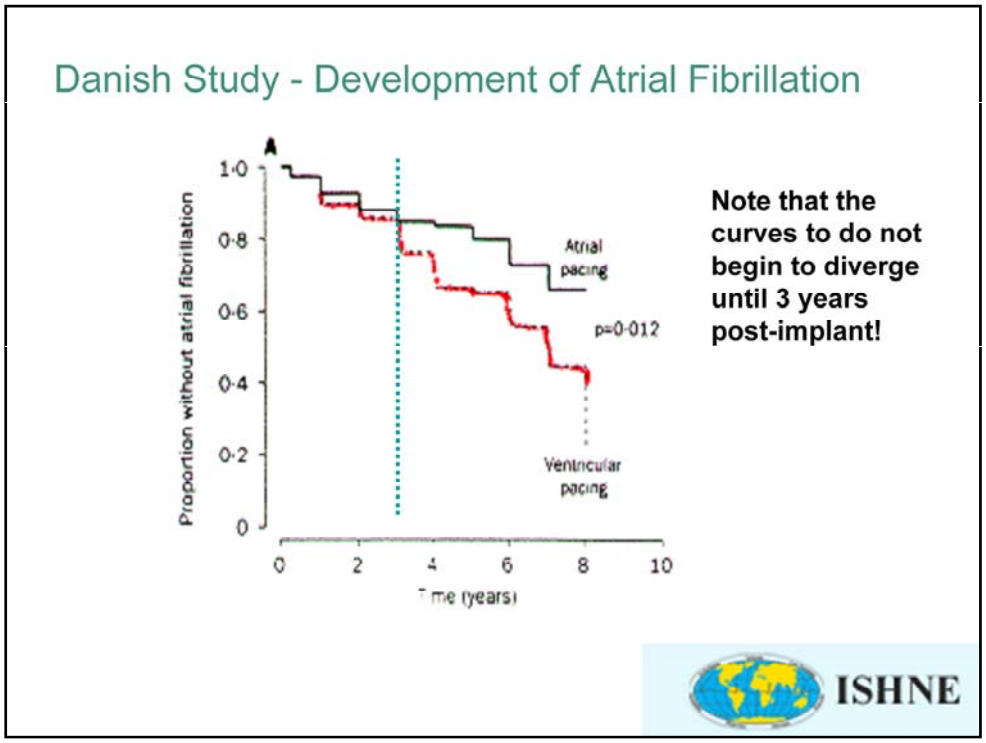


Danish Study - H.R. Andersen, et al

This is the first prospective randomized trial comparing AAI to VVI pacing for management of sinus node dysfunction. It was performed at a single center in Denmark. The end points were development of atrial fibrillation, systemic emboli, CHF and mortality. They did not specifically look at Quality of Life.

When the study was first presented after approximately 2 years of follow-up, the only significant marker was systemic emboli with a lower incidence with AAI pacing compared to VVI pacing All the other end points did not reach statistical significance although there was a trend favoring AAI over VVI pacing.

According to Dr. Andersen, the VVI group was programmed to a low rate so that the pacemaker was often inhibited. During this time, the intrinsic rhythm was sinus. It was only with time and progression of disease that pacing dominated at which point, a clear benefit of AAI over VVI pacing was demonstrated with respect to all endpoints.



Danish Study - Comparison of AAI vs VVI with respect to atrial fibrillation

This is the published graph. It should be noted that during the first few years, there was virtually no difference between the two groups. Whether or not this was due to the pacemaker being inhibited in the VVI mode due to a low programmed rate or the fact that it may take sufficient time to manifest the benefit of AAI or the adverse consequences of VVI pacing.

By eight years of follow-up, only 40% of the VVI group still had an intact atrial rhythm where as 70% of the AAI group were still in an organized atrial rhythm, sinus or atrial paced. This difference was significant at the p=0.012 level.

PAcing Mode Selection in the Elderly (PASE)

- Multicenter prospective randomized trial comparing VVIR to DDDR n = 409 pts
- Sinus node dysfunction n = 175 pts
- Base rate 50 ppm, F/U 550 days
- Primary end point - Quality of Life
- Secondary end points
  - Atrial fibrillation, CHF, mortality

Lamas GA, NEJM 1998; 338: 1097

PASE - Influence of pacing mode in patients with SND

- QOL was superior in DDD compared to VVI
- Trend towards reduction in atrial fibrillation in DDD over VVI but “ns”
- Limitations
  - Relatively short follow-up
  - Low base rate (50 ppm) - VVI mode often inhibited
  - 26% of VVI group crossed over to DDD due to pacemaker syndrome

Lamas GA, NEJM 1998; 338: 1097

Canadian Trial on Physiologic Pacing (CTOPP)

- Multicenter prospective randomized trial comparing VVIR and DDDR pacing
- n = 2568 patients
- Primary endpoints
  - Death and Stroke ns
- Secondary endpoints
  - Atrial fibrillation

Connolly SJ, New Engl J Med 2000; 342: 1385-1391

CTOPP - Influence of pacing mode on Atrial Fibrillation

- Entire group
  - DDD group 5.3% incidence
  - VVI group 6.6% incidence
    - Relative risk reduction 18%
    - p = 0.05
    - NO difference at 2 years
    - Progressive difference at 4 yrs
- Sinus node dysfunction
  - n = 800; no discernable difference

Connolly SJ, New Engl J Med 2000; 342: 1385-1391

CTOPP - Continuing Follow-up

- Factors favoring development of chronic atrial fibrillation
  - Age > 74 years
  - Sinus node dysfunction as pacing indication
- 4 year follow-up
  - 27.1% reduction in incidence of chronic atrial fibrillation in DDDR vs VVIR (p = 0.016)

Skanes AC, J Amer Coll Cardiol
2001; 38: 167-172

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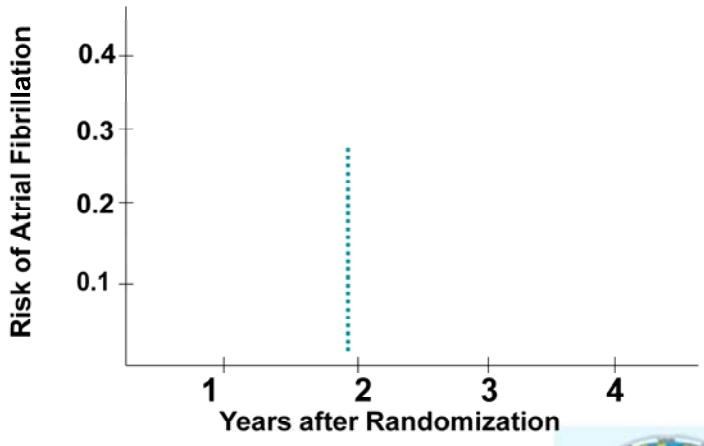
CTOPP - Risk of Atrial Fibrillation



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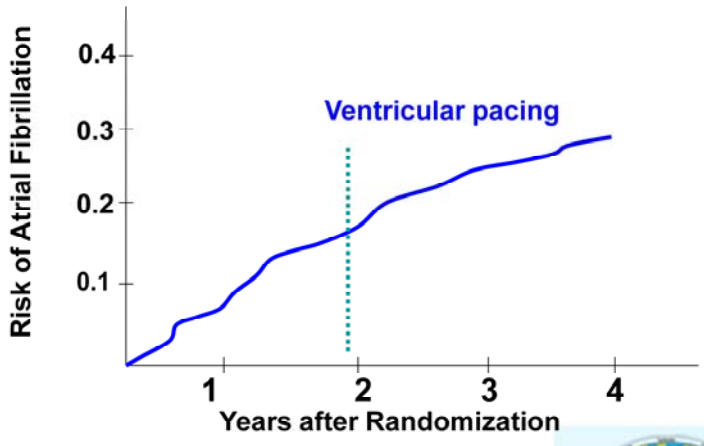
CTOPP - Risk of Atrial Fibrillation



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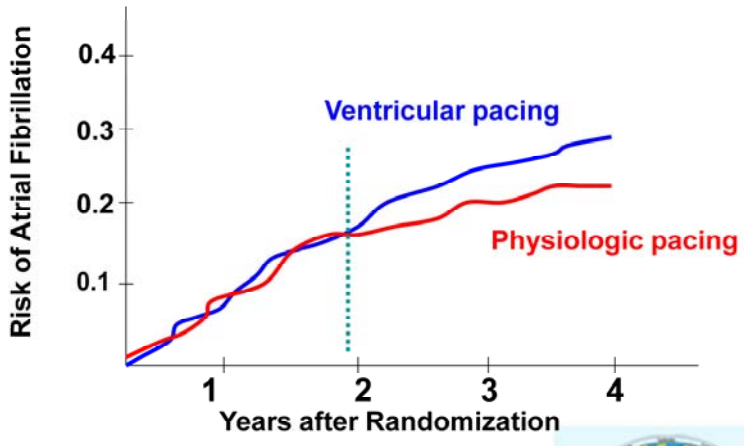
CTOPP - Risk of Atrial Fibrillation



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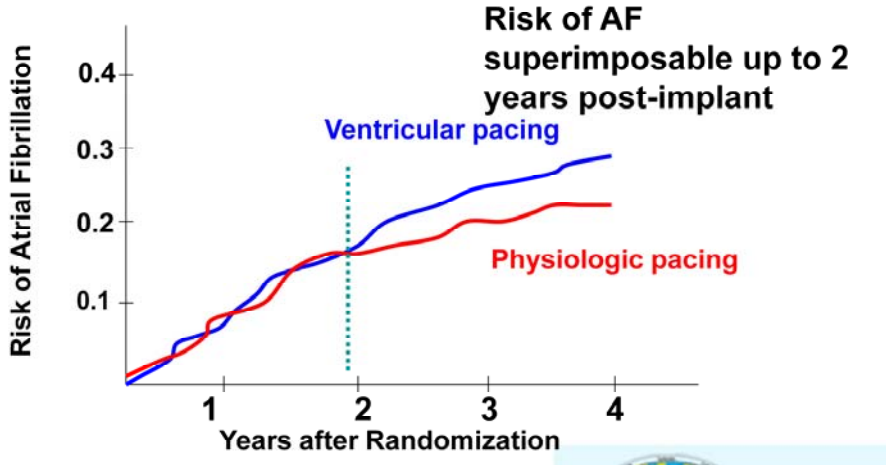
CTOPP - Risk of Atrial Fibrillation



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Pacing MOde Selection Trial (MOST)

- Prospective randomized trial of 2010 patients with sinus node dysfunction
- DDDR vs VVIR
- Primary endpoints: all cause mortality, non-fatal strokes
- Secondary endpoints: QOL, AFib, Pacemaker Syndrome
- AT (SVT or AF) in 53%, AAD in 18% (based on first 1000 patients)

MOST Results

- Mortality - ns
- Strokes - ns
- Health Related QOL $p < 0.001$
- Atrial fibrillation $p < 0.008$
- Hx of PAF $p < 0.001$
- Hospitalization for CHF $p < 0.01$

} in favor of DDDR over VVIR

Presented at NASPE 2001 - Late Breaking Clinical Trials

Summarized by Daubert C, Eur Heart J 2002; 23: 437-441

Sinus Node Dysfunction and Progression to Chronic A Fib

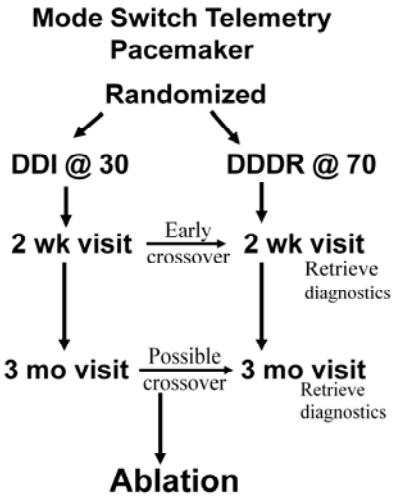
- Mode Selection Trial (MOST)
- 21% of patients with pre-implant PAF developed chronic atrial fibrillation
  - VVIR pacing: 26.7 %
  - DDDR pacing: 15.2%

  P = 0.001
- Time to development of chronic AF
  - VVIR pacing: 52 days
  - DDDR pacing: 124 days

Leon A, et al, PACE 2002; 25: 765 (abstract 714)

Atrial Pacing Peri-ablation for Prevention of Paroxysmal Atrial Fibrillation (PA^3)

- 97 patients with > 3 PAF episodes within past 1 year
- Intolerant or refractory to medical RX and hence, scheduled for AVN ablation
- **NO primary bradycardia indication for pacing**
- No pacing arm (DDI at 30 ppm)
- Used pacemaker diagnostics
- 2 week stabilization period
- 11 patients completed "no pacing" arm and crossed over to pacing



Gillis AM, Circ 1999; 99: 2553

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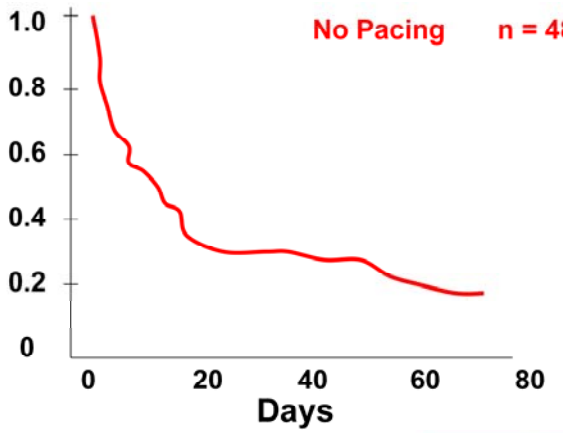
Atrial Pacing Peri-ablation for Prevention of Paroxysmal Atrial Fibrillation (PA^3)

Event Free Survival to First Recurrence of PAF



Gillis, AM Circ 1999; 99: 2553

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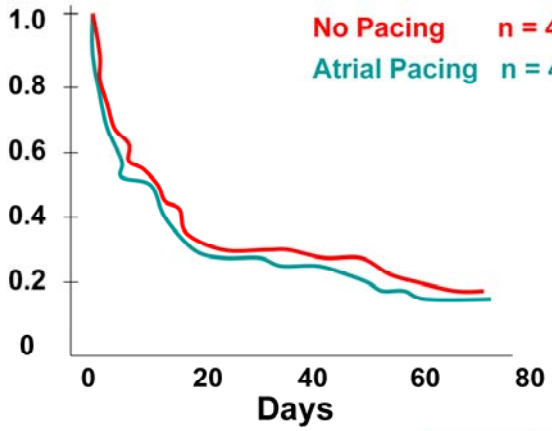

Gillis, AM Circ 1999; 99: 2553

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Atrial Pacing Peri-ablation for Prevention of Paroxysmal Atrial Fibrillation (PA^3)

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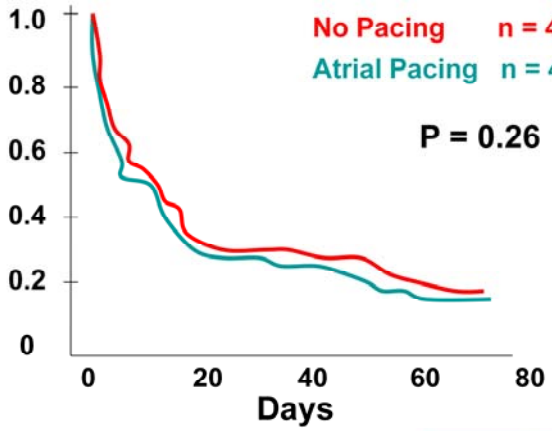

Gillis, AM Circ 1999; 99: 2553

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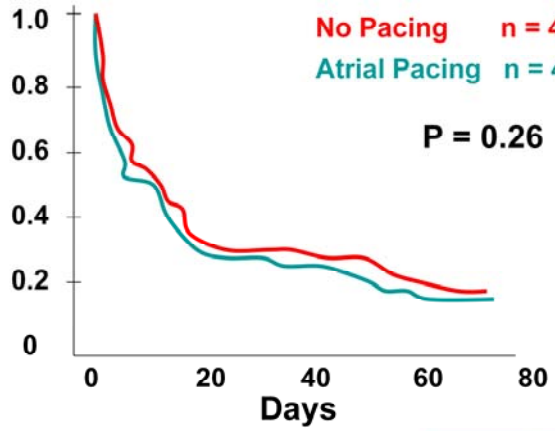
Atrial Pacing Peri-ablation for Prevention of Paroxysmal Atrial Fibrillation (PA^3)

Event Free Survival to First Recurrence of PAF

DDD vs no pacing does NOT increase the time to recurrence of PAF



No Pacing n = 48

Atrial Pacing n = 49

P = 0.26

Gillis, AM Circ 1999; 99: 2553

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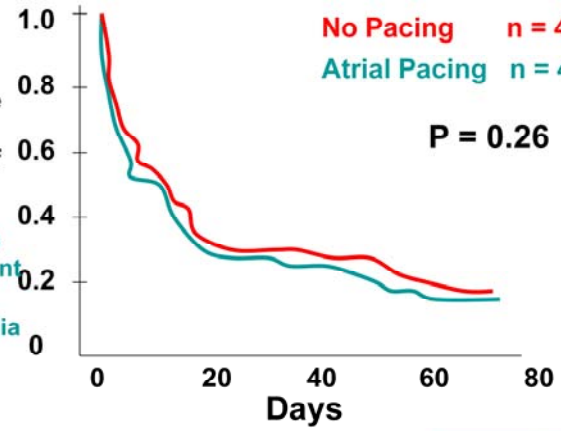
Atrial Pacing Peri-ablation for Prevention of Paroxysmal Atrial Fibrillation (PA^3)

Event Free Survival to First Recurrence of PAF

DDD vs no pacing does NOT increase the time to recurrence of PAF

WHEN there is not a concomitant symptomatic sinus bradycardia



No Pacing n = 48

Atrial Pacing n = 49

P = 0.26

Gillis, AM Circ 1999; 99: 2553

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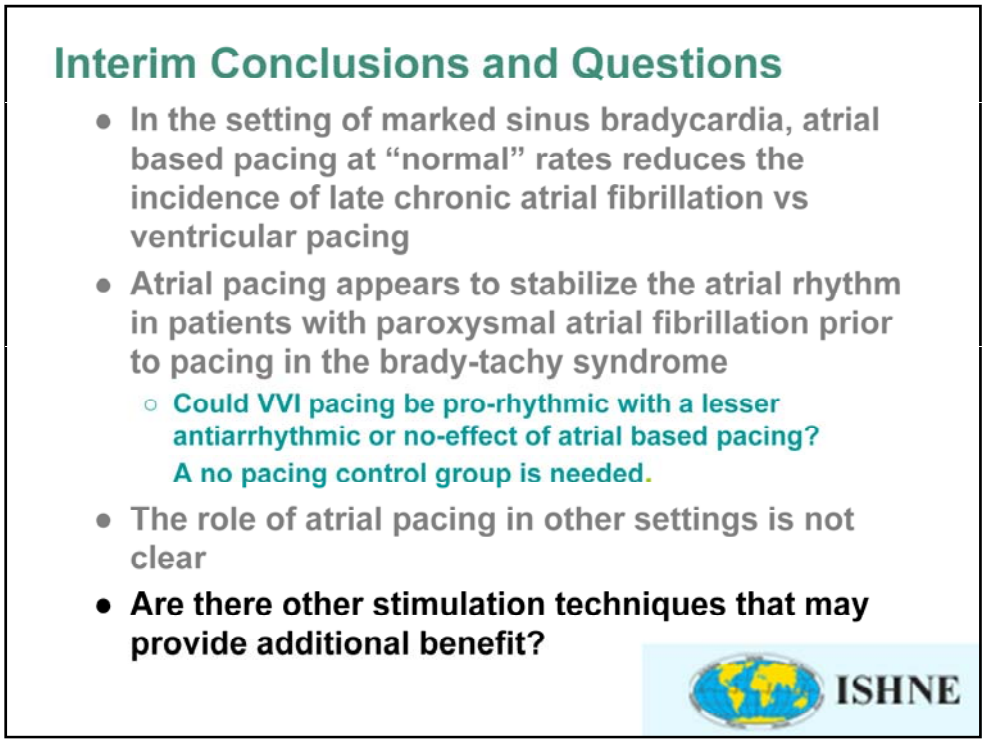
Comparison of DDDR vs VDD after AVN Ablation for Prevention of PAF

- 67 patients who participated in PA[3] and underwent AV junctional ablation
- Crossover at 6 months
- Time to first and second occurrences of PAF is the same between groups
- 35% in DDDR group and 32% in VDD group had permanent AF within 6 months
  - DDDR lower rate limit 70 ppm
  - VDD lower rate limit 60 ppm
- 43% had permanent AF at 1 year

Gillis AM, Circulation 2000; 102: 736-741

Traditional Atrial-Based Pacing to Prevent Paroxysmal Atrial Fibrillation

- The population with multi-drug resistant PAF **without** a concurrent bradycardia does not appear to benefit from standard atrial-based pacing
- Neither time to recurrence of PAF nor progression to chronic atrial fibrillation are impacted by standard atrial-based pacing

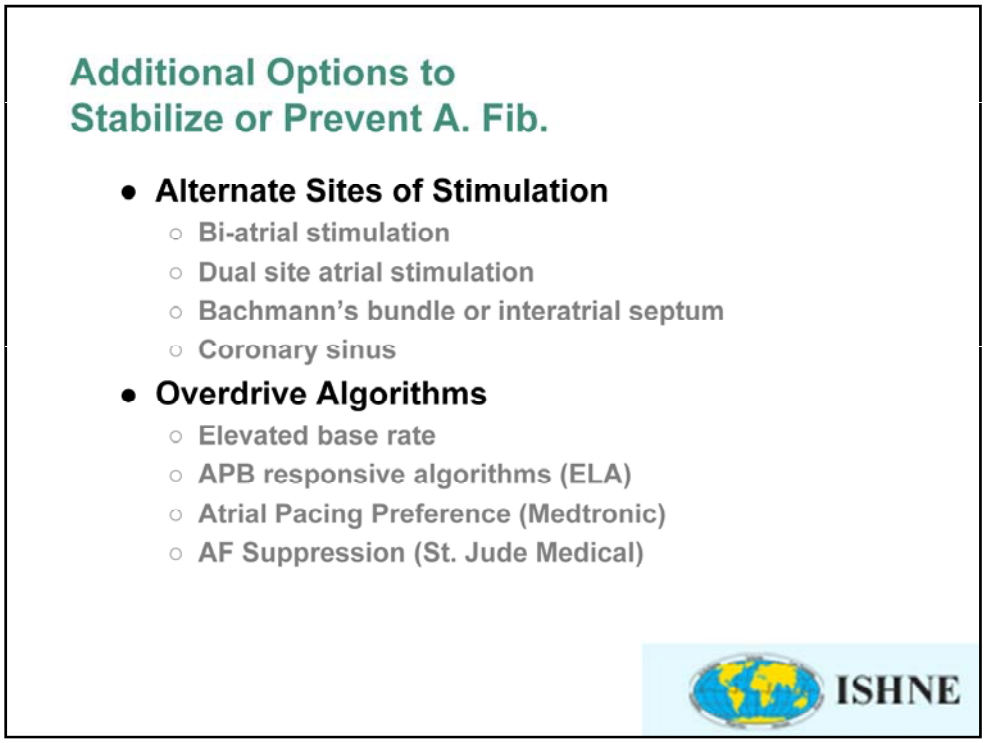


Interim conclusions and questions

The major studies claiming a benefit of atrial based pacing over VVI pacing were retrospective. The two prospective randomized trials had "mixed" results with the early results suggesting that there was no benefit while long term follow-up (Andersen study only) indicated a benefit.

The major benefit appears to be in the subgroup of patients with a marked bradycardia or in whom the episodes of atrial fibrillation appeared to be triggered by atrial premature beats in the setting of a sinus bradycardia. In addition, where the patient already has episodes of paroxysmal atrial fibrillation, particularly with intervening sinus bradycardia - atrial based pacing appears to help to stabilize the atrium. The presumed mechanism is "overdrive suppression."

This raises the question as to whether or not there may be other stimulation techniques or sites of pacing that may offer additional benefit with a further reduction in the episodes of paroxysmal atrial fibrillation.



Alternative options with respect to suppression of atrial fibrillation

There are two different approaches. One is changes in the site of stimulation but using standard pacing. The other involves special algorithms with standard lead placement.

The unique sites of stimulation involve either a single lead (Bachmann's bundle, interatrial septum or coronary sinus) but these often involve technical challenges to achieve these specific locations The other approach requires two leads for atrial pacing connecting the two with a bifurcated adapter. There is bi-atrial pacing (one lead in RA and one in LA via the coronary sinus) or dual-site right atrial stimulation (one lead in Right atrial appendage and the other in the ostium of the coronary sinus).

There are a variety of overdrive algorithms. One is simply a further increase in the programmed base rate. ELA introduced an algorithm where the atrial paced rate increased in response to APBs. Medtronic used a more dynamic overdrive algorithm which they termed Consistent Atrial Pacing (CAP). St. Jude Medical introduced Dynamic Atrial Overdrive (DAO) which will be described in additional detail later in this series.

Hypothesis

- Suppression of paroxysmal and possibly persistent atrial fibrillation can be achieved by stimulation at one or more sites using a variety of overdrive or APB responsive algorithms.
- Proposed mechanism(s)
  - Reduced dispersion of refractoriness
  - Reduction in triggers
  - Improved atrial homogeneity

Bi-Atrial Pacing

- In patients with inter-atrial conduction times of > 90 ms
- Improves atrial electrical synchronization
- Decreases P wave duration
- Requires two leads - one in RA and one stimulating LA (via coronary sinus)

Daubert JC, JACC 1995; 25: 230A

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Dual-Site (RA) Atrial Pacing

- Pacing from two sites in the right atrium - high right atrium and ostium of coronary sinus
- Pacing at relatively high rate (80 ppm)
- Evaluated time to first recurrence of AF vs time between episodes pre-implant
  - HRA 71 days vs 12 days (p = 0.001)
  - CS ostium 47 days vs 5 days (p = 0.06)
  - Dual site 85 days vs 10 days (p = 0.001)

Saksena S, JACC; 1996: 28: 687-694

Dual-Site RA Pacing

- n = 30, cross-over designed study
  - Antiarrhythmic drug therapy continued
- Arrhythmia free-interval
  - Control period prior to pacing: 9 +/- 10 days
  - Single Site: 143 +/- 110 days ($p < 0.0001$)
  - Dual Site: 195 +/- 96 days ($p < 0.005$ to single site and $p < 0.0001$ to control)
- Free of AF recurrence
  - Single site: 62%
  - Dual site: 89%

Delfaut P, JACC 1998: 32: 1900-8

The Dutch Study - DRAPPAF

- Prospective randomized within-patient crossover study
- Dual-site Right Atrial Pacing for Prevention of Atrial Fibrillation
- End points:
  - Time to first recurrence of AF
  - Need for DC cardioversion
  - Development of Chronic AF

Ramdat AR, Amer J Cardiol 2000; 86: 20K-24K

The Dutch Study - DRAPPAF

- N = 26
- Group 1 - dual site first followed by single site (HRA)
  - No difference between arms of the study
- Group 2 - single site first followed by dual site
  - Fewer electrical cardioversion in dual site compared to single site pacing
- Arrhythmia free interval was NOT modified by pacing mode

Ramdat AR, Amer J Cardiol 2000; 86: 20K-24K

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Dual Site Right Atrial Pacing

- Drug-refractory paroxysmal atrial fibrillation in 20 patients, single blind randomized trial
- Dual site pacing compared to RAA pacing
- End point - QOL and Atrial Fib burden (percent time spent in atrial fibrillation)
- DDDR mode, base rate 70 ppm
  - Percent atrial pacing: 85 - 87%

Levy T, et al, Internatl J Cardiol 2001; 85: 58-52

Dual Site Right Atrial Pacing

	RAA	Dual Site	p Value
# PAF episodes	77	52	ns
Duration of PAF	4.8 days	6.3	ns
% AF burden	14%	19%	ns

- No significant difference based on site of pacing
- Significant improvement (QOL, episodes of AF) compared to baseline - hence, pacing is effective.

Levy T, et al, Internatl J Cardiol 2001; 85: 58-52

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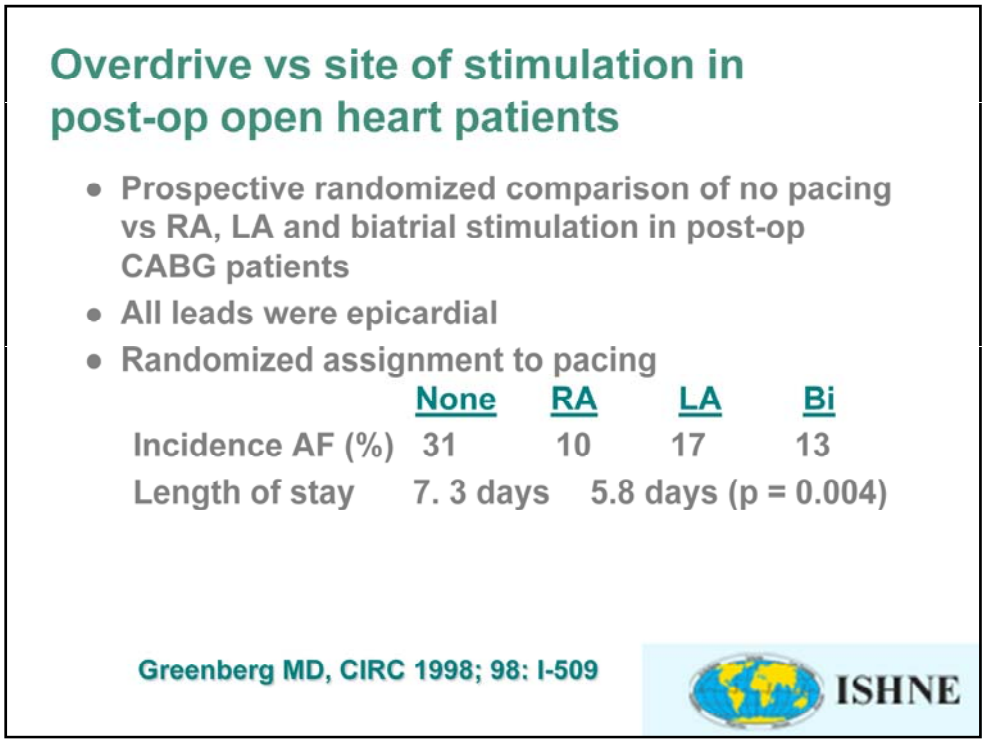

Overdrive vs Site of Stimulation (Biatrial)

This was a short term study using post-operative open heart patients who had undergone coronary artery bypass grafting (CABG). There is a relatively high incidence of paroxysmal atrial fibrillation in these patients and while this usually resolves, it does increase the length of stay in both the ICU as well as in the hospital. At the time of the procedure, the surgeons commonly place temporary epicardial atrial and ventricular pacing wires in case pacing support is required. In this group, they placed temporary wires on the Left Atrium as well as the right atrium.

In this study patients were randomized to no pacing or overdrive pacing from the RA, LA or both atria. In the no pacing group, this was only on a prophylactic basis. If pacing support was needed for standard clinical indications, it was allowed.

Patients were paced at a relatively high rate (between 80-90) in those randomized to RA, LA or Bi-A and over the period of time that they were in the hospital or until the temporary wires were removed, the incidence of atrial fibrillation was documented. The group without pacing support had a 31% incidence of atrial fibrillation with a mean stay in the hospital of 7.3days. The paced groups, from any site had a much lower incidence of atrial fibrillation with bi-atrial being no better than a single site. The length of stay for this group was 5.8 days or 1 1/2 days shorter which translates to a significant financial saving. It also suggests that simple overdrive pacing may be all that is needed although the post-op patient has a different disease substrate than those in whom AF occurs spontaneously.

Temporary Bi-Atrial Pacing in Post-Op Open Heart Patients

- N = 132
- Comparison of biatrial left atrial, right atrial and no pacing (control)

AAI @ 90 ppm	% AFib	LOS	
Control	42%	9.6 days	
Right Atrial	36%		
Left Atrial	33%		P < 0.05
Bi-Atrial	12.5 %	7.0 days	

Fan K, et al, Circulation 2000; 102: 755-760

Temporary Bi-Atrial Pacing in Post-Op Open Heart Patients

- N = 118
- Prospective randomized to AAI @ 45 (control), Right Atrial (AAT) at 85 and Bi-Atrial AAT at 85 ppm
- Continuous Holter (AF = 5+ minutes of AF)

	Control	RA	Bi-Atrial
% Atrial Fib	2 %	28 %	10 %

Daoud E, et al, Circulation 2000; 102: 761-765

Low left atrial pacing from CS

- Acute EP Lab study - unselected patients undergoing EP study
- Ability to induce AF using premature stimuli from HRA
- Pacing from distal CS caused low atrial depolarization rendering it refractory to premature stimuli delivered from HRA and precluded induction of atrial fibrillation

Papageorgiu P, CIRC, 1997; 96: 1893-1989

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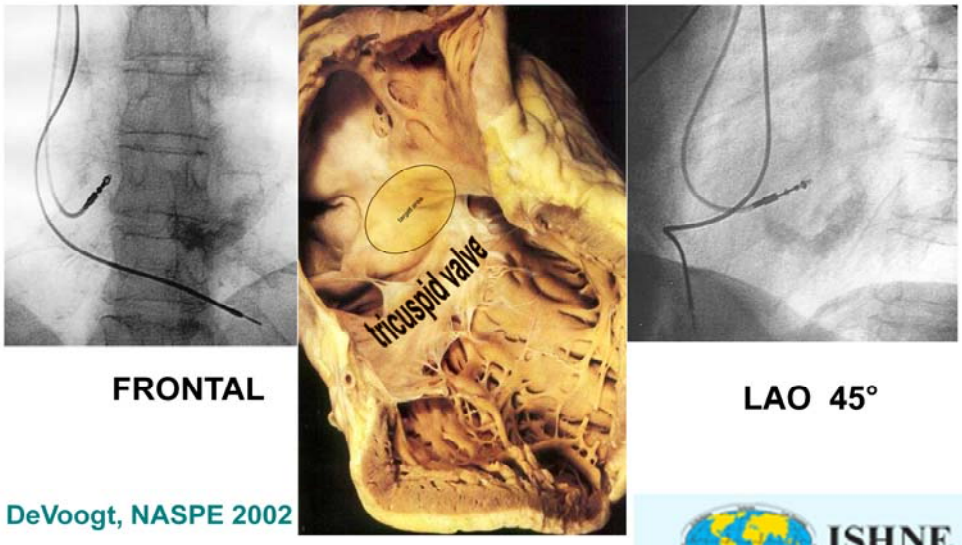
Interatrial Septal Pacing



FRONTAL

LAO 45°

DeVoogt, NASPE 2002

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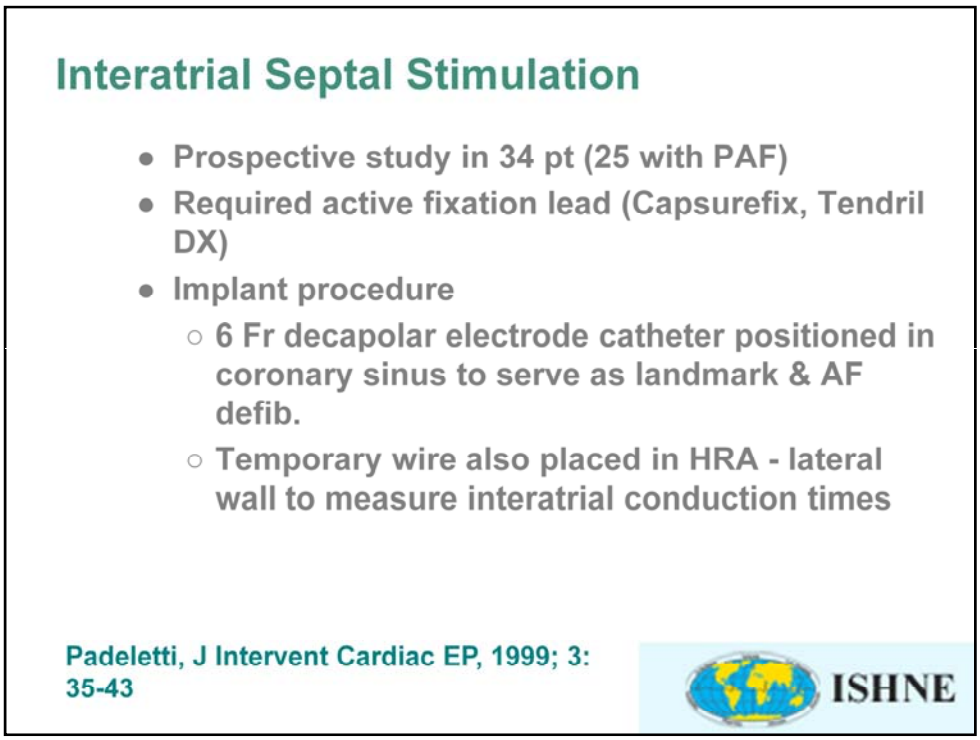
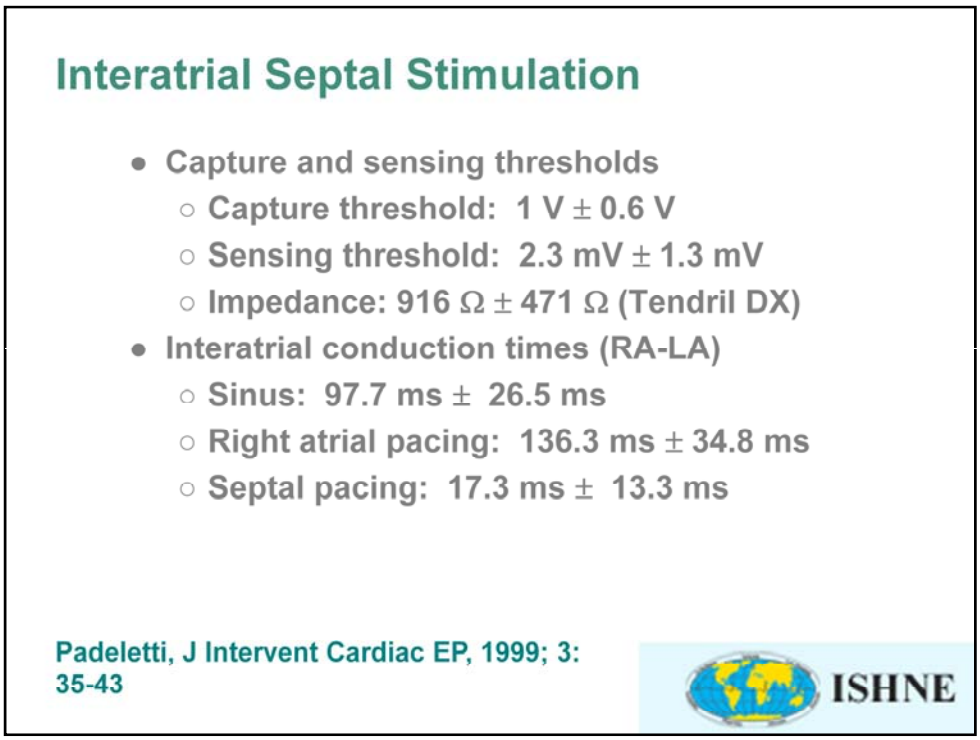


Interatrial Septal Stimulation

This was a prospective study using standard atrial pacing but with leads positioned in the interatrial septum. The wave of atrial depolarization spreads out from the stimulation to both atria, virtually simultaneously;.

As this atrial location has no trabeculae, an active fixation lead is required. The investigators used the Medtronic CapsureFix and the SJM Tendril DX with equal success.

Identification of the atrial septal location required placement of a temporary lead in the coronary sinus. It was also a decapolar lead to allow for internal atrial cardioversion, if needed. A second lead was positioned in the high right atrium. The lead in the HRA and the distal CS (distal pair of electrodes on the decapolar CS lead) allowed the investigators to measure atrial conduction times. This would not be part of a routine pacemaker implantation if the desired site for atrial stimulation were the interatrial septum.

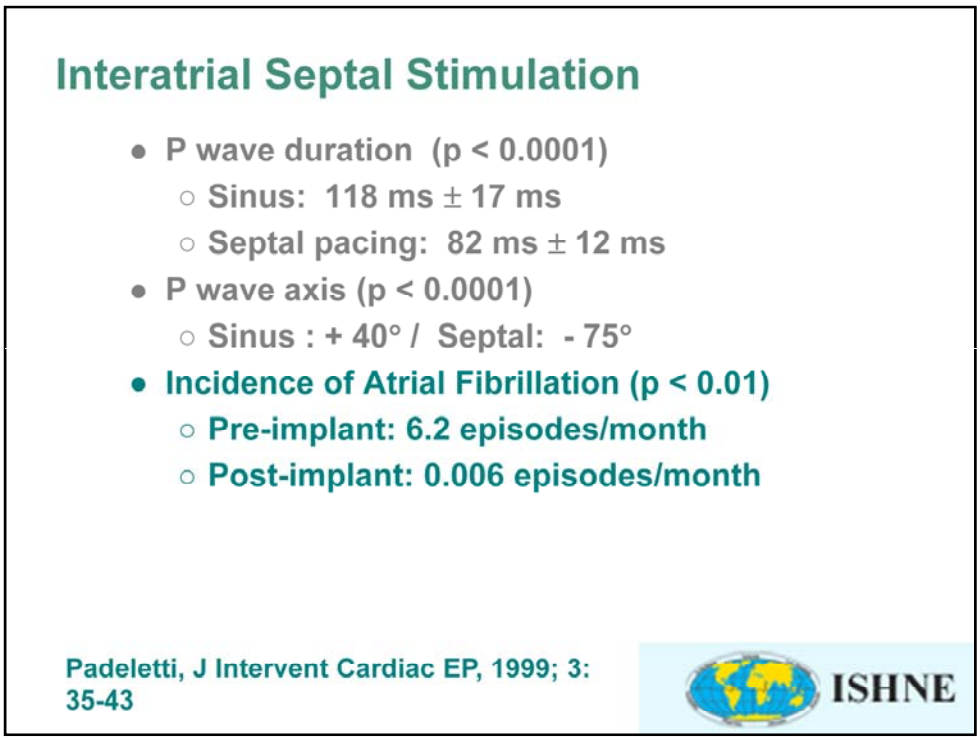


Interatrial septal pacing

The capture and sensing thresholds from this location were similar to those obtained from standard positions in the atrium. The reported stimulation impedance (data extracted just for Tendril DX lead) appears to be higher than is usually recorded for the Tendril DX lead placed in the atrium. The reason for this is not clear.

The interatrial conduction times were impressive. During sinus rhythm, the interval from the high right atrium to the distal CS electrodes was almost 98 ms. Pacing from the high right atrium was 136 ms since this impulse may not follow the normal intra- and inter-atrial conduction pathways or there may be a delay before it depolarizes one of these pathways to then be conducted. However, with septal pacing, there is virtually simultaneous stimulation of both atria.

Pacing from this site may eliminate the need for two leads as proposed by both Daubert and colleagues (bi-atrial pacing) and Saksena (dual site atrial pacing) making for a simpler system with similar electrophysiologic benefits.



Interatrial septal stimulation

The result of pacing from the interatrial septum resulted in a pacemaker evoked P wave duration of 82 ms which was significantly shorter that the P wave duration in sinus rhythm (118 ms) , $p < 0.0001$

The P wave axis was superior and to the left (- 75^{o}) as compared to the P wave axis during sinus rhythm which is directed toward inferior and to the left (+ 40^{o}).

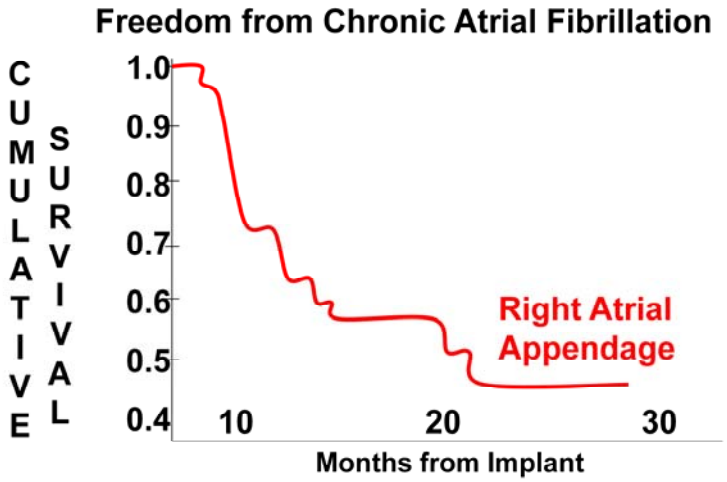
Each patient averaged 6+ episodes of documented atrial fibrillation per month prior to the implant. Following the implant, the average incidence of paroxysmal atrial fibrillation decreased to 0.006 episodes per month and this was using standard pacing techniques with no special overdrive algorithms.

Bachmann's Bundle Pacing

- Paroxysmal atrial fibrillation and standard bradycardia indication for pacing
  - 69% had sinus node dysfunction
- N = 170 randomized to either right atrial appendage or Bachmann's bundle (high septal)
- Atrial overdrive maintained with base rate **80 ppm**
- Chronic atrial fibrillation defined as atrial fibrillation lasting > 2 months in duration

Bailin S, J Cardiovasc EP 2001; 12: 912-917

Bachmann's Bundle vs RAA pacing



Bailin S, J Cardiovasc EP 2001; 12: 912-917

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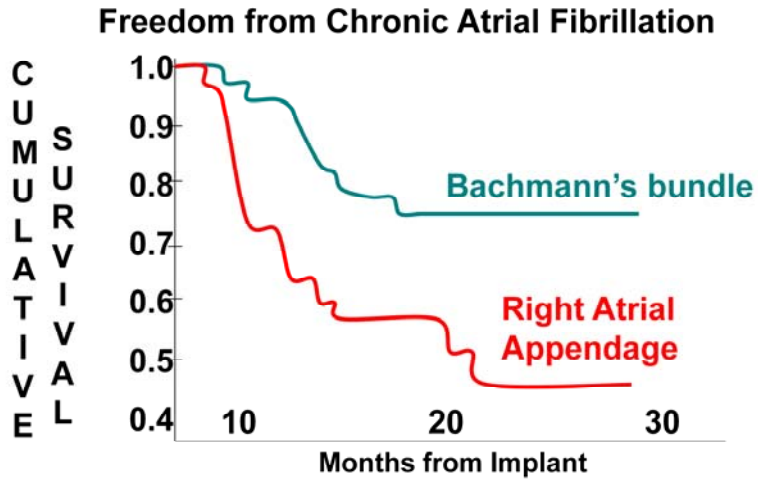
Bachmann's Bundle vs RAA pacing



Bailin S, J Cardiovasc EP 2001; 12: 912-917

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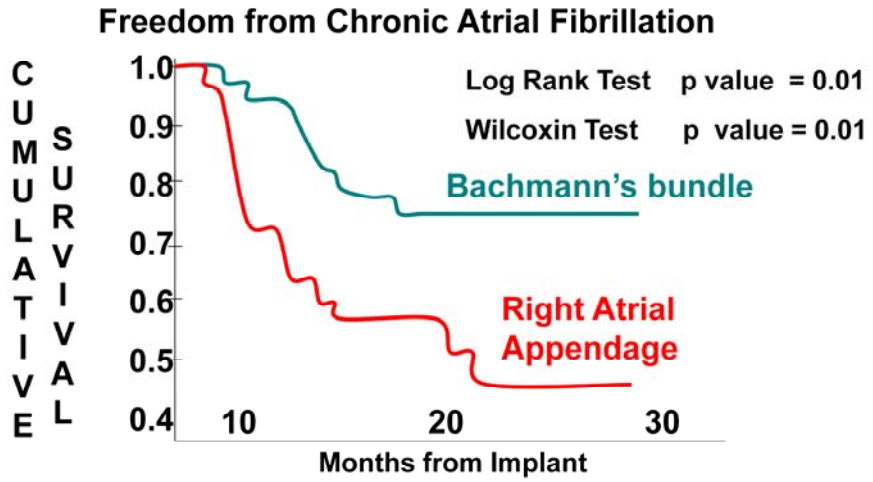
Bachmann's Bundle vs RAA pacing



Bailin S, J Cardiovasc EP 2001; 12: 912-917

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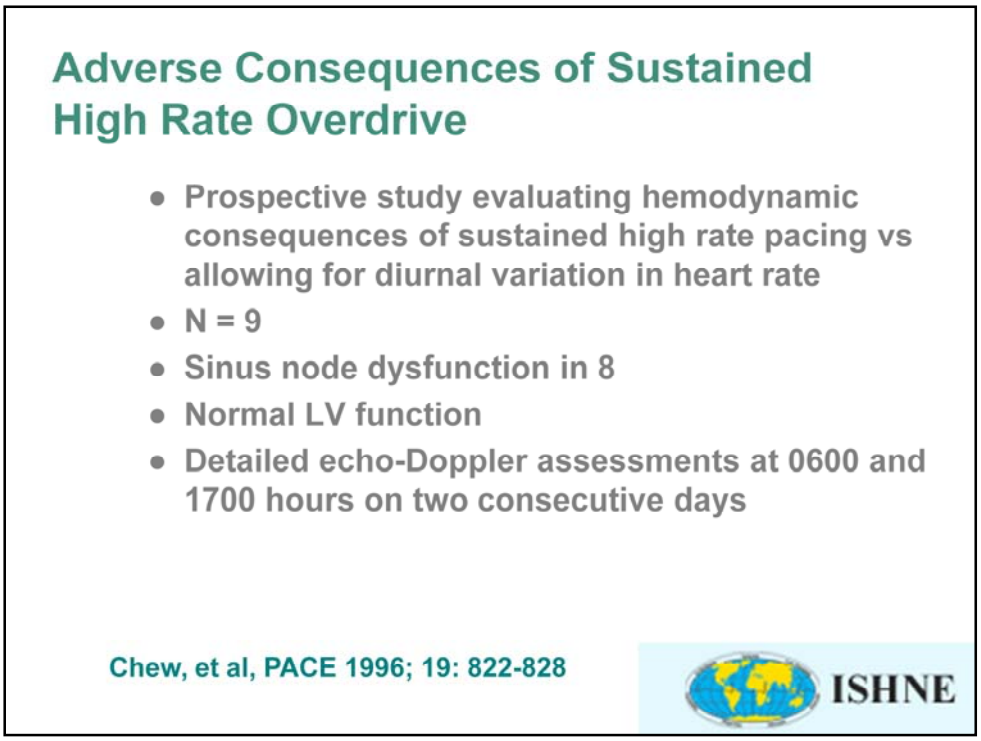


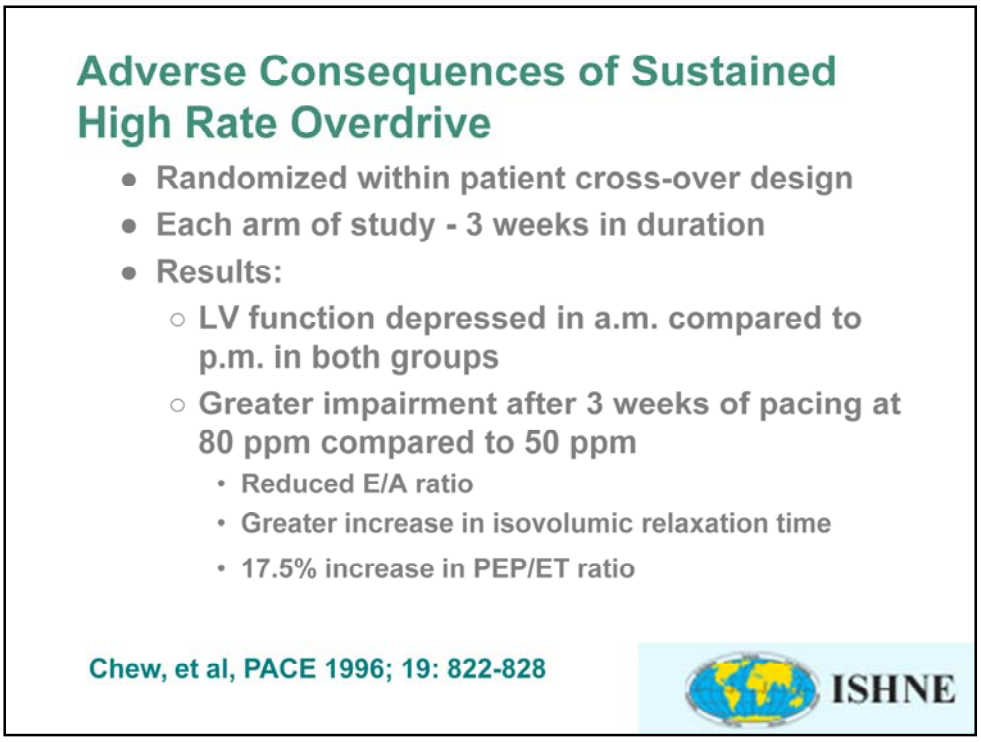
Adverse consequences of sustained high rate pacing

The normal diurnal variation is heart rate, blood pressure and other physiologic behaviors is well described but the clinical benefit of this behavior has not been well established. It is also known that sustained high heart rates as with an incessant tachycardia or atrial fibrillation with persistent rapid ventricular responses may result in marked ventricular dysfunction that will improve once the heart rate is controlled.

Chew and colleagues from Johns Hopkins University did an echo-Doppler study on a series of 9 patients, each of whom had normal LV function. Eight of the patients had sinus node dysfunction so were frequently controlled by the pacemaker.

After 3 weeks of pacing with the base rate set to either 80 ppm or 50 ppm, the patient was subjected to two consecutive days of detailed noninvasive hemodynamic testing using the Echo-Doppler system. Tests were performed at both 6 a.m. and 5 p.m. The results for the similar times on the two consecutive days were averaged. The pacemaker was then set to the other rate, another 3 weeks ensued after which similar studies were obtained.

No patient had clinical symptoms during this time except for a couple of reports of palpitations or awareness of the rapid heart beat when at rest. When the base rate was reduced to 50 ppm, the actual rate was the patients own intrinsic rhythm at rates in the 50's to low 60's during the night.



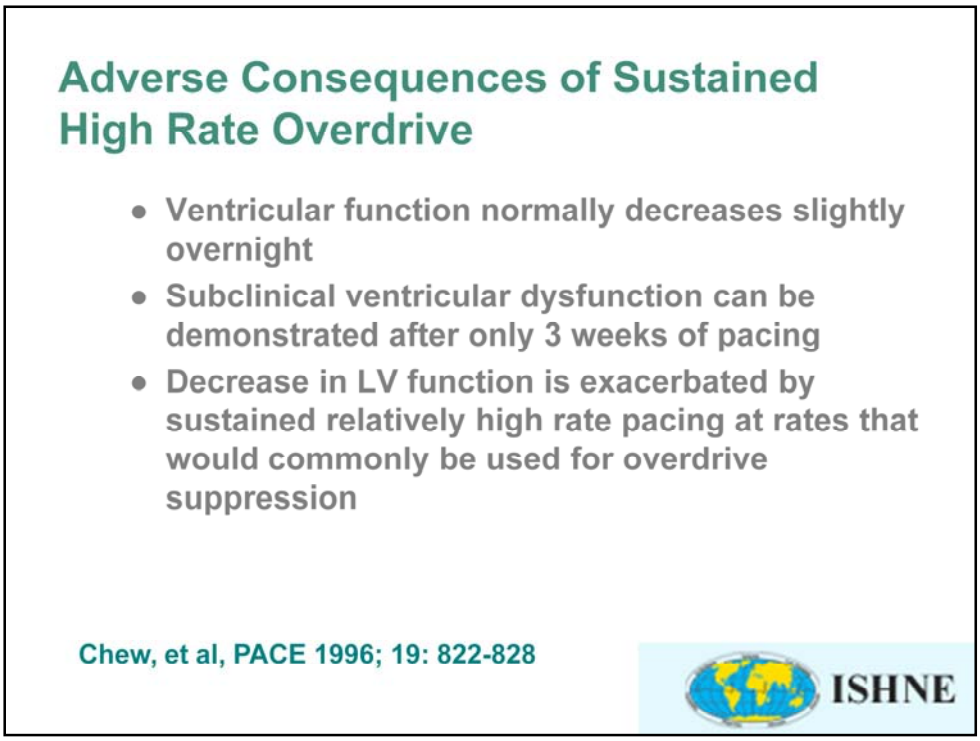
Adverse consequences of sustained high rate overdrive - 2

The results of the study were that LV function was mildly depressed in the morning in comparison to the afternoon. This was independent of the programmed base rate.

However, when the group was programmed to a base rate of 80 ppm, they were paced virtually 100% of the time, particularly at night. Measures of LV function demonstrated more abnormalities and depression in both the morning and afternoon and was more pronounced in the morning compared to these same patients when the base rate was 50 ppm that allowed for the normal diurnal variation in rate.

The prime markers were a reduction in the E/A ratio associated with mitral valve or LV inflow, a greater increase in isovolumic relaxation time and an increase in the PEP (pre-ejection period) to ET (ejection time) ratio. This means that it takes longer for the ventricular muscle to generate the power to begin ejection of blood.

All of the measurements were subtle and none of the patients demonstrated an overt clinical problem. However, with chronic overdrive pacing, if one selects a high base rate of 80 to 90 ppm as Dr. Saksena has done for his dual site atrial pacing patients, the long term consequences of this relatively high rate are unknown.



Adverse consequences of sustained high rate pacing - 3

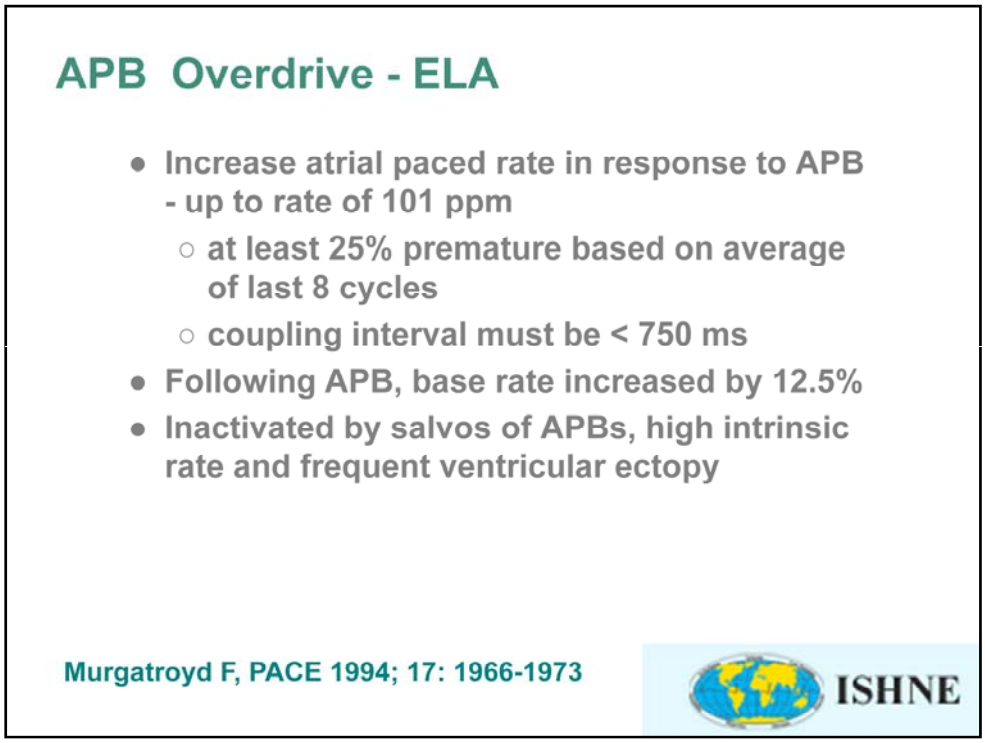
Based on the Chew data, a minimal decrease in ventricular function is normal overnight such that ventricular function in the a.m. is depressed compared to the p.m. This may be a diurnal or circadian variation in another physiologic state - namely, cardiac function.

While the further dysfunction that appeared to be associated with pacing at 80 ppm (higher rates could occur under sensor drive or tracking atrial activity) were subtle, these were manifested after only 3 weeks of pacing at this rate. Consider the usual patient for whom overdrive pacing might be utilized in an attempt to stabilize the atrium and prevent atrial fibrillation. The duration of pacing at these rates is likely to be months if not years. The adverse long term consequences, over and above any bothersome palpitations that the patient may experience from these rates when at rest, are simply not known.

Hence, one goal would be to identify an algorithm that only increased the rate when this was needed for overdrive suppression. At other times, when faster paced rates were not required, the algorithm would allow the paced rate or sinus controlled rate to rhythmically wax and wane in accord with normal physiology.

Interim Conclusions

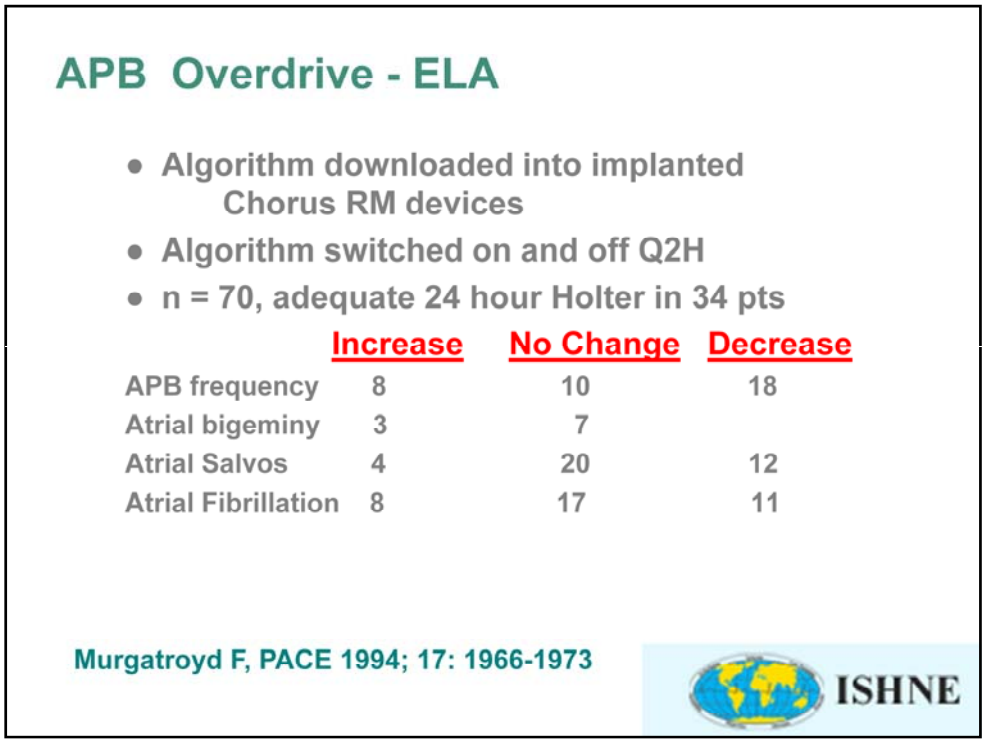
- Ventricular-based pacing may be pro-arrhythmic
- Patients with sinus node dysfunction are more likely to develop permanent AF if physiologic pacing is not used
- Atrial-based pacing from traditional right atrial appendage site does not appear to prevent progression of AF without preexisting sinus node dysfunction
- **Special overdrive algorithms perhaps in conjunction with unique stimulation sites may be required to provide additional antiarrhythmic benefit in patients with sinus node dysfunction and propensity for PAF**



Special Overdrive Algorithms - APB Protection - ELA

ELA was the first to introduce a special algorithm in an attempt to preempt and prevent paroxysmal atrial fibrillation. Reasoning that atrial premature beats (APBs) were the trigger initiating AF, they increased the atrial paced rate in response to detected APBs. The definition of an APB was the coupling interval for the premature beat was at least 25% shorter than the preceding atrial or sinus cycle length based on an average of the previous 8 cycles. Following detection of an APB that fulfilled this criteria, the base rate of the pacemaker would be increased by 12.5%. If APBs continued to be detected, the baser rate would continue to increase.

However, the rate was limited to 101 ppm and if there were very frequent APBs, (the very setting indicating electrical instability), the algorithm would disable. In addition, high atrial rates reflecting increased catecholamine stimulation which may be a mediating factor for increased ectopy at high rates in those patients who develop Parox. Atrial Fibrillation in the absence of an absolute bradycardia, will also disable this algorithm as will frequent ventricular ectopy.



APB Overdrive Algorithm - ELA

ELA took advantage of already implanted Chorus RM (DDDR) devices where patients were identified as having frequent episodes of paroxysmal atrial fibrillation. The special algorithm was downloaded into the already implanted devices. They also included an algorithm where it was enabled and then disabled in two hour periods and used a standard 24 hour Holter monitor to evaluate the effectiveness of this algorithm.

Of the 34 patients in whom adequate studies were obtained, there was a wide divergence in results. While a significant number of patients demonstrated a decrease in various features of the atrial arrhythmias, in some such as atrial salvos (the algorithm specifically disables in this setting) and incidence of atrial fibrillation, there was no change in the majority and an increase incidence in approximately 10 to 20 percent.

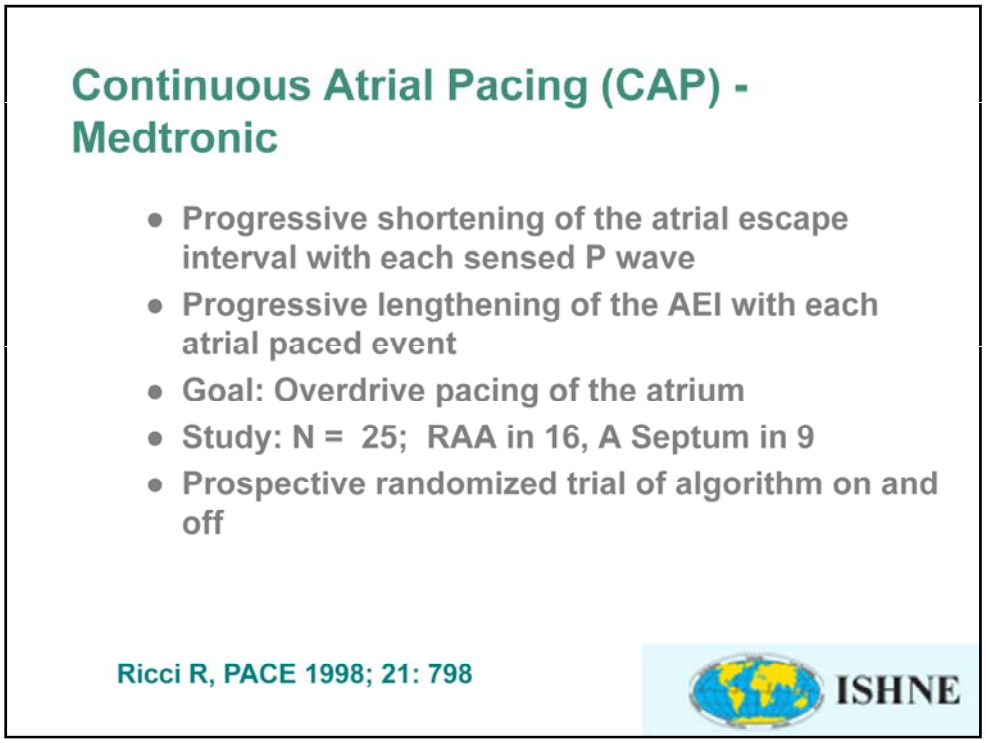
ELA is continuing to refine this algorithm but the results are not known as this set of slides was being put together.

APB Suppression - ELA

- DDD @ 70 ppm +/- overdrive algorithm
  - Sinus rhythm overdrive
  - Post-extrasystolic pause suppression
  - Acceleration on APB
- Prospective randomized cross-over design, 3 months in each arm; n = 38

	DDD 70	DDD 70+	p
# episodes/wk	6.0 ± 10.4	5.9 ± 8.7	ns
Duration (hours)	12.0 ± 24.2	11.7 ± 23.5	ns

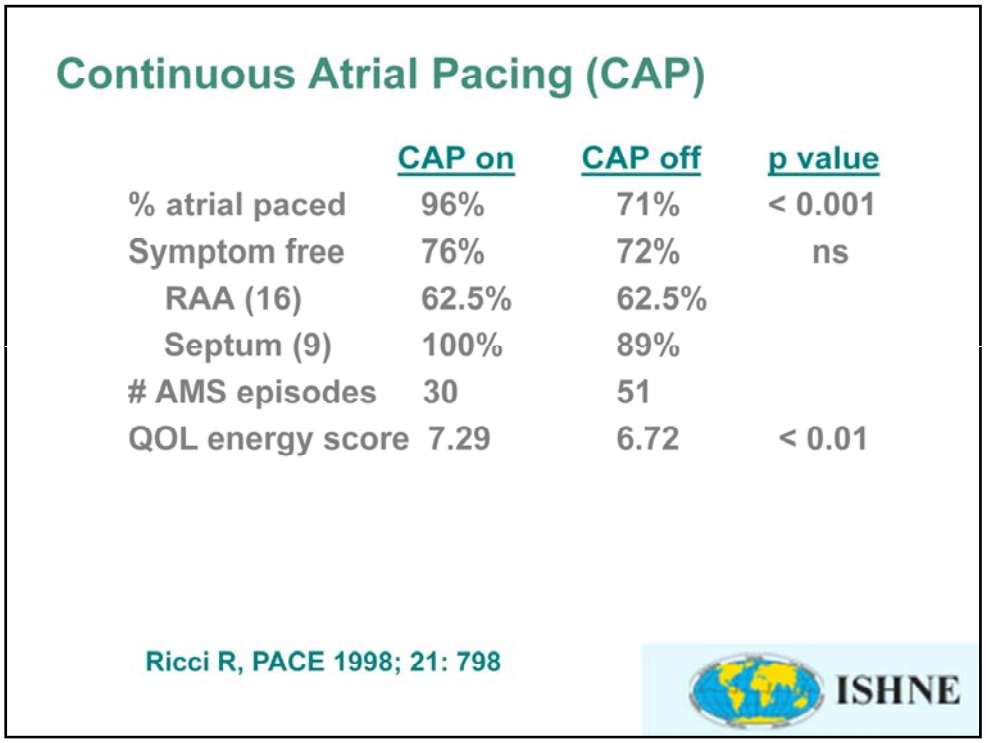
Mansourati J, JACC 2002; 84A (abstract 1043-107)



Continuous Atrial Pacing Algorithm - Medtronic

Medtronic developed an algorithm which they have labeled Continuous Atrial Pacing (CAP) which is an overdrive algorithm responding to native events. Starting from the programmed rate, a sensed atrial event (P wave) causes the atrial escape interval to shorten by a programmable interval. If, despite this shortening, the next atrial event is also sensed (native rate being faster than paced rate), the AEI is again shortened. This continues until there is a single cycle of atrial pacing (AR or AV). Once atrial pacing begins, there is no period of overdrive pacing at this higher rate but the system immediately begins to lengthen the AEI (rate slows). As such, the atrial paced rate will continue to wax and wane. The goal was > 90% control of the atrial rhythm by pacing and thus hoping to reduce the development of atrial fibrillation.

In this first study, 25 patients received devices with this software loaded into it. This was a within patient randomized cross-over designed trial with the algorithm either enabled or disabled. A total of 235 patients were enrolled. What should be independent of the algorithm but may be very important is the fact that of the 25 patients, 16 had the atrial lead placed in the standard right atrial appendage location while 9 had the lead positioned on the inter-atrial septum (see summary of Padeletti paper presented earlier).



Continuous Atrial Pacing (CAP) - Medtronic

This is the results of the study. With respect to controlling the atrial rate, the algorithm was extremely effective compared to standard pacing with CAP disabled (96% vs 71% , $p < 0.001$). However, there was not a significant difference in the incidence of symptoms (76% with CAP enabled vs 72% with it disabled). When one factors in the site of stimulation, there was no difference in symptoms with CAP on or off when the lead was in the Right Atrial Appendage. However, when CAP was disabled but the lead was placed on the inter-atrial septum, the patients were free of symptoms 89% of the time. When the lea was placed on the inter-atrial septum and the CAP algorithm was enabled, 100% of patients (but it was only a very small number, 9) were free of symptoms.

The number of AMS episodes based on the event counter data was reduced with CAP on as compared to off. Although the AMS event counter in the Medtronic devices simply reports the number of AMS episodes and their algorithm is prone to far field sensing and frequent mode switch oscillation, in that each patient served as his or her own control, these results are relative and probably accurately reflects a true reduction in the incidence of PAF or other tachyarrhythmia that might trigger a mode switch episode.

Although the differences are small, they are significant with an improvement in QOL with CAP enabled. This is to be expected if the incidence of AF is reduced.

CAP - 2nd Generation

- N = 61 patients
- Prospective randomized within-patient cross-over study
- Modified algorithm
  - Shortening of AEI with each sensed P wave
  - Same degree of AEI shortening at all rates, hence more aggressive rate acceleration at higher rates
  - Plateau phase added (5 beats at higher rate) before begin to extend AEI

Ricci R, J Intervent Card Electrophysiol 2001; 5: 33-44

CAP - 2nd Generation Algorithm

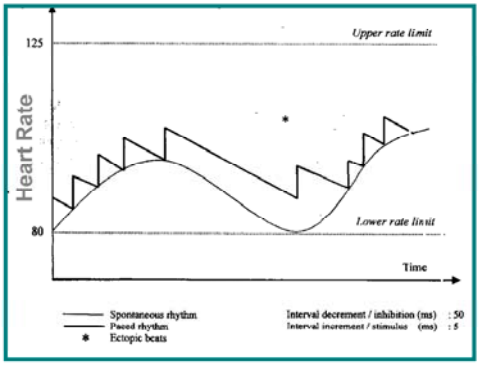
- Algorithm enabled or disabled for only one month

	CAP on	CAP off	p value
Symptomatic AF	27%	23%	ns
# PAF episodes	1.9 ± 5.4	3.4 ± 14.7	ns
Baseline	6.2 ± 6.7	6.2 ± 6.7	
% Atrial pacing	97%	77%	<0.0001
Daily Duration AMS	96 min	105 min	ns
# APBs	556 ± 704	2566 ± 4468	0.02

Ricci R, J Intervent Card Electrophysiol 2001; 5: 33-44

Continuous Atrial Pacing and Post-Operative AF

- AF reduced from 27% to 10% (p=0.036)
- More benefit in patients with preserved LV function



Blommaert *et al*, JACC 2000;35:1411-5

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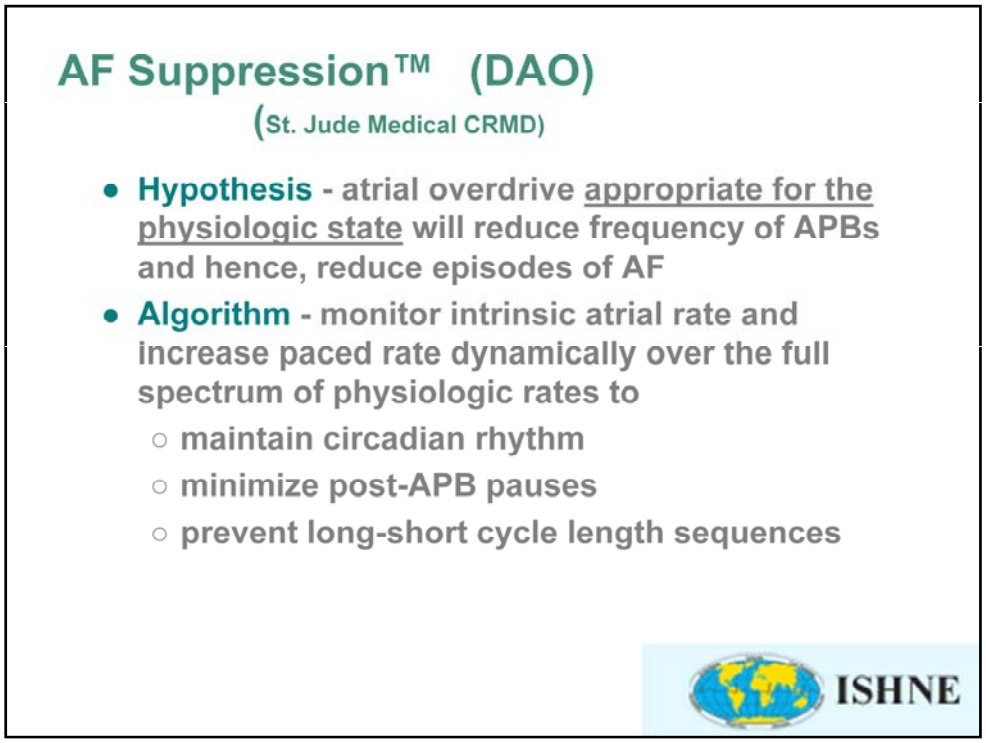
Pacing in Prevention of PAF
Italian AT500 Registry (Medtronic)

- N = 105 Pacing for SND or AV Block
  - All patients had paroxysmal atrial tachycardia or fibrillation
- One month monitoring period before enabling algorithm (CAP)

Algorithm:	OFF	ON	P value
Atrial pace %	69	95	0.01
Vent. Pace %	74	77	ns
PAC per day	2981	769	0.05
AT episode/day	2.6 ± 14.4	2.0 ± 12.9	ns
AF burden (hr/d)	3.3 ± 7.9	2.2 ± 6.6	ns

Botto GL, Padelleti L, JACC 2002; 84A (Abstract 1043-109)

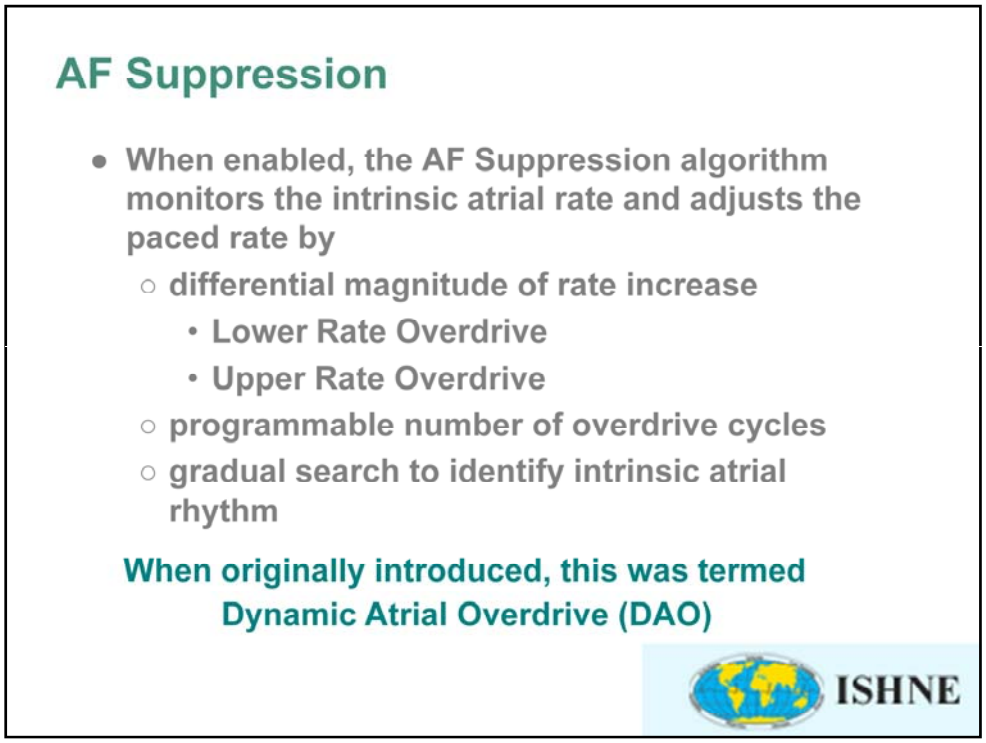


Dynamic Atrial Overdrive (DAO) - St. Jude Medical

Based on the preceding work and data, it seems as if those patients with an underlying bradycardia as the substrate from which atrial fibrillation develops benefit from standard pacing at a slightly faster rate than their native rate with a reduction in or delay before the recurrent of atrial fibrillation. However, atrial fibrillation also develops in patients who do not have an underlying bradycardia by standard criteria, although their native heart rate may constitute a relative bradycardia for their physiologic or electrophysiologic requirements at the time.

Simply increasing the base rate as was done by Saksena may be relatively effective for these other patients but Chew and colleagues have demonstrated subtle manifestations of ventricular dysfunction in the setting of sustained moderately high rate (80 ppm) pacing for periods as short as 3 weeks.

The DAO algorithm was designed to allow a maintenance of the circadian variation in heart rate using the sinus node as its guide (when the sinus mechanism is intact) but with increases in the intrinsic rhythm, be it due to APBs apropos of ELA or an organized (not premature) atrial rhythm as may occur with periods of stress, recognize this and progressively increase the atrial paced rate to a slightly faster rate. This will minimize the post-APB pauses and prevent the long-short cycle sequences that appears to be arrhythmogenic.



Dynamic Atrial Overdrive (DAO)

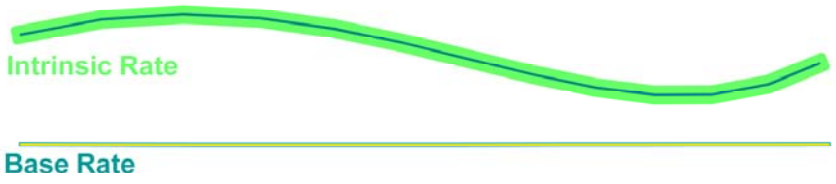
When DAO is enabled, the system monitors the intrinsic atrial rate and automatically adjusts the paced atrial rate (could be AR or AV) in a variety of independently programmable ways.

First is Lower or Upper Rate Overdrive - this is the number of pulses per minute increase in rate that occurs based on the detected atrial rate. LRO and URO are independently programmable. The absolute limit will be a high rate of 180 ppm.

Once atrial pacing is achieved (the atrial paced rate being faster than the native rate), the rate is maintained at that value for a number of cycles which is also programmable (number of overdrive cycles). If before the number of cycles is reached, native atrial activity is detected (at least 2 native P waves within a 16 cycle window), the atrial paced rate is again incremented in accord with the LRO/URO settings.

If the Overdrive period times out, the rate begins to decrease in accord with a programmable Dynamic Rate Recovery (DRR) sequence that is also programmable. Thus sustained high rate pacing is avoided when there are no intrinsic high intrinsic atrial rates or sensor drive is not maintaining the higher rate.

Schematic behavior of AF Suppression



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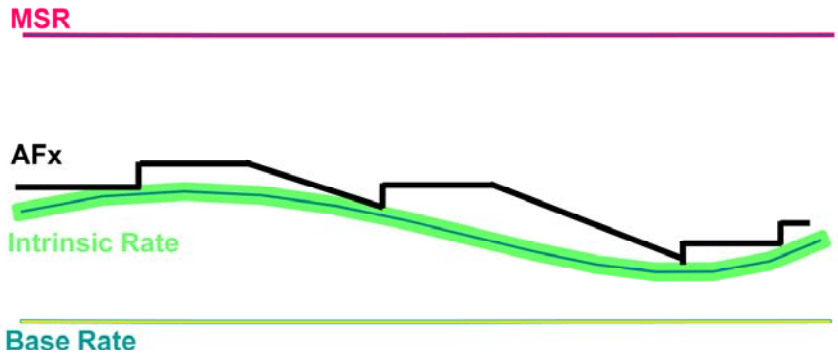
Schematic behavior of AF Suppression



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Dynamic Atrial Overdrive (DAO)

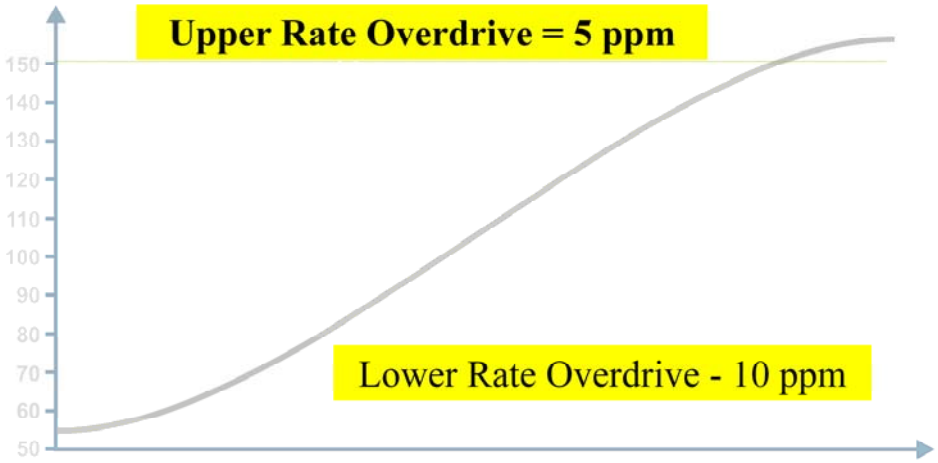
There are four independently programmable parameters. These include

- Lower Rate Overdrive (LRO)
- Upper Rate Overdrive (URO)
- Number of overdrive pacing cycles
- Dynamic Recovery Rate (DRR)

These will be described in detail in the subsequent slides and there are printouts from an Event Record demonstrating these in subsequent slides in this series.

This degree of programmability allows the physician to fine tune the algorithm for the individual patient. At this time, however, there is not a lot of experience with few guidelines to aid in the programming of these devices. Based on early experience from the ADOPT trials, it seems as an aggressive overdrive algorithm combined with sustained overdrive pacing works better than the less aggressive rate increases for shorter periods of time.

AF Suppression - Overdrive



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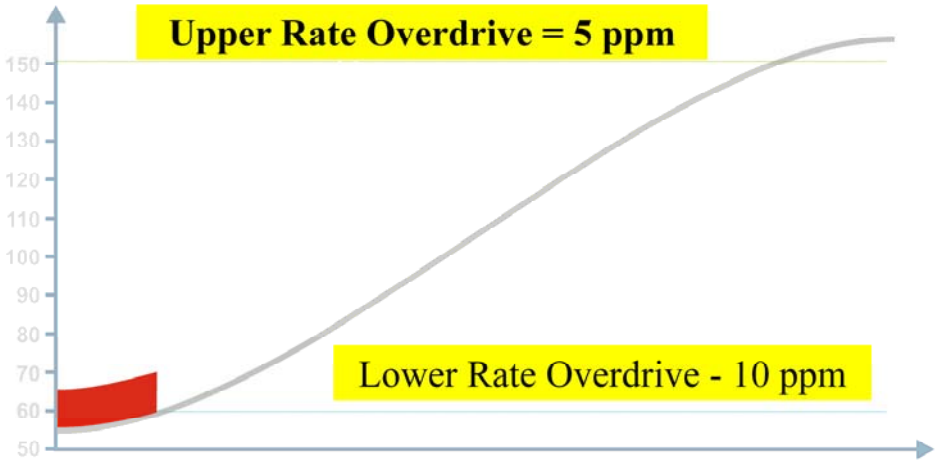
AF Suppression - Overdrive



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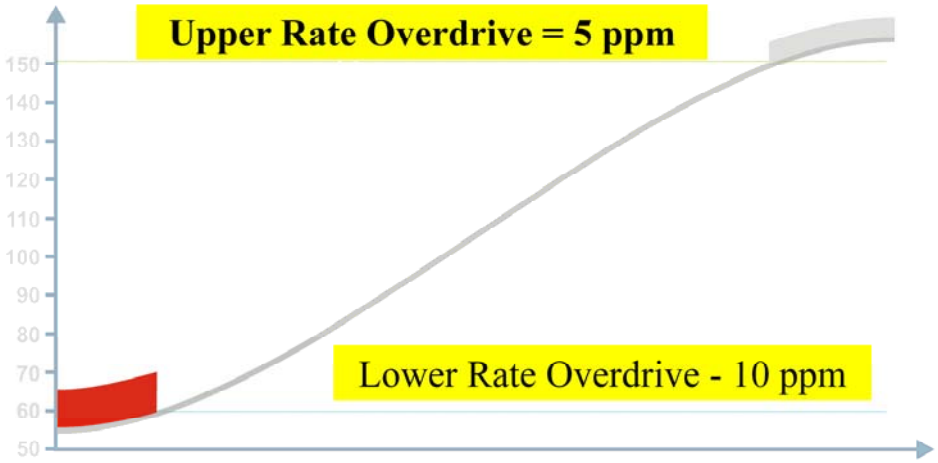
AF Suppression - Overdrive



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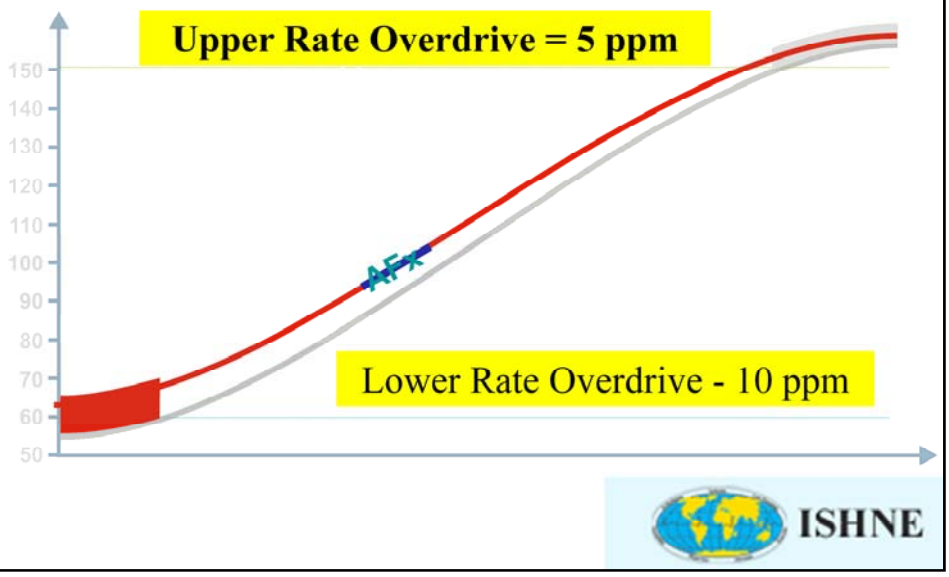
AF Suppression - Overdrive



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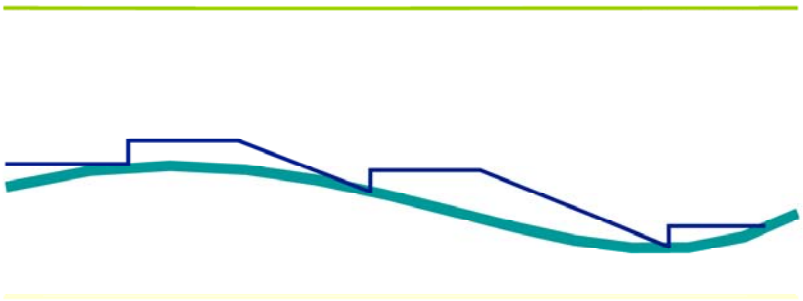
AF Suppression

Number of Overdrive Pacing Cycles



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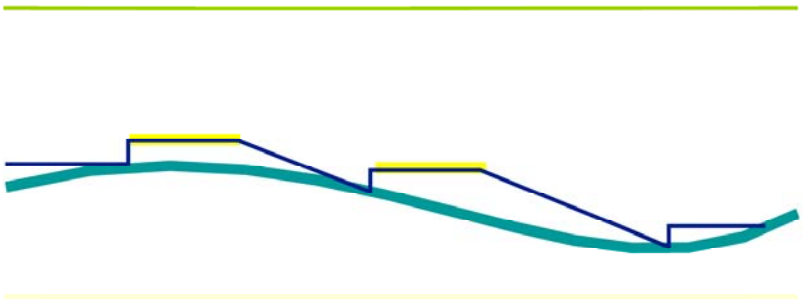
Number of Overdrive Pacing Cycles



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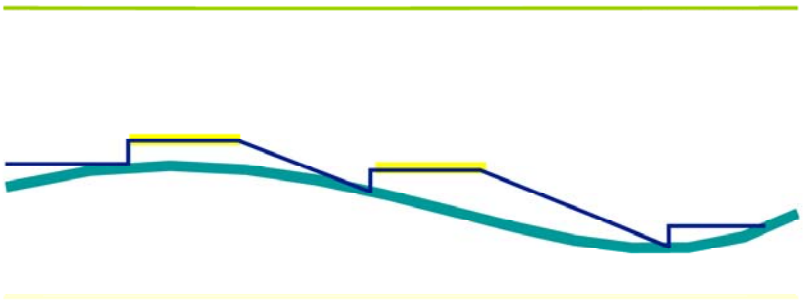
AF Suppression

Number of Overdrive Pacing Cycles

Highest allowed overdrive rate = MSR*



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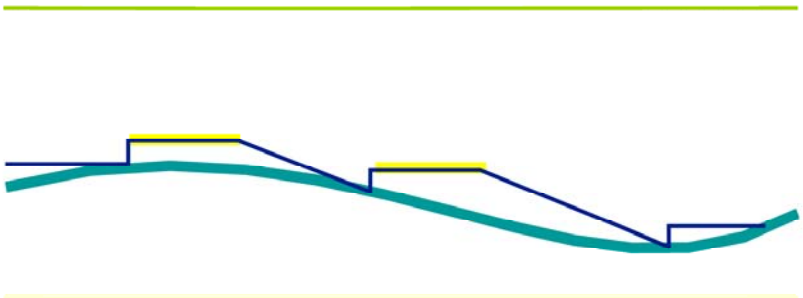
AF Suppression

Number of Overdrive Pacing Cycles

Highest allowed overdrive rate = MSR*



*** even if rate modulation is disengaged or passive**

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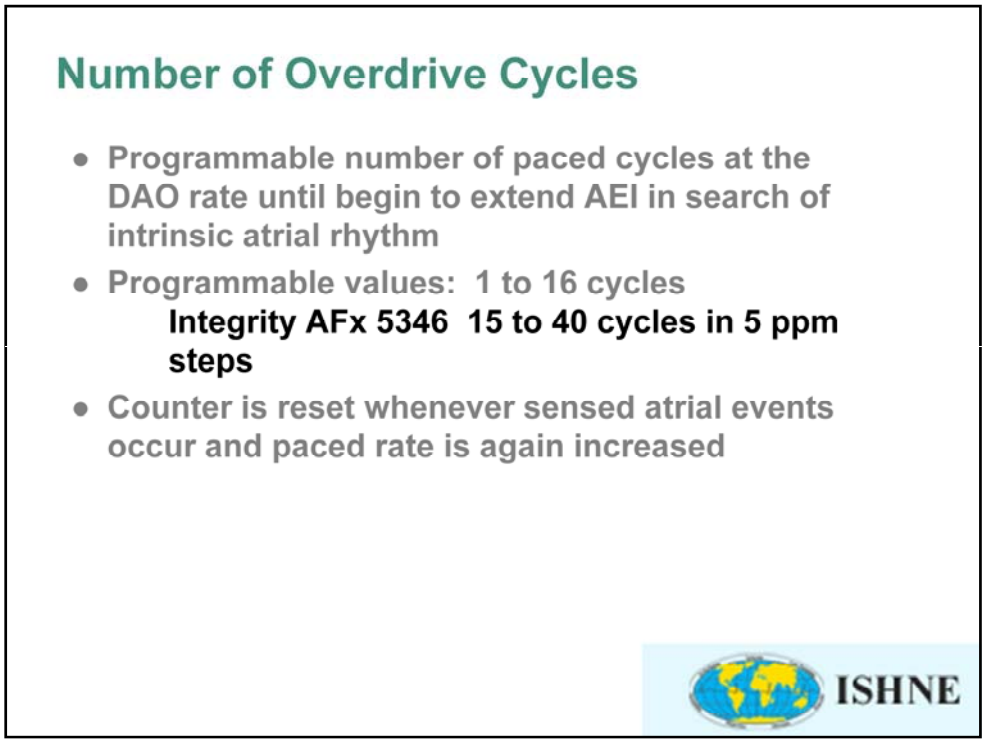
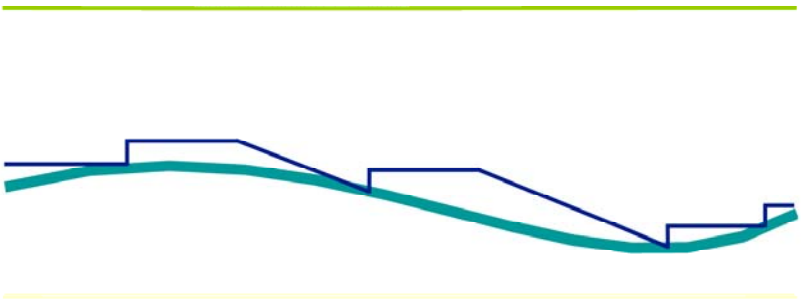


DAO- Number of Overdrive Cycles

This refers to the number of cycles (programmable from 1 to 16) during which time the pacemaker will continue to pace at the increased rate before starting to return towards the baseline. However, if before this time-out occurs, additional sensed atrial events occur (the only way for this to occur is if the native atrial events are at a higher rate), the pacemaker will again increment its rate and restart the # overdrive cycle counter.

Preliminary data suggests that the longer duration of overdrive is more effective than the shorter duration. In contrast to Medtronic's Continuous Atrial Pacing algorithm which has virtually no overdrive duration, with the first atrial paced event, the atrial escape interval for the next cycle is lengthened resulting in a virtually immediate slowing of the rate.

AF Suppression
Dynamic Rate Recovery



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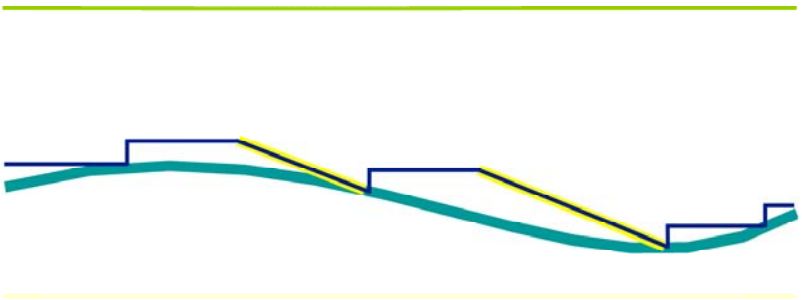
Dynamic Rate Recovery



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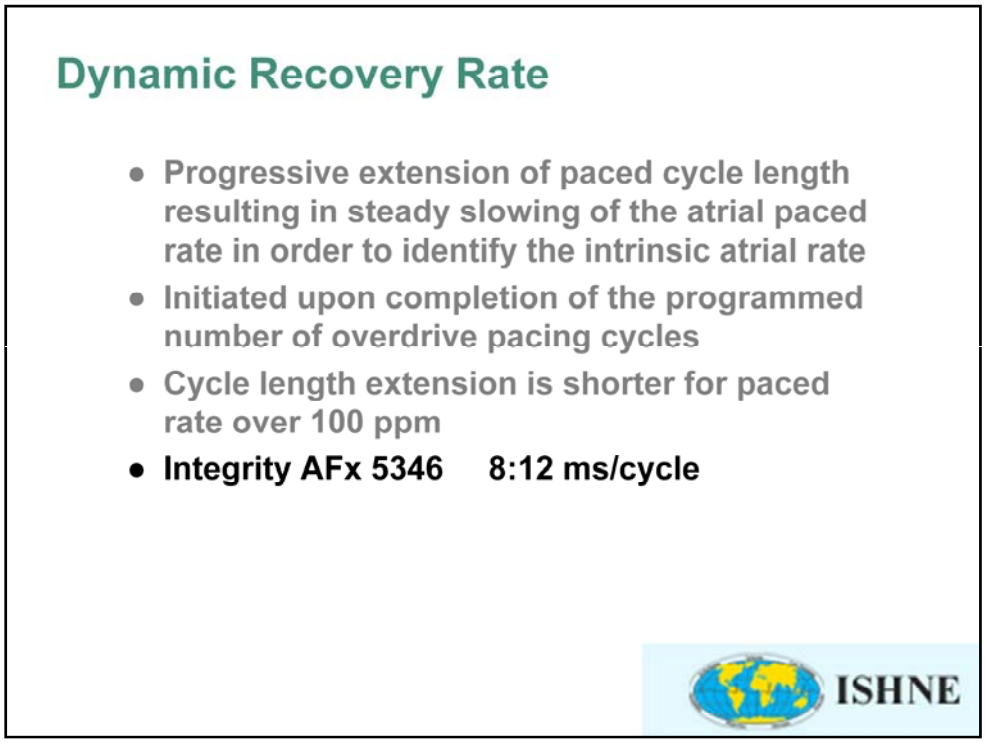
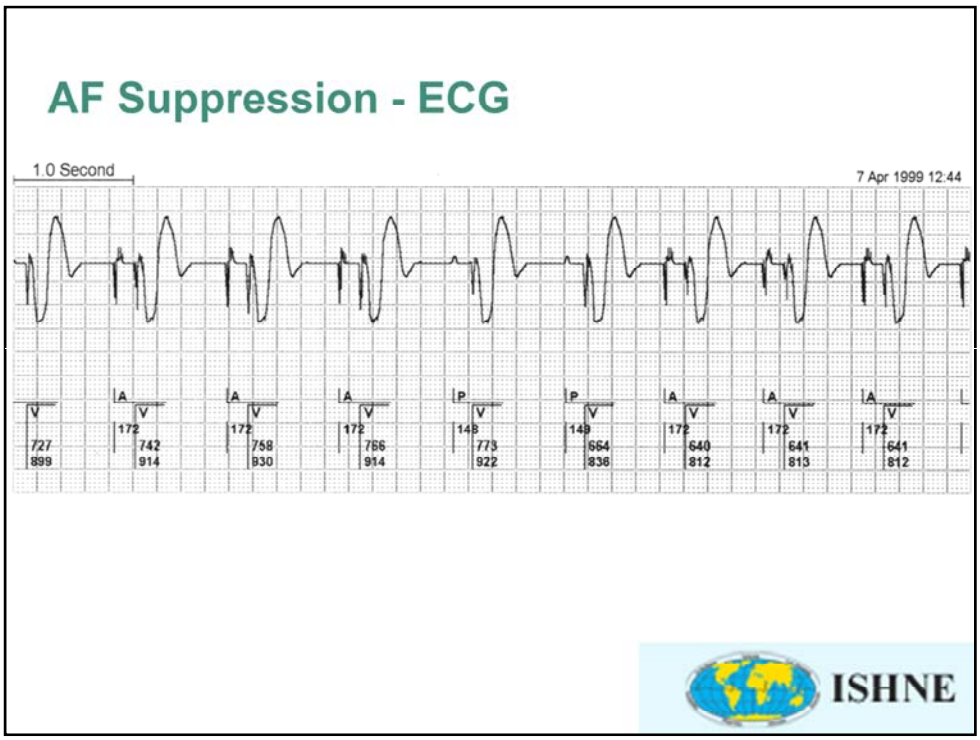


DAO Dynamic Recovery Rate (DRR)

If the rate were allowed to return to the baseline too abruptly, the patient is likely to experience bothersome palpitations and these abrupt changes may be arrhythmogenic in and of themselves. Hence, once the number of overdrive pacing cycles have timed out, the rate begins to decrease. At the higher rates, the relative decrease on each cycle is smaller (since smaller intervals still translate into equivalent rate decreases) while the millisecond increase in the cycle length increases at the lower rates.

The critical rate is 100 ppm. Above that, the first number shown in the programmable values is the millisecond change per cycle. Below 100 ppm, the second number represents the millisecond per cycle lengthening.

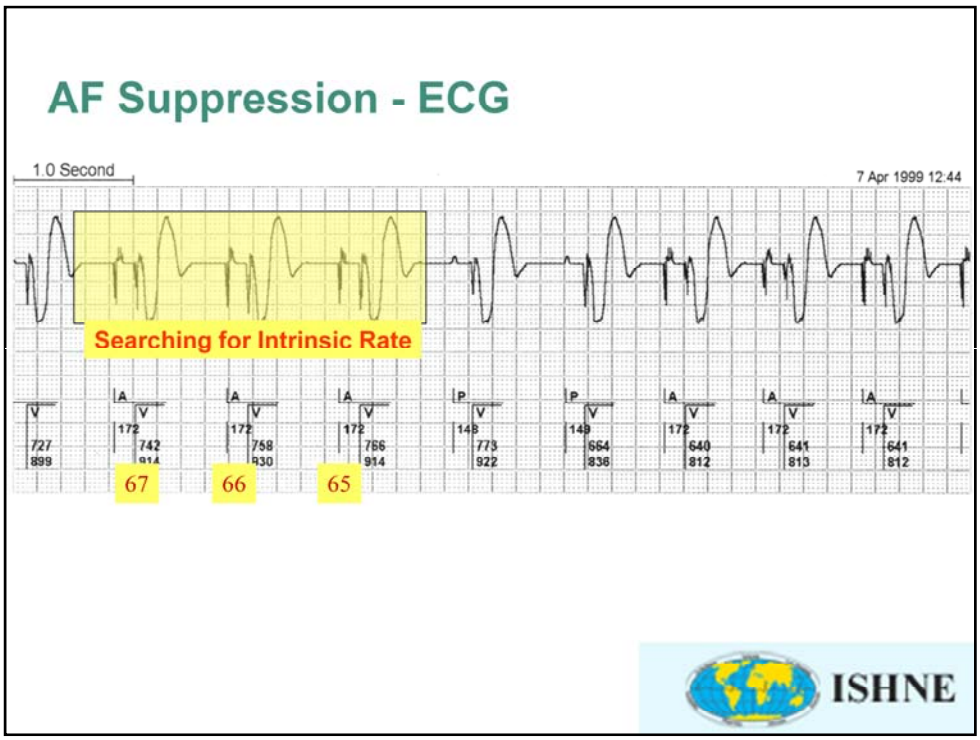


DAO - ECG Rhythm Strip

This tracing was recorded from the same subject from whom the Event Record was retrieved. The annotated event markers and electronic calipers document the behavior of the algorithm which in Frontier, continues to function while the device is in communication with the programmer. In Trilogy DR/DAO, the magnet which is integral to the telemetry module effectively inactivates the microprocessor and so demonstration of DAO behavior combined with markers will not be possible.

On the first three cycles on this recording, there is AV pacing (at a short AV delay, this was intentionally programmed as the Frontier was being studied for biventricular pacing and short AV delays for treatment of CHF) with a progressive lengthening of the VV cycle. There are then two native (sensed) atrial beats at a higher rate resulting in an increase in the atrial paced rate in accord with the programmed LRO/URO parameter.

Special Note: This rhythm strip is recorded at an expanded scale of 50 mm/sec. If one inadvertently interprets it as being recorded at a chart speed of 25 mm/sec, the rate will be misdiagnosed as being slower than it really is. As it was, the rate was above 100 ppm which means that if this were the ELA algorithm, it would automatically be disabled, In addition, if this were an ELA device, since the native P waves were not sufficiently premature, the algorithm would not have been enabled for this reason.



DAO - ECG Rhythm Strip

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On the first three cycles on this recording, there is AV pacing (at a short AV delay, this was intentionally programmed as the Frontier was being studied for biventricular pacing and short AV delays for treatment of CHF) with a progressive lengthening of the VV cycle. There are then two native (sensed) atrial beats at a higher rate resulting in an increase in the atrial paced rate in accord with the programmed LRO/URO parameter.

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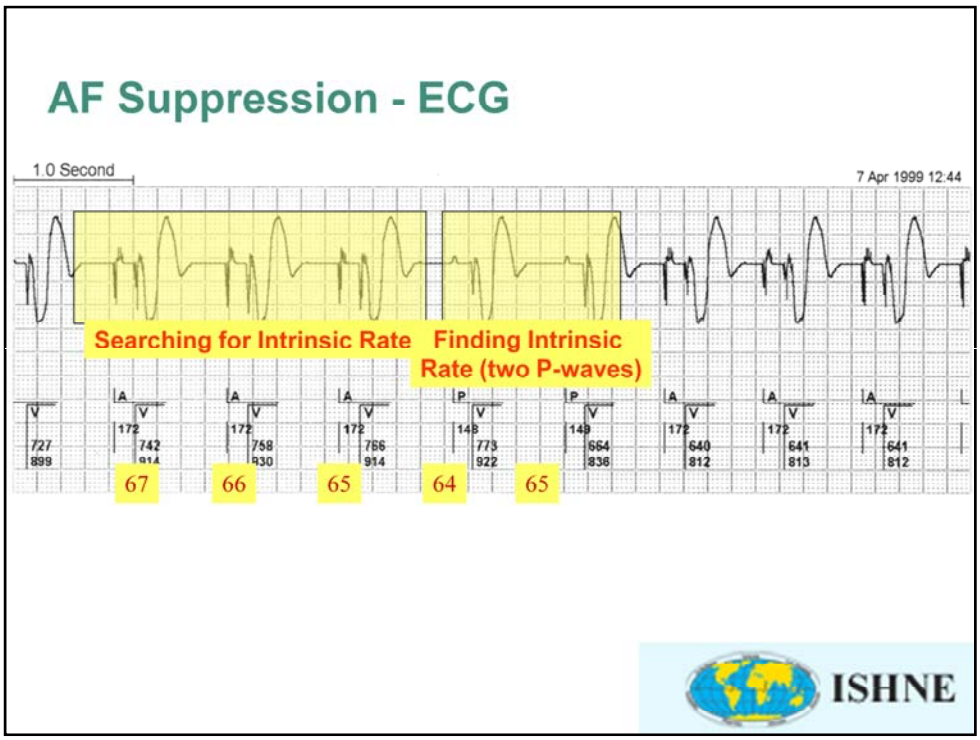

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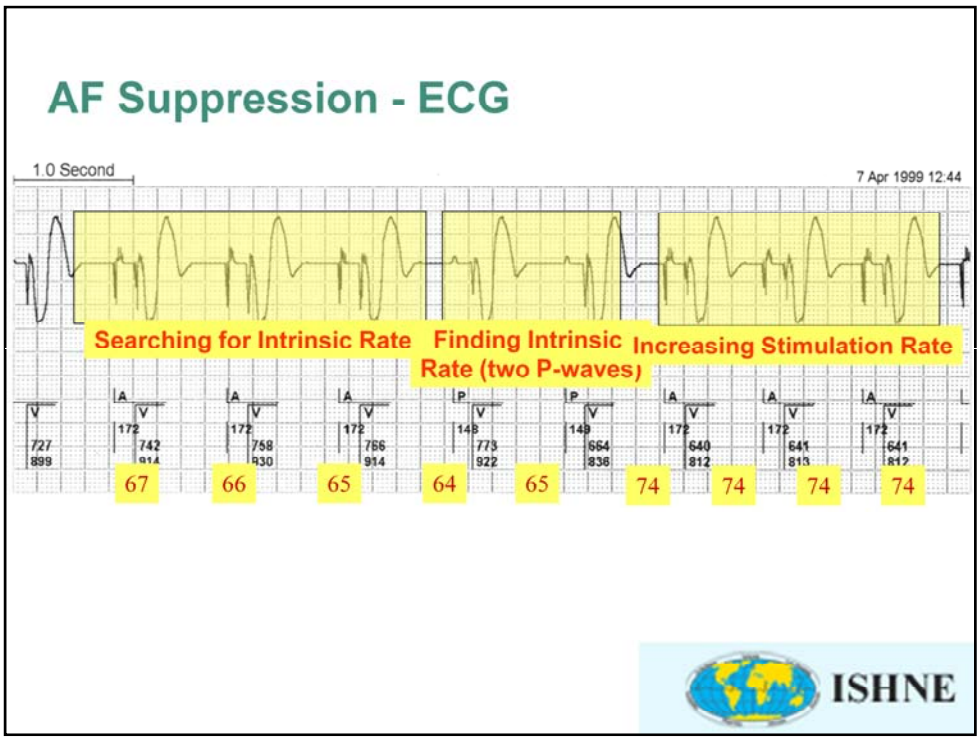

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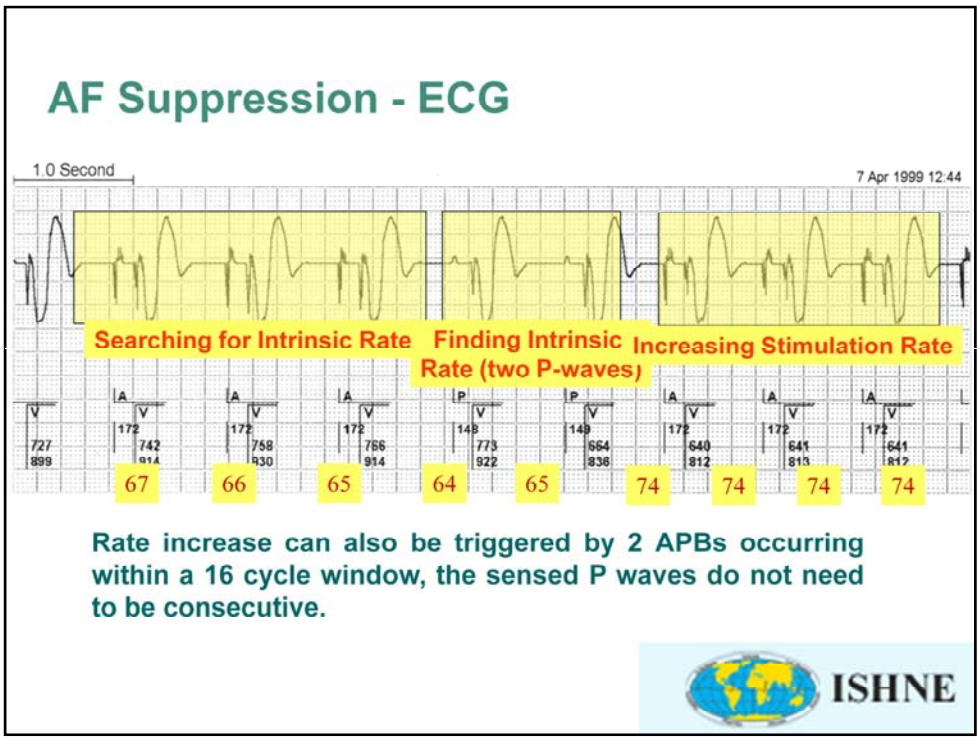

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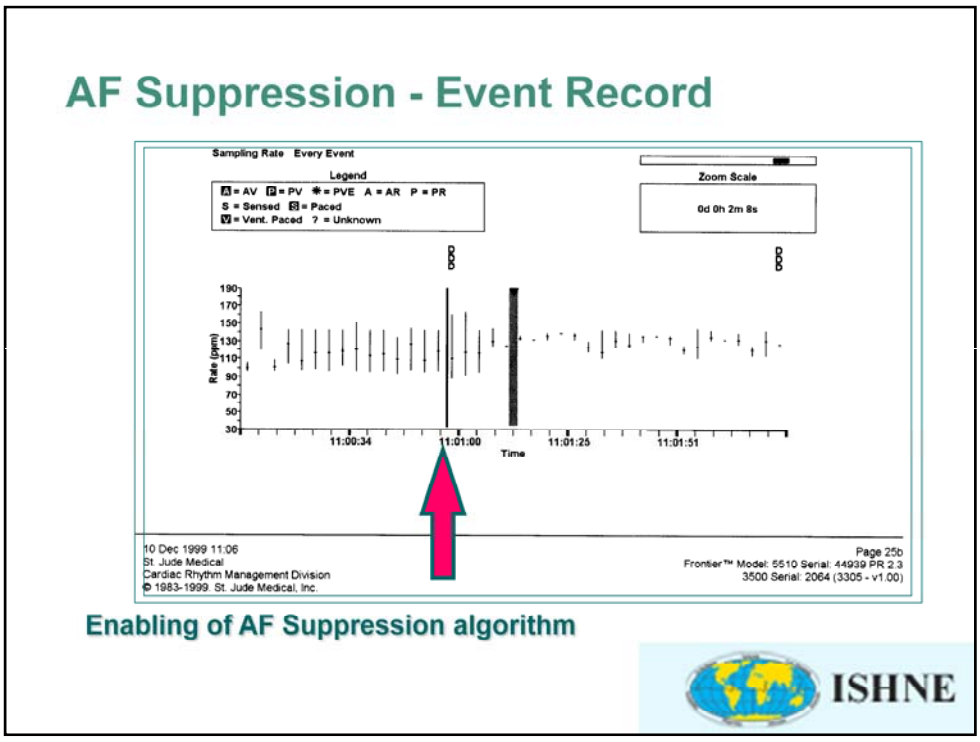
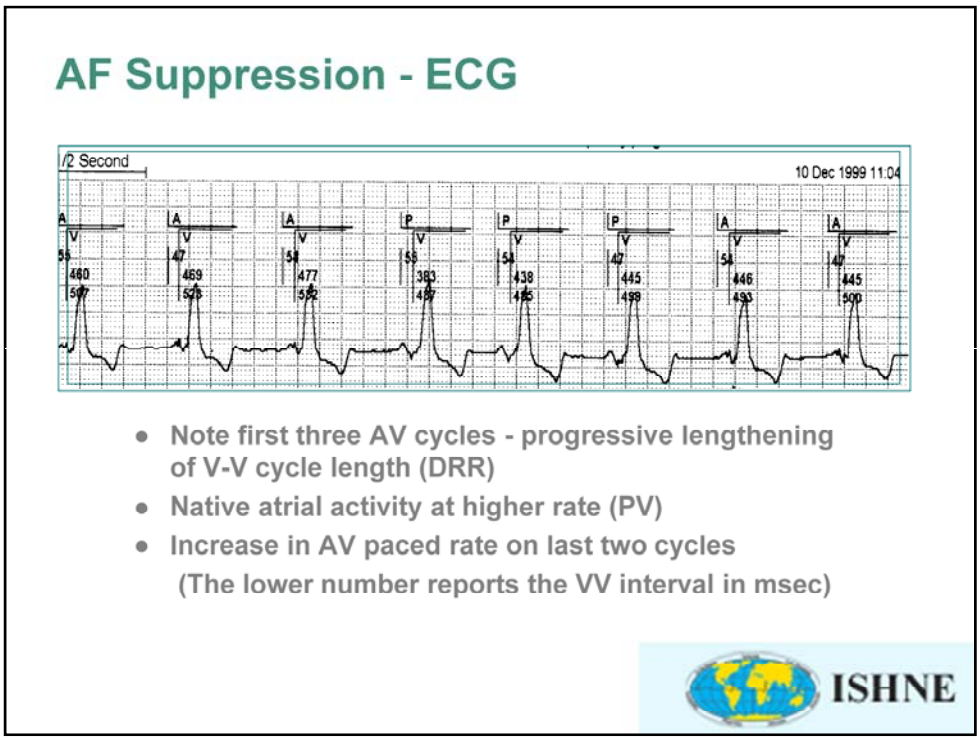


Event Record demonstrating the effect of DAO

This Event Record was obtained in an animal implanted with a Frontier DDDR pacing system. Frontier has both the DAO algorithm and allows for biventricular stimulation. This "patient" did not have paroxysmal atrial fibrillation but the intrinsic rhythm demonstrated a marked sinus arrhythmia with between 40-50 bpm fluctuations in heart rate. Activation of the DAO algorithm occurs at the arrow. This is also marked by a vertical line on the graphic printout with the label DDD above it. Within a few seconds, the rhythm stabilized with a marked reduction in the degree of rate fluctuation.



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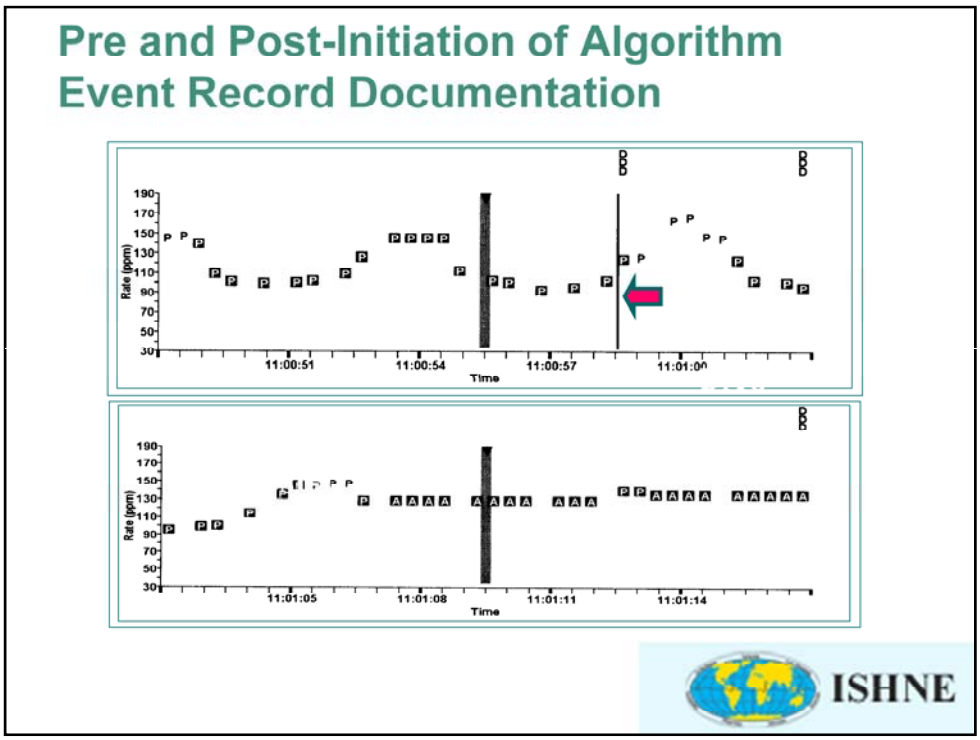
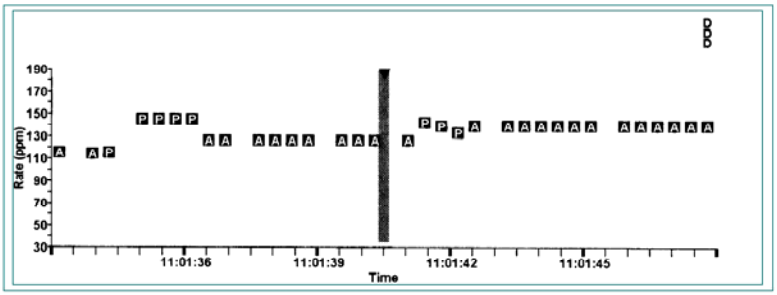


Event Record demonstrating development of rate stabilization

A series of two Event Record printouts showing the marked rate fluctuation before DAO is enabled. The vertical line on the top rhythm is the point of enabling DAO. There is a short period of time where the system is setting itself, looking at the rhythm before it starts to increment the rate. In addition, since the atrial rate was a sensed rate, the increment in atrial paced rate started at the base rate or sensor driven rate (which were the same in this case because the animal was at rest during these recordings). With each rate increment in accord with the LRO parameter, the system looked to determine if there were still sensed beats or was pacing present. When sensing was still present, it incremented the rate again.

As shown on the bottom printout, there is rate stabilization which then continues in accord with the overdrive cycle. Before this ends, there are two cycles of PV pacing at a slightly higher rate and the atrial paced rate is again increased in accord with the DAO algorithm.

Dynamic Rate Stabilization



- If, during stable atrial pacing, intrinsic atrial beats are sensed (P), by definition at a slightly faster rate, the algorithm automatically adjusts with a further increase in rate

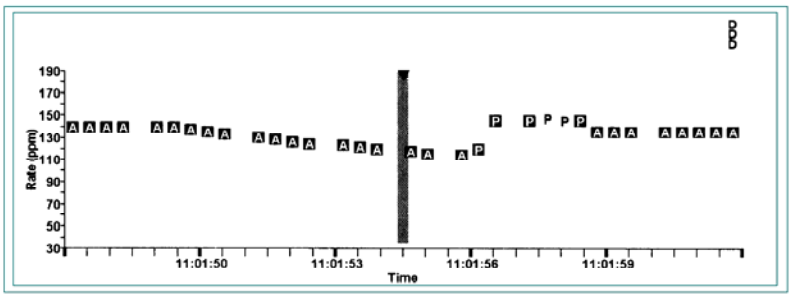
ISHNE

DAO Behavior during Overdrive Pacing

In another section of the Event Record, there is a stable rhythm. The periodic sensed atrial events cause an increment in the atrial paced rate. Again, each rate increment is limited to the programmed LRO/URO settings but rate increments will continue until atrial pacing is established.

The rate does not increment from the sensed rate but gradually works it way up so that overdrive occurs at the lowest rate possible which may be either at or even slightly below the native rate.

Dynamic Recovery Response



- After the period of stable overdrive is completed, the algorithm begins to progressively decrease the paced rate. When native atrial activity is again detected, the system increases the atrial paced rate.

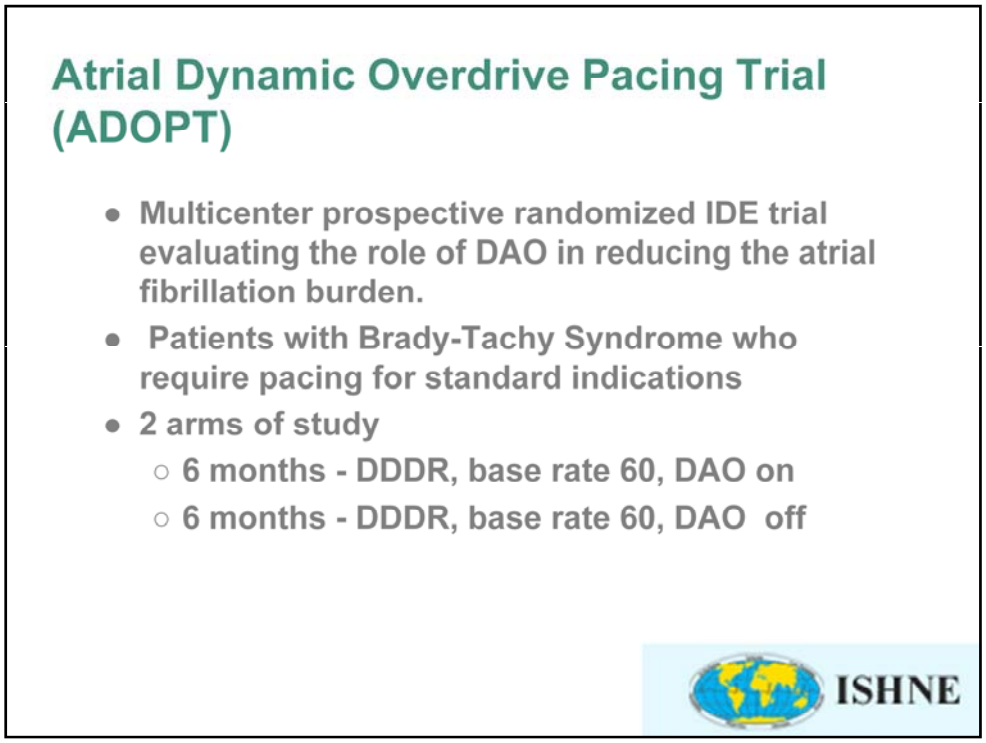
ISHNE

Event Record showing Dynamic Recovery Rate Behavior

From another section of the Event Record, the rhythm is stable, the overdrive pacing cycles have completed and the rate begins a smooth steady decrease in accord with the Dynamic Recovery Rate parameter. When it reaches a level that unmasks the presence of native P waves, the rate is incremented in accord with the LRO/URO parameters.

If there was stable atrial activity without ectopy and without higher rates, the DRR would allow the pacemaker to decrease all the way to the base rate or, if enabled and if engaged at the time, the sleep or rest rate.

The DAO algorithm does not supplant or usurp control from other algorithms that are integral to the pacemaker. Hence rate modulation, autointrinsic conduction search, sleep mode all continue to be functional.



ADOPT-A

This trial (ADOPT-A) involves patients with documented bradycardia-tachycardia syndrome who would normally receive a pacemaker for their symptomatic bradycardia. They will be randomized to DAO enabled or disabled. The base rate, rate-modulation and other parameters that affect the timing of the pacemaker will be identical.

For this initial study, the investigators are being asked to select the various DAO parameters from a reduced number of options for each component of the algorithm.

The patient will be in each arm for a 6 month period.

ADOPT-A

- 399 patients enrolled
- Enrollment concluded in December 2000

- Data presented at Late Breaking Clinical Trials session at NASPE; May 5, 2001

FDA approval of Integrity AFx 5346 with DAO algorithm in July 2001

ADOPT-A Results

Presented at NASPE, May 5, 2001

- Over 90% of atrial arrhythmias were atrial fibrillation
- Percentage of atrial pacing:

  DAO enabled 92.9%

  DAO off 67.9%

  P < 0.0001
- Overall AF burden reduced by 25.03% in DAO group compared to DAO off **P < 0.05**
- Excluding all patients with no AF episodes more than 30 days post-implant, DAO associated with a further 36.33% reduction **P < 0.02**

ADOPT-A Results

Presented at NASPE, May 5, 2001

- Symptomatic "AF Burden"
  - Any 20 second episode of ECG documented AF (all patients had transient arrhythmia monitors for the duration of the study) in a given day was accepted as "1 day of AF"
  - For the purpose of this study, 20 seconds of AF was the equivalent of a full day of AF
- Biased the analysis against the DAO algorithm

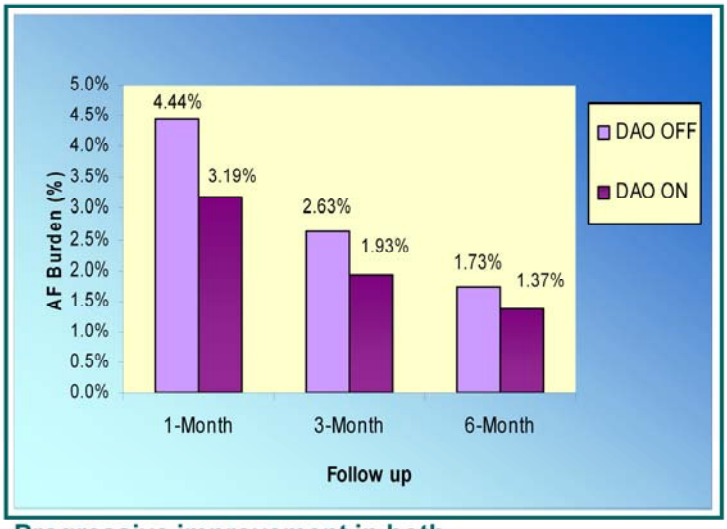
ADOPT-A Results

Presented at NASPE, May 5, 2001

- Reduction in AF levels from baseline
  - DAO enabled 60% **P < 0.001**
  - DAO off 45% **P < 0.001**
- Quality of Life - significant results
  - DAO enabled
    - Standardized physical **P = 0.013**
    - Standardized mental **P < 0.001**
  - DAO off
    - Standardized mental **P < 0.001**

Presented at NASPE 2001

ADOPT-A



Progressive improvement in both groups but AF Suppression always had a lower symptomatic AF Burden

ISHNE

ADOPT-ALL

Presented at European Society of Cardiol - Sept 2001

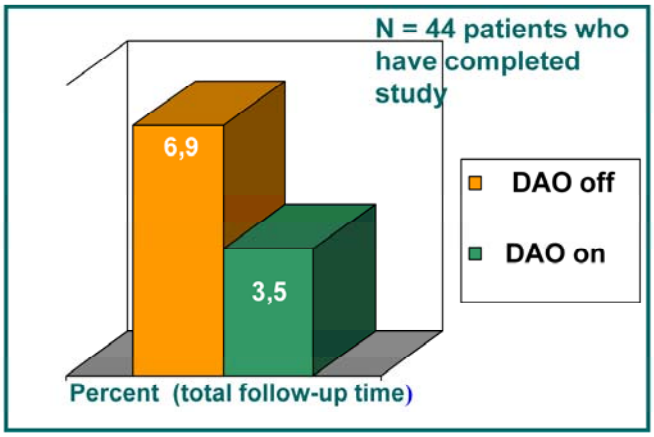
- N = 250 (planned) Results on first 50 patients
- Prospective randomized cross-over study @ 4 centers

Results	DAO on	DAO off	% decrease
AMS burden (all)	75.5	98.1	23%
AF burden (all)	39.9	65.6	39%
AMS burden (Aus.)	45.5	126.7	64%
AF burden (Aus.)	26.1	56.4	54%

burden = minutes/day

Beinhauers A, Eur Heart J 2001; 22: 554

AMS Burden
Austrian Centers in ADOPT-ALL



AMS burden reduction 49.4%*

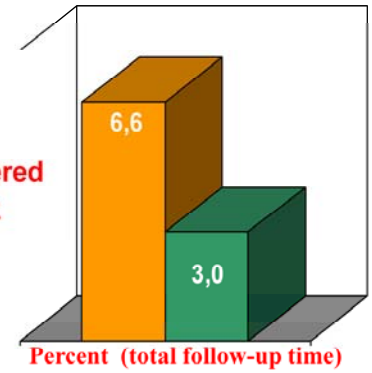
***p = 0.039**

Beinhauer, et al, Europace 2002
(Presented at Cardiostim 2002)

ISHNE

AF Burden
Austrian Centers - ADOPT-ALL

AF = all AMS episodes triggered by atrial rates ≥ 275 ppm +



N = 44 patients who have completed study

- DAO off
- DAO on

AF burden reduction 54.4%*

*p = 0.033

ISHNE

CAP + Site Specific Location

- N = 46, Randomized to RAA (24) or IAS (22) pacing
- All patients had PAF + Symptomatic Sinus Brady
- Within each arm, randomized to CAP on or off for 3 month periods

	Rt. Atrial Appendage		Inter-Atrial Septum		P value
Algorithm	OFF	ON	OFF	ON	
% A Pacing	79	96*	83	97*	* 0.001
Symptomatic PAF	2.1	1.9	0.2	0.2	
PAF burden	140 m/d	193	47	41	
Time to 1st AF	6.8 d	6.7	9.6 d	6.7	
Asymp. Pts	20	18	20	21	

Stimulation site location impacted PAF but not the CAP algorithm

Padeletti L, et al, Am Heart J 2001; 142: 1047-1055

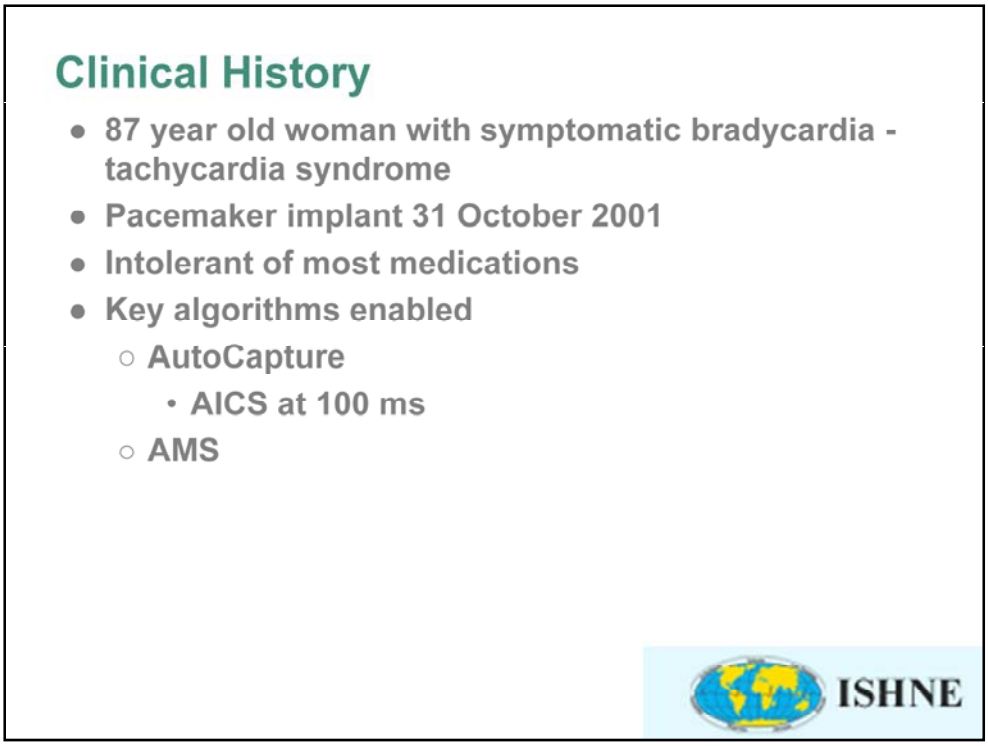
Overdrive stimulation

- Designed to minimize pauses following ectopic beats
- Suppresses ectopy
- Reduces dispersion of refractoriness by maintaining control of rate and rhythm

But at a fixed high rate it may. . .

- Be uncomfortable for the patient
- Induce cardiomyopathy and decrease ventricular function over time
- Lose protection if the atrial rate exceeds the programmed rate
- Limit device functionality

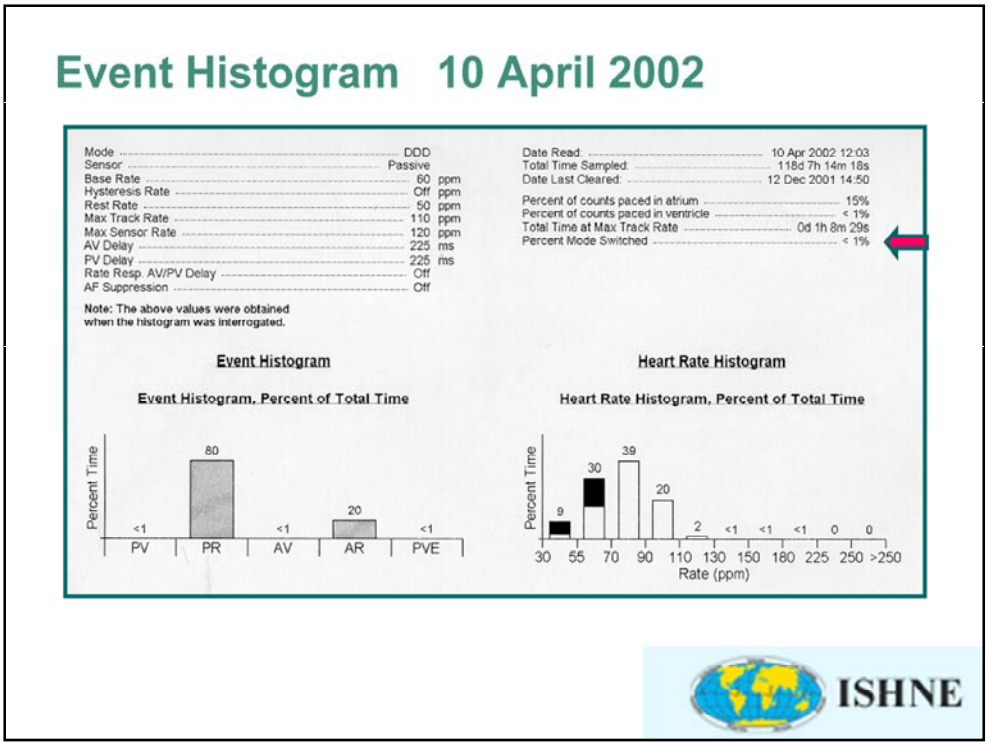
AF Suppression (DAO) provides *all the benefits* of overdrive stimulation *without the drawbacks* of high fixed rate pacing



Clinical History

The patient is an 87 year old woman, very frail with severe sinus node dysfunction and documented paroxysmal atrial fibrillation. She was near-syncopal with the pauses in her rhythm associated with spontaneous termination of her AF episodes. In addition, the AF episodes were frequent. A number of pharmacologic agents were tried in an effort to stabilize the rhythm, (digoxin, beta blockade, sotalol, and flecainide) - all of which were either ineffective or further exacerbated her bradyarrhythmia. In addition, she complained of side effects with virtually every one of them. She was placed on Coumadin because of the frequent episodes of AF.

An Integrity micro was implanted on October 31, 2001. At that time, AutoCapture was enabled with a bipolar back-up pulse and AMS was enabled to quantify the frequency and severity of her AF episodes.

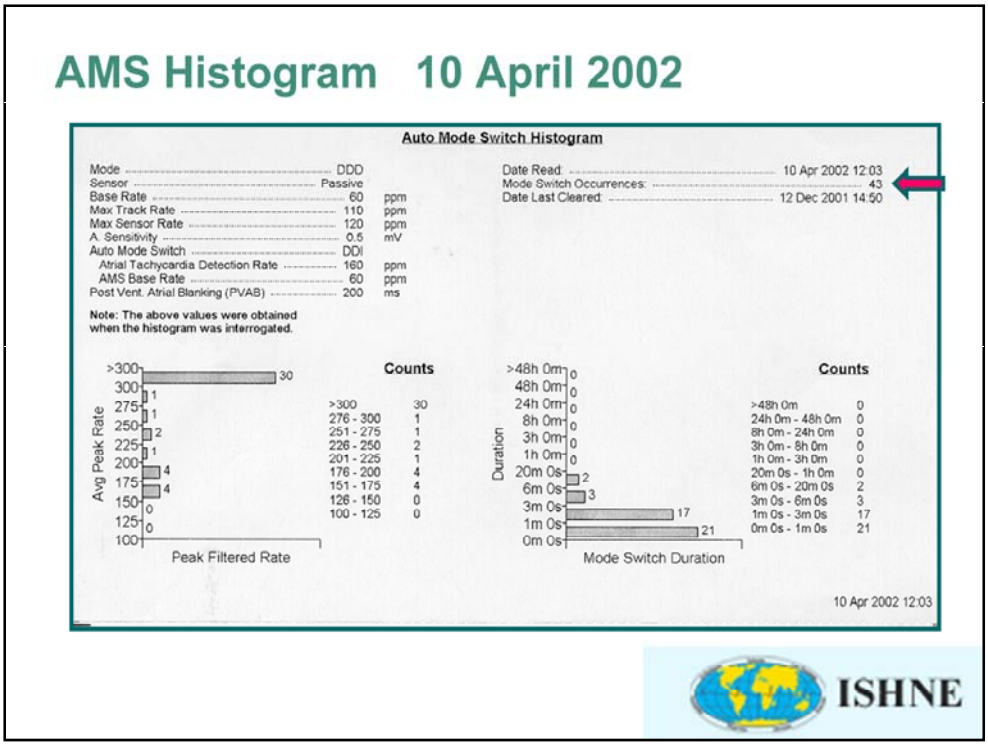


Event Histogram

This is the top half of the Event Histogram. In Integrity, it only displays the pacing states and heart rate distribution when in the DDD mode. It will not display the heart rates during DDI (Automatic Mode Switch) and hence, we cannot determine the degree of control (or lack of control) of the ventricular rate that is present during AMS.

Based on this HRH, it does not appear that this patient needs rate modulation. Her HRH shows the expected normal (bell-shaped) distribution suggesting normal chronotropic function. However, this may be misleading in that some of the higher rates may also be due to frequent atrial ectopy. As a standard DDD pacemaker, her system would protect her from the profound pauses following termination of the atrial fibrillation episodes.

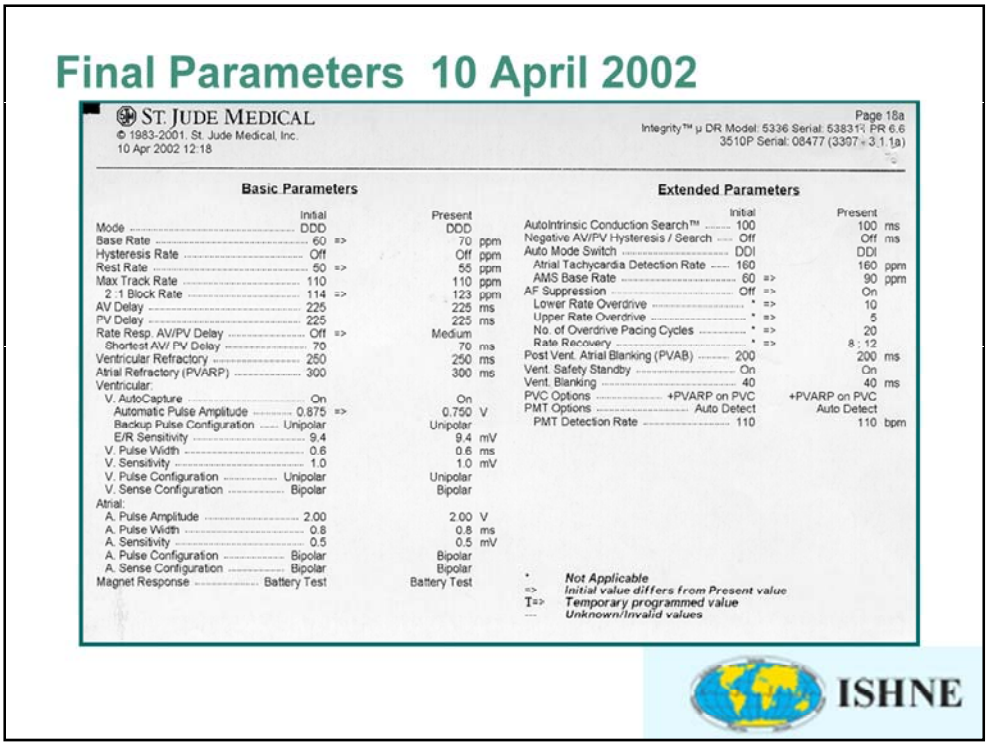
Note that less than 1% of the time was spent in AMS.



AMS Histogram

There were a total of 43 AMS episodes. Two thirds were triggered by detected atrial rates > 300 ppm consistent with atrial fibrillation. The others at the lower rates probably represent some signal drop out resulting in detection of lower rates. This patient was never previously identified as having organized atrial tachycardias. Most of the episodes were brief in duration but 2 lasted between 6 to 20 minutes and 17 lasted between 1 to 3 minutes.

When AMS was enabled, the presence or absence of far field R waves was specifically evaluated. Far Field R waves were present at a ventricular stimulus to far field P wave at 140 ms. The PVAB was programmed to 200 ms. While this makes the identification of an organized atrial tachycardia more difficult, it does not limit the identification of atrial fibrillation. This is another reason why I believe that the AMS episodes triggered by the lower rates is probably atrial fibrillation with signal drop-out.



Final Programmed Parameters - April 10, 2002

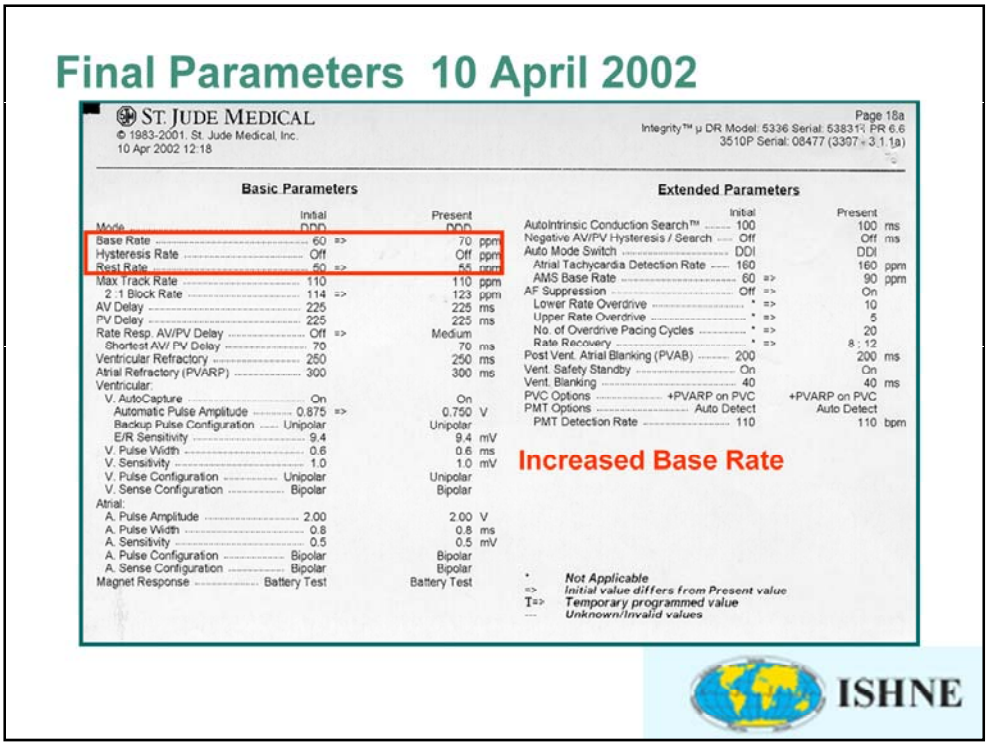
This is the printout documenting the final programmed settings after the April 10th evaluation. The base rate was increased by 10 ppm to 70 ppm and the Rest Rate was increased from 55 to 60 ppm.

An AMS base rate was increased to 90 ppm. This was an original oversight when AMS was first enabled. The higher AMS base rate should have been enabled at that time.

AF Suppression was also enabled.

Assuming that no special algorithms are enabled at the 4-5 month post-implant evaluation, my routine is to ask the patient to return in approximately 6 months. When special algorithms are enabled, it is appropriate to see the patient sooner to assess the response to the special algorithm. The same would hold for enabling of rate modulation, increasing the PVAB if it was thought that some of the AMS episodes were inappropriate due to FFRW sensing…..

Hence, this patient was scheduled to return in July, three months after the current evaluation.



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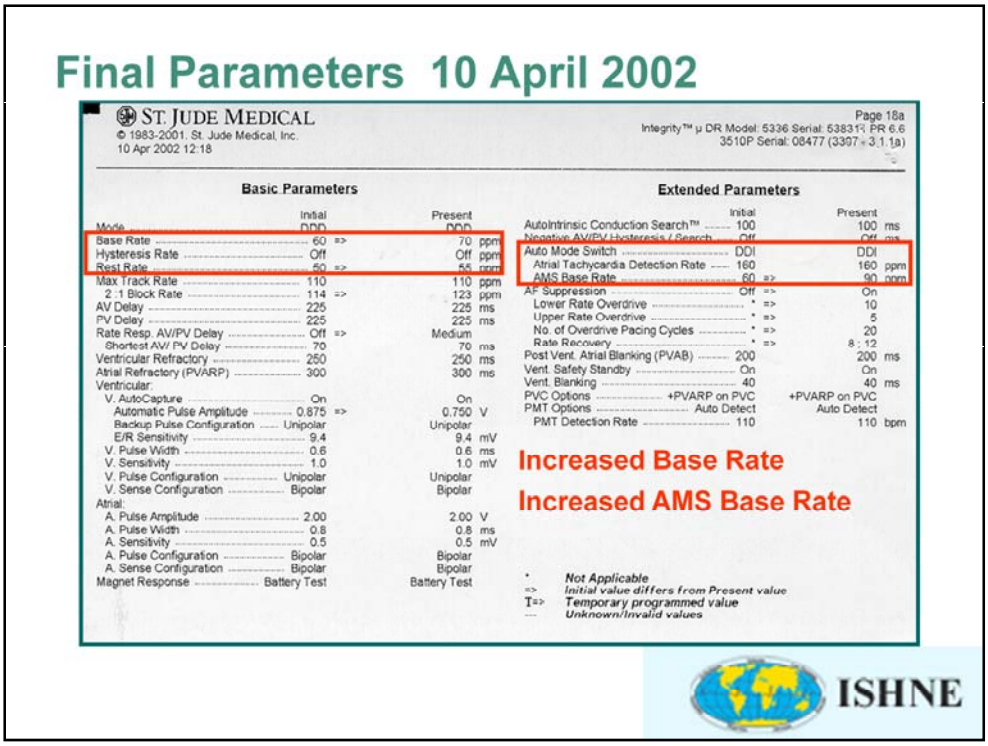

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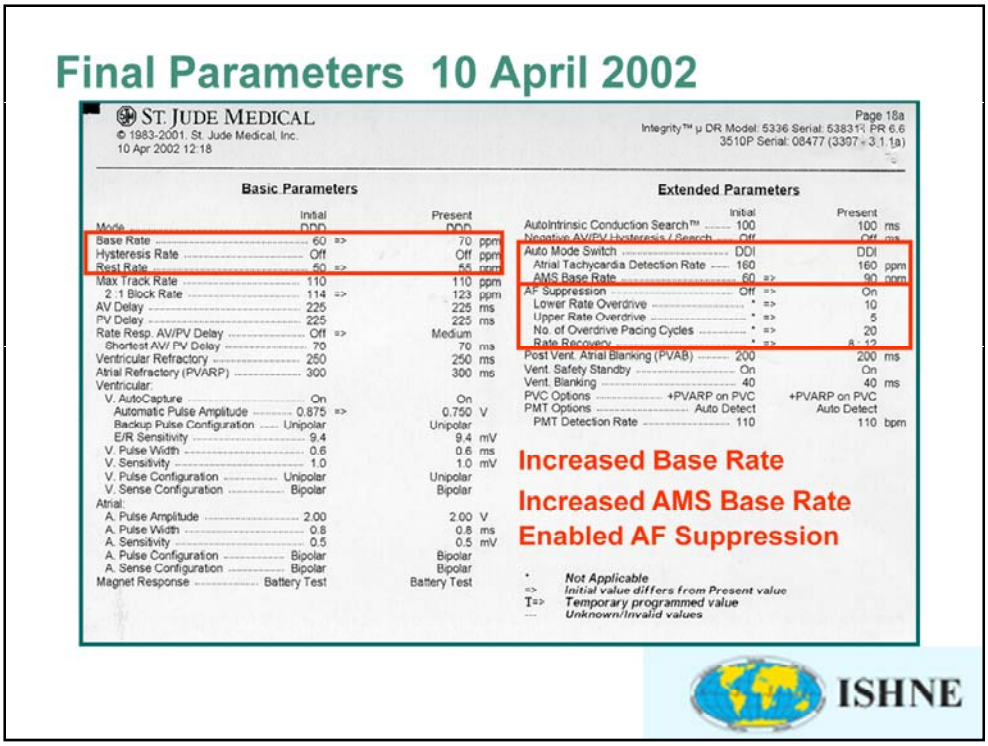

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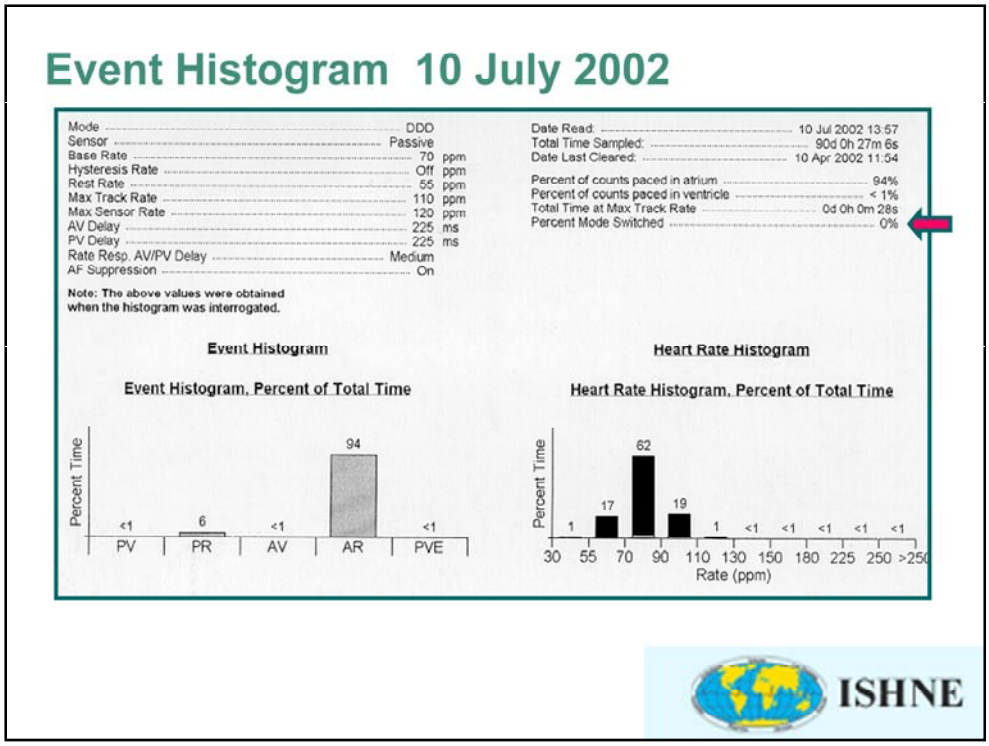
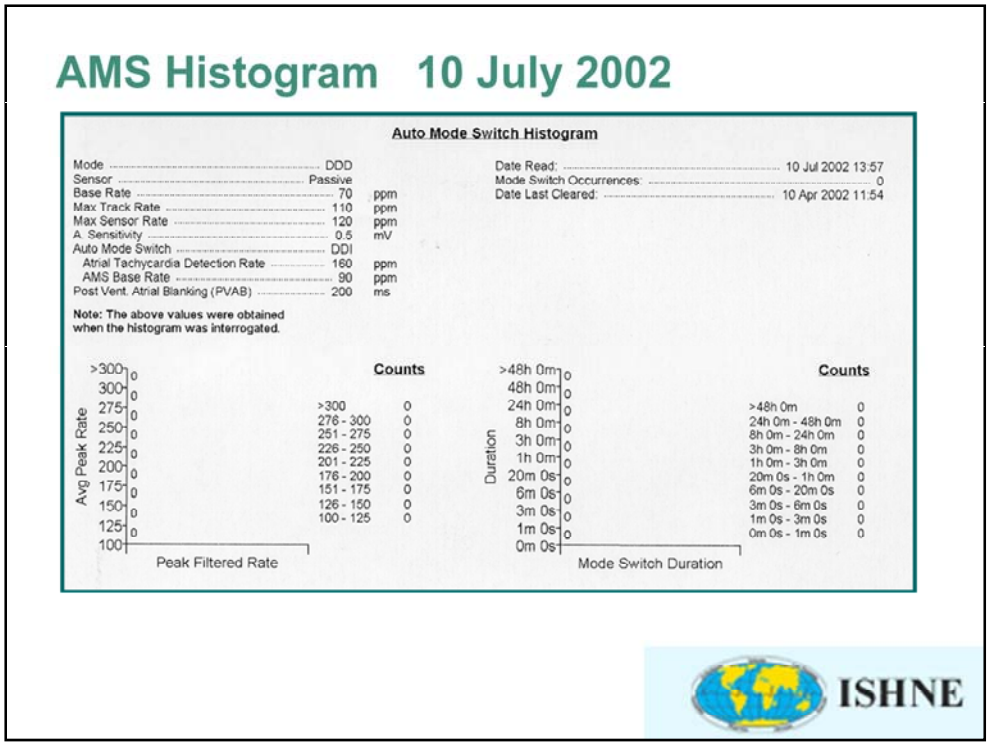


Event Histogram - July 10, 2002

This is the follow-up Event Histogram from her evaluation on July 10, 2002. The distribution of pacing states has gone from 20% AR and 80% PR to 94% AR and 6% PR. The Heart Rate Distribution shows a much narrower range of rates that are virtually all atrial paced. This is a pattern that one might expect to see when rate modulation is enabled but, in this case, it is due to AF suppression as rate modulation is disabled.

Where as pure rate modulation may result in some competition between the native P waves and the atrial paced events depending on how the sensor is programmed, there is absolutely no competition with AF Suppression as detected atrial events (2 within a 16 cycle window) result in an acceleration of the paced atrial rate such that it usurps control of the atrium from either the sinus node or an ectopic focus, which ever happens to be controlling the atrial rhythm at the time.

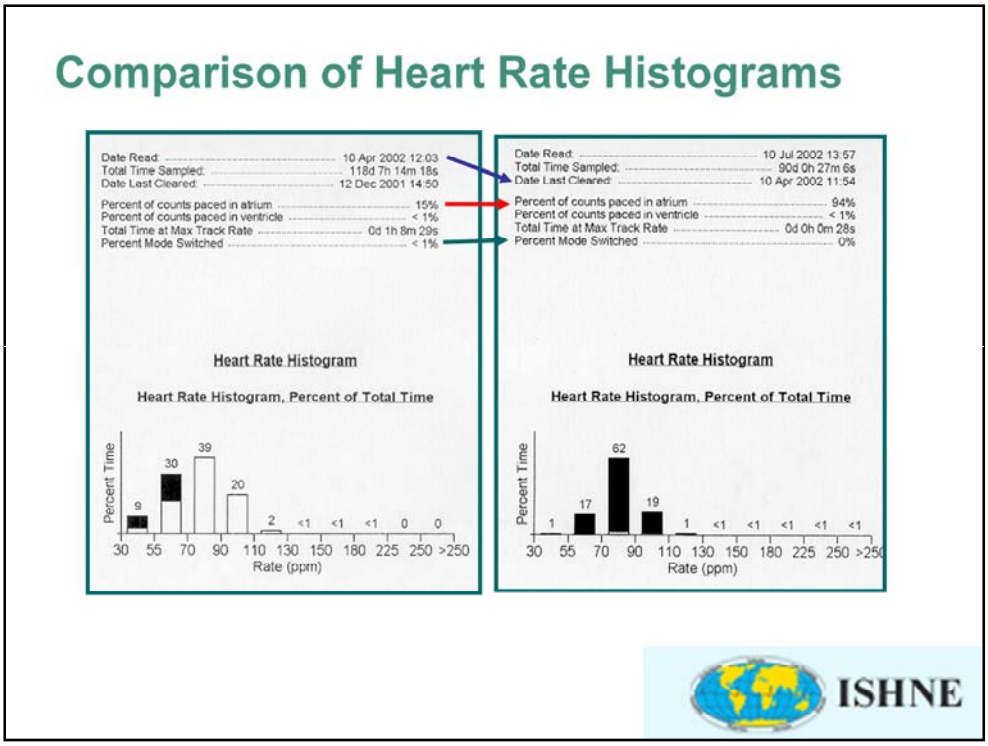
Also note that 0 (zero) % of the time is spent in AMS.



AMS Histogram - 10 July 2002

This is the AMS histogram showing that there are absolutely no AMS episodes. This is not simply the printout after the histogram had been cleared. In that setting, look at the top right corner of the printout. The date read and date last cleared would be the same. This is the AMS histogram for the entire period since the last evaluation in April 2002.

[Note: Medtronic Kappa provides an AMS log but if NO AMS episodes have occurred, it cannot be printed or even displayed on the programmer. This makes some sense in that there is no data available but on the other hand, the printout showing no events is further documentation and confirmation that no events have occurred during the monitoring period.]

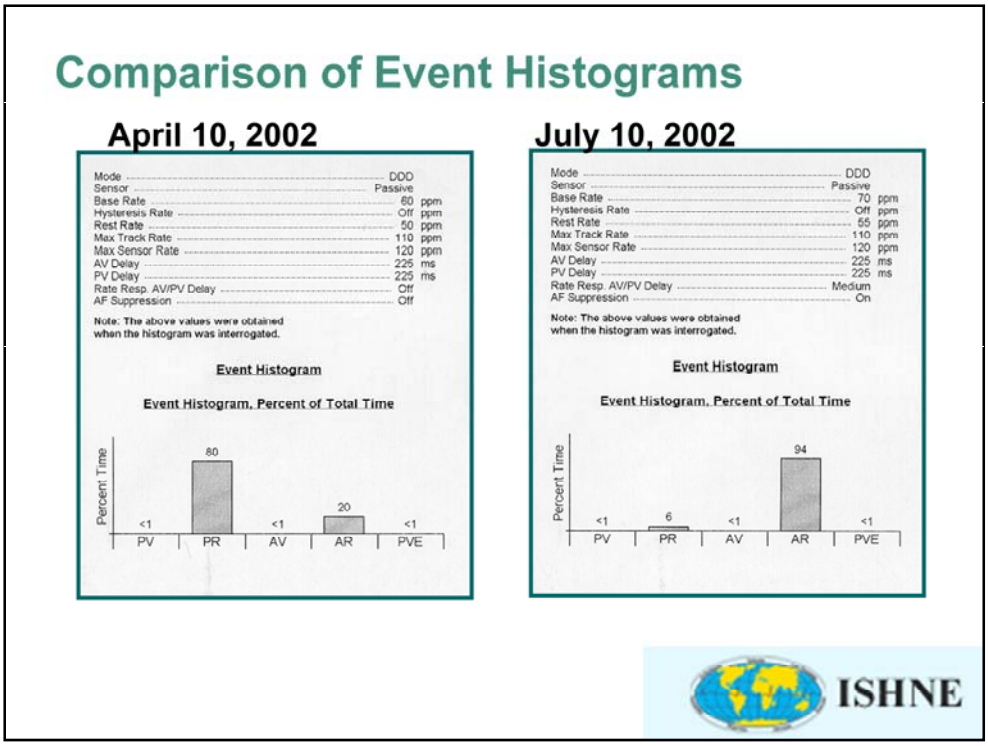


Side-by-Side Comparison of Heart Rate Histograms

This is a side by side comparison of the Heart Rate Histograms. On the printout from April 10, the Rest Rate was programmed to 50 ppm accounting for significant events in the lowest rate bin. Also, there were significant native P waves occurring in the 55-70 rate bin and all the rates above that were due to intrinsic atrial activity as rate modulation was not enabled.

Following activation of the AF Suppression algorithm along with a slight increase in the programmed base rate and Rest Rate, the HRH shows the majority of events are atrial paced with the largest percentage being in the base rate (70-90) rate bin. Seventeen percent were below the programmed base rate due to a Rest Rate of 60 ppm.

Arrows identify the key points of comparison with respect to percent atrial paced and percent mode switch. An arrow is also directed from when the April 10 Event Histogram was retrieved to when it was cleared. The time difference was due to the resetting of the programmer for Daylight Savings Time since it is the programmer that puts in the times based on its calculations from the data.

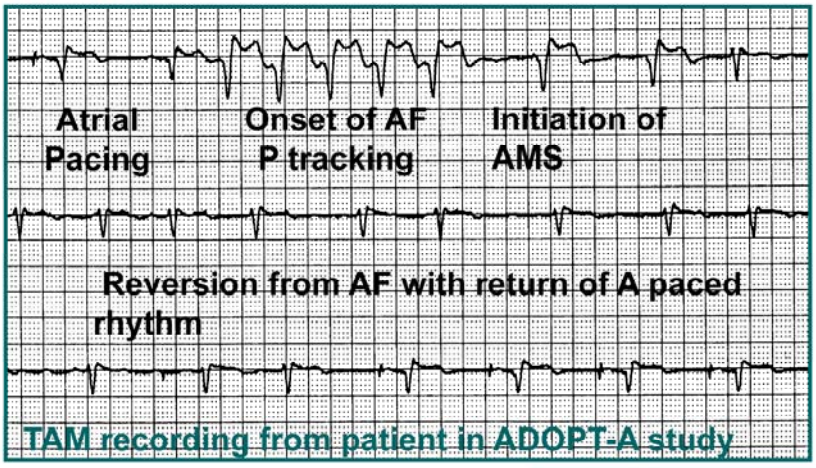


Side-by-Side Comparison of the Event Histogram

This is a side-by-side comparison of the pacing state portion of the Event Histogram. The control of the atrial rate due to the AF suppression algorithm is very apparent. Indeed, during the ADOPT A trial, atrial pacing accounted for approximately 60% of the events in the group randomized to AF Suppression OFF and 92% when the algorithm was enabled.

This patient is even more dramatic with 96% of the events being atrial paced after AF Suppression was enabled compared to only 20% of the events prior to enabling this algorithm. It should be noted that the relatively low percentage of atrial pacing prior to enabling the AF Suppression algorithm was due to the indication for pacing. This patient did not have a persistent bradycardia. The most marked sinus bradycardia with long asystolic pauses followed spontaneous termination of the episodes of paroxysmal atrial fibrillation. Between spells, her sinus rate was often slow but would increase with activity and thus, her level of sinus node dysfunction was not as marked as in other patients.

Management of Patients with Paroxysmal Atrial Fibrillation who already have a permanent pacemaker



TAM recording from patient in ADOPT-A study

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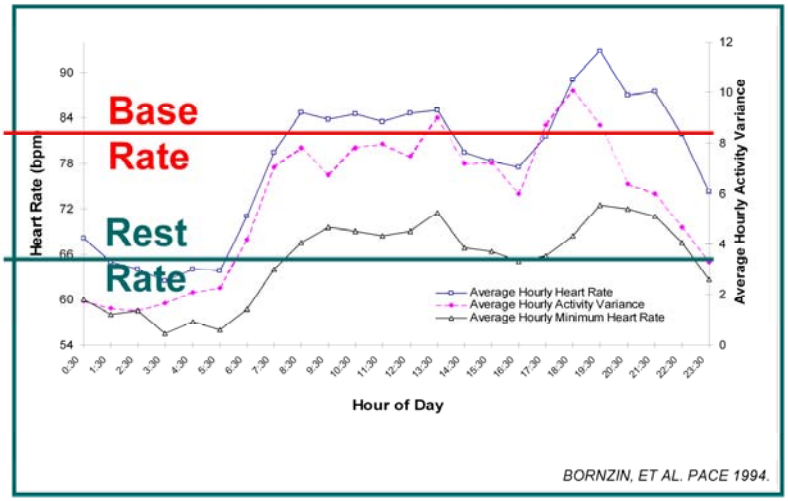
Management of PAF in the Paced Patient when special algorithms are not available

- Programmed mode DDDR (or AAIR)
  and
- Fixed high base rate (e.g. 80 to 90 ppm)
  or
- Combine higher base rate with dynamic rest rate (e.g. COP study, PROVE study)

Normal Heart Rate Behavior



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Atrial Fibrillation Prevention by Overdriving study (PROVE - ELA Medical)

- Prospective single blind study
- Group I: Base Rate 80 ppm, Rest Rate 60 ppm; APB overdrive algorithm increasing base rate in response to APB, DDDR mode; DC Meds
- Group II: Base Rate 70, Rest Rate 55 or Base Rate 60 and no Rest Rate; Meds continued
- Fixed overdrive + Rest Rate "seems to prevent atrial arrhythmias" (trend but not significant)

Funck RC, PACE 2000; 23: 1891-1893

Circadian Overdrive Pacing (COP) Trial - St. Jude Medical

- Prospective randomized trial comparing fixed base rate pacing versus higher base rate combined with rest rate on the frequency of atrial fibrillation episodes
- N = 55 patients
  - Sinus node dysfunction and PAF (35 pts)
  - AV block (20 pts)

de Vusser P, Europace 2001: 2: A71

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Circadian Overdrive Pacing (COP) Trial - St. Jude Medical

	Mode switch Occurrences				
Base rate in ppm	**Fixed Overdrive** Base Rate 70 ppm	**Fixed Overdrive** Base Rate 50 ppm	**Circadian Overdrive** Base Rate 95 ppm Rest Rate 65 ppm	**Circadian Overdrive** Base Rate 80 ppm Rest Rate 65 ppm	**Fixed Overdrive** Base Rate 70 ppm
All patients (N= 55)	490±55	550±77	257±45	249±73	511±69
AV block (N=20)	10±10	15±61	11±20	11±9	6±8
SSS + PAF (N=35)	480±66	535±32	246±36	238±63	505±62

P < 0.01

Sequential 3 month periods - total duration 15 months

Appropriate AMS confirmed by Holter

de Vusser P, Europace 2001: 2: A71

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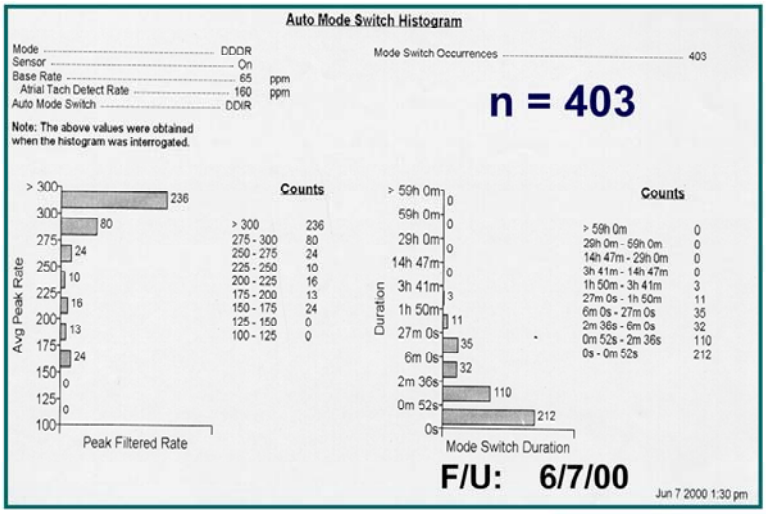
Clinical History

- 75 year old male with classic bradycardia-tachycardia syndrome
- DDDR pacemaker implanted for symptomatic bradycardia - Functional AAIR pacing
  - Base rate 65 ppm
  - Long AV delay
- Repeated frequent episodes of paroxysmal atrial fibrillation
  - Started on Sotalol - titrated to 120 mg BID

Continuing palpitations and dyspnea; 6 weeks of Sotalol; Blunted heart rate response



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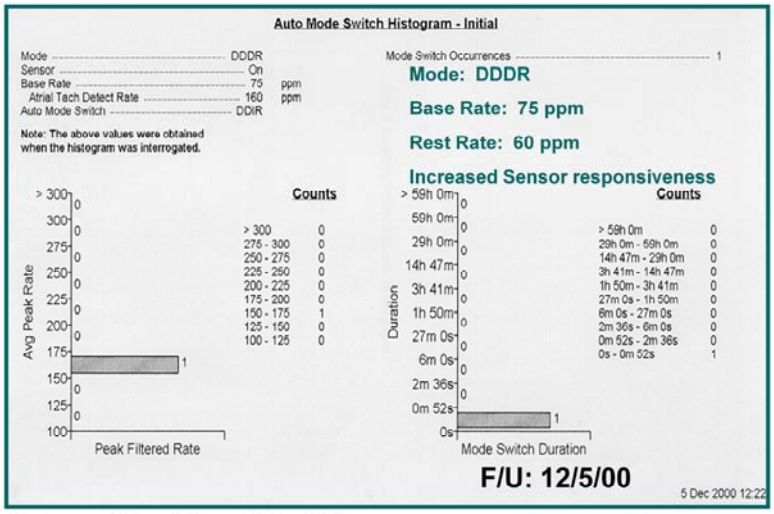
Patient Asymptomatic



Between Dec '00 and Mar '01 - weaned off of Sotalol

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Cardiac Output - Sinus rhythm vs Atrial Fibrillation

- Higher base rate required to compensate for loss of atrial transport
- Similar Cardiac Outputs (lone paroxysmal AF)

	Sinus Rhythm	Atrial Fib
Rest	60 ppm	90-100 ppm
Mild Ex.	90 ppm	130 ppm

Resnekov, Brit Heart J, 1971; 33: 339-350

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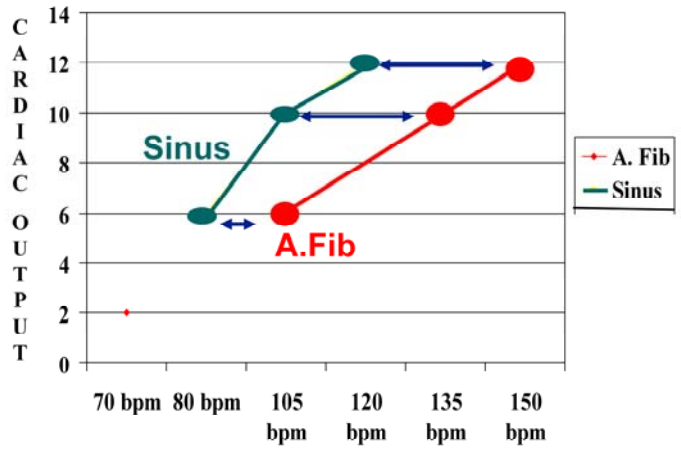
Cardiac Output - Sinus rhythm vs Atrial Fibrillation



Resnekov, Brit Heart J, 1971; 33: 339-350

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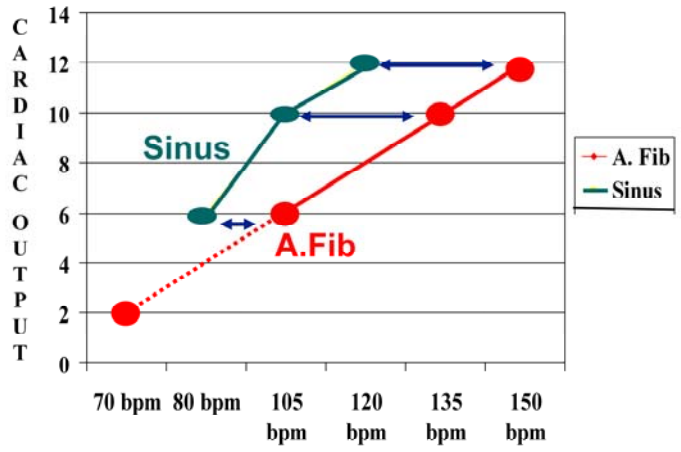
Cardiac Output - Sinus rhythm vs Atrial Fibrillation



Resnekov, Brit Heart J, 1971; 33: 339-350

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Hemodynamics of AF vs Sinus

- Comparison of sinus rhythm to induced AF @ rest

	Sinus	AFib	p value
Heart Rate	84 bpm	132 bpm	<0.001
Syst. BP mmHg	169	152	<0.01
PCW mmHg	9.7	18.6	<0.01
CO L/min	4.4	3.8	< 0.02

Differences attributed to the loss of atrial transport

Lau, Eur Heart J 1990; 11: 219-224

Optimal Heart Rate in association with Atrial Fibrillation during AMS

- "Achieving a target ventricular rate of 90 to 100 bpm **at rest** would result in the control of the cardiac output with the least compromise in such patients."
- "There is a general consensus that the ventricular rate, when in atrial fibrillation, needs to be 30 to 40 bpm faster than when in sinus to compensate for the loss of atrial transport."

Brunner HP, PACE 2000; 23: 32-39

"Base" Rate during Atrial Fibrillation and Intact AV Conduction

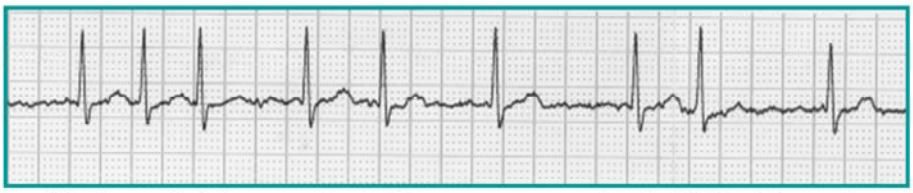
- N = 38

	VVI @ 40	VVI @ 80	p value
% pacing	8.2	82.8	< 0.01
Mean Abs. Diff	215 ms	63 ms	< 0.01
R-R instability	24 %	8.1%	< 0.01
HR > 80 bpm	29%	14.2%	< 0.01

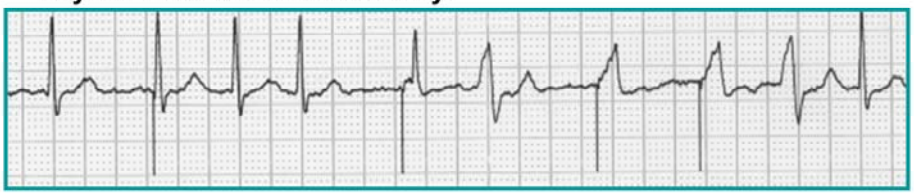
Proposed mechanism: retrograde concealed conduction into AV node

Chudzik M, Europace 2001; 2: A95

Atrial Fibrillation and AMS
Effect of Base Rate



Mode switch base rate at 60 ppm, pacemaker inhibited by native rhythm. Marked rate instability.



Mode switch base rate at 90 ppm, pacemaker plays an active role. Increase in rate stability due to retrograde concealed conduction.

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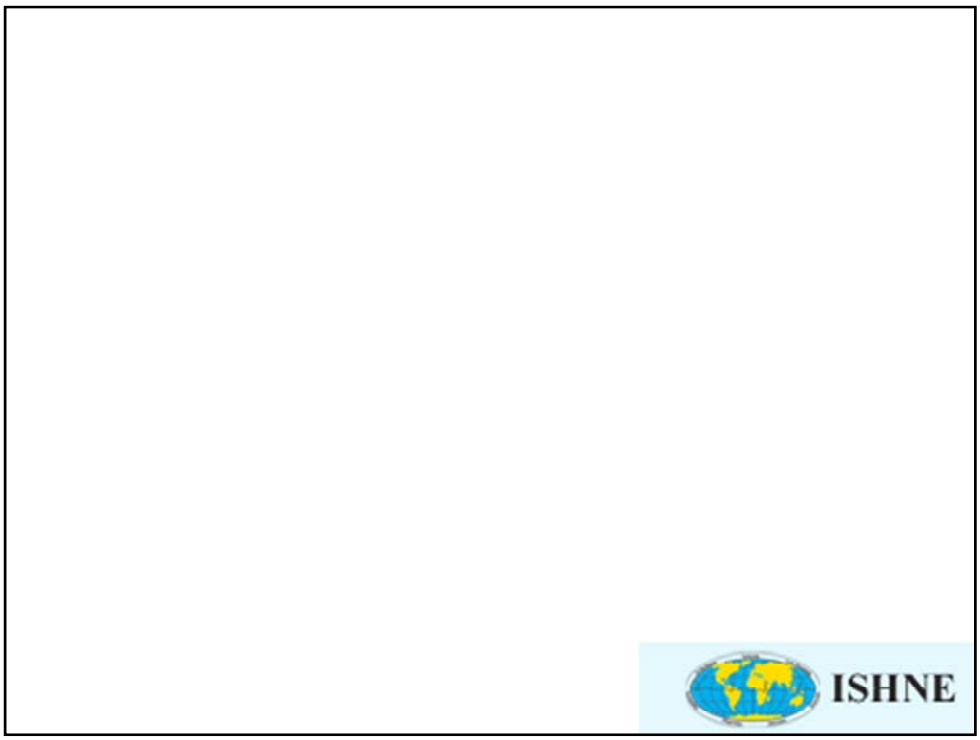
Pacemaker Programming for Atrial Fibrillation

- Chronic Afib: VVIR
  - Base rate: 80 to 90 ppm
  - Rest rate: 70 to 75 ppm
- Paroxysmal Afib: DDDR with Automatic Mode Switch when AF Suppression is not available
  - Base rate in sinus: 75 - 80 ppm
  - Rest rate: 60 ppm
  - AMS Base rate: 90 - 100 ppm
  - AV Delay dependent on status of AV conduction



This is a divider slide at the end of the basic presentation