964-105 Should Algorithms for Minute Ventilation Based Rate Adaptive Pacemakers Compensate for Metabolic Acidosis During Exercise?

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Most rate adaptive algorithms for ventilation based pacemakers (PM's) provide a linear increase in paced heart rate (PHR) for a given increase in minute ventilation (MV). It was the objective of this study to determine whether the PHR to MV slope should decrease at the PM patient's ventilatory threshold, a known correlate to metabolic acidosis.

15 Meta VVI-R 1206 PM patients (mean age 64 ± 10 yrs; 11 male, 4 female) with AV-nodal ablation (4) and bradyarrhythmic atrial fibrillation (11) and 23 age-matched healthy subjects performed treadmill exercise tests using the "Ramping Incremental Treadmill Exercise" protocol with "breath-by-breath" gas exchange. A 3rd generation algorithm using a rate augmentation factor of "low" coupled with a rate response factor was programmed to reduce the HR to MV slope midway between the lower and upper programmed rates (= 90% of the age predicted maximum rate).

The HR/MV slope from rest to ventilatory threshold (slope A) in the PM patients was 2.0 ± 0.9 beats/l, as compared to 1.4 ± 0.6 beats/l in the 23 age-matched normals ($p < 0.05$). No significant difference was observed in the HR/MV slope between ventilatory threshold and peak exercise (slope B), as compared to normals; 0.9 ± 0.5 beats/1 vs. 1.0 ± 0.3 beats/l, respectively. The ratio of slope A to slope B in the PM group was 2.8 ± 1.5 vs. 1.45 ± 0.7 in normals, indicating a decrease from slope A to B in the PM patients of 54.5%, as compared to 28% in normals.

In contrast to the linear coupling of MV changes and PHR, the 3rd generation algorithm can generate a "biphasic" HR to MV slope during exercise, more closely simulating the physiological HR to MV ratio. Rate augmentation can provide an appropriate response to the increase in MV above the ventilatory threshold. However, its initial response below the ventilatory threshold should be reduced in order to normalize the PHR to MV's ratio of slope A to slope B.

964-106 Does Faster Heart Rate Response With Rate Responsive Pacing Translate Into Better Oxygen Kinetics?

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Heart rate (HR) response and O_2 kinetics were assessed during fixed work-rate submaximum treadmill exercise (Ex) test of 10 patients with ablation induced complete AV block and a dual sensor Legend Plus pacemaker (PM). Each patient performed Ex to achieve peak VO_2 = 72 ± 12% of anaerobic threshold when the PM was randomly programmed to VVI, VVIR-activity (act), minute ventilation (mv) or combined(dual). The max VO_2 achieved with all 4 modes were not different. The max HR were not different among the 3 VVIR modes.

	VVIRact	VVIRmv	VVIRdual
Ex HR latency (sec)	15.5 ± 4.5	44.5 ± 14.2*	16.1 ± 9.5
Ex HR time constant (sec)	34.9 ± 17.2*	60.8 ± 18.5	68.8 ± 26.7
Time to ½ HR increase	39.7 ± 11.6*	86.7 ± 23.8	63.8 ± 23.3
Recovery HR latency	18.9 ± 9.3	53.0 ± 15.2*	37.4 ± 22.0
Recovery HR time constant	35.7 ± 10.3*	80.1 ± 17.2	82.9 ± 18.9
Time to ½ HR decrease	64.4 ± 10.7*	108.5 ± 12.8	94.8 ± 10.0

*Significantly different from the other 2 modes

The time constant of the VO_2 changes at the onset of exercise and at recovery were longer for VVI than for the 3 VVIR modes which were not different from each other. O_2 deficit and debt were larger for VVI than for the 3 VVIR which were not different from each other.

Conclusions: Act provided the fastest HR response during onset and recovery of Ex, and mv was slowest, while dual was intermediate. However, there was no significant difference in the O_2 kinetics among the 3 VVIR modes. This study suggests that in these relatively well patients the speed of the HR response of the sensors is not important in the exercise performance of the patients.

964-107 Increased Prevalence of Significant Tricuspid Regurgitation in Patients With Transvenous Pacemaker Leads

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The purpose of this study is to determine if transvenous pacemaker leads (TP) are associated with an increased prevalence of moderate to severe tricuspid regurgitation (TR). We reviewed 37,705 consecutive echocardiograms performed at Mount Sinai Medical Center between 1987–94. There were 745 patients who had transvenous pacemaker leads identified by echocardiography. Patients with left ventricular (LV) dysfunction, moderate to severe mitral regurgitation, significant mitral annular calcification, moderate to severe pulmonary hypertension, significant left ventricular hypertrophy, and moderate to severe aortic stenosis were excluded since these conditions may exacerbate tricuspid regurgitation.

Patients with TP (n = 355) were compared to an age–sex matched control population (CP) (n = 703). The mean age of the TP group (77 ± 12 years) was similar to the CP (76 ± 12 years) (p = 0.18). The percentage of females in each group was also similar (TP 57.3% vs. 55.6% p = 0.64).

The prevalence of moderate to severe TR in patients with TP was significantly greater than the CP (TP 18.9%; 95% CI 15.1–23.4% vs. CP 8.5%; 95% CI 6.6–10.9% Chi square $p < 0.00001$). The odds ratio for moderate to severe TR in the TP population vs. the CP was 2.5 (95% CI 1.69–3.70).

Transvenous pacemaker leads are associated with an increased prevalence of moderate to severe tricuspid regurgitation and therefore may be a risk factor for its development.

964-108 Is There a Risk for Interactions Between Mobile Phones and Single-Lead VDD Pacemakers?

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Mobile phones (MP) are increasingly regarded as a potential source of pacemaker (PM) interference. Close contact to a PM may cause tracking, inhibition or conversion to the noise mode. Patients with single-lead VDD-pacemakers might be at special risk, since the atrial sensitivity is routinely programmed to low values.

Methods: We studied 31 consecutive patients (pts), 14 f, age 61 ± 18 y, with high degree AV-block and a single-lead VDD-PM, during routine follow-up. 12 pts. with a Unity 292–07 (Intermedics), 10 with a Thera 8948/8968i (Medtronic) and 9 with a Saphir 600 (Vitatron) VDD-PM. After a complete PM check the atrial and ventricular channels were programmed to minimum sensitivity thresholds (A: 0.1–0.25 mV, V: 1.0 mV) and to unipolar ventricular sensing to simulate "worst conditions". During continuous ECG recording, the antenna of a MP (Orbitel 902, 2 W, digital D-net), was brought in direct contact with the pts' skin, parallel to the PM-lead. Then the following operations were performed: Connection to the net, making a call, ringing phase, receiving a call and leaving the net. Thereafter the PM was inquired and checked for changes of the programmed parameters.

Results: In our group of pts with VDD-PMs we observed no case of PM-interaction with the MP. All PMs showed unchanged programmed parameters after the test.

Conclusion: Although tested at minimum sensitivity thresholds with direct skin contact of the antenna, the single-lead VDD pacemakers examined were free from interference with a 2 Watt mobile phone in the digital D-net. Therefore the use of such phones should not be restricted for patients. with one of the pacemakers tested.

965 Sudden Death and Defibrillation

Tuesday, March 26, 1996, Noon–2:00 p.m.
Orange County Convention Center, Hall E
Presentation Hour: 1:00 p.m.–2:00 p.m.

965-96 Encircling Overlapping Waveforms for Transthoracic Defibrillation

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Rotating the electrical shock vector 360° around the chest during transthoracic defibrillation may facilitate defibrillation by depolarizing myocytes with different orientation vis-a-vis the shock field. To evaluate this, we recorded the percent successful defibrillation achieved by several waveforms at varying energy levels (25, 50, 100, 150 Joules (J)) in 15 dogs with electrically induced VF of short duration (30 secs). The waveforms tested included three encircling overlapping truncated exponential waveforms lasting 6, 7, 14 ms (6 EO, 7 EO, 14 EO) respectively, delivered from 6 electrode pads oriented circumferentially. These were compared to a standard damped sinusoidal waveform (lateral-lateral pathway) and a truncated exponenital biphasic waveform (5 msec positive, 1 msec negative (B5-1) (lateral-lateral pathway).

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Results:

Energy (J)	% Success Defibrillation				
	DS	Bi5-1	6 EO	7 EO	14 EO
25	0 ± 0	20 ± 12	60 ± 13*#	67 ± 8*#	53 ± 11
50	23 ± 12	59 ± 11	88 ± 6*#	91 ± 4*#	85 ± 8*
100	50 ± 14	96 ± 2*	100 ± 0*	100 ± 0*	95 ± 2*
150	67 ± 12	100 ± 0*	97 ± 3*	100 ± 0*	95 ± 5

$p < 0.05$ vs DS; # < 0.05 vs. Bi5, ANOVA; mean ± SEM.

Conclusion: The encircling overlapping and biphasic waveforms performed better than the standard damped sinusoidal waveforms at 100 and 150 J. The shorter duration (6 EO and 7 EO) encircling overlapping waveforms performed significantly better than the damped sinusoidal waveform and biphasic waveforms at low energies, whereas the longer duration encircling waveform (14 EO) was not superior at 25 J. We conclude that encircling overlapping multipulse waveforms and biphasic waveforms appear a superior approach to transthoracic defibrillation; short duration encircling waveforms may be optimal.

965-97 Comparison of Damped Sinusoidal and Truncated Exponential Waveforms for External Defibrillation

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We and others have presented a model of defibrillation where the heart is represented as a parallel resistor-capacitor network. One prediction of this model is that the heart acts as a low pass filter and so defibrillation waveforms with a slow onset should be more efficient at defibrillating the heart than waveforms with a fast onset. We tested this hypothesis in an animal model of external defibrillation.

Probability of defibrillation success (PDS) curves were generated in six 25 kg anesthetized pigs for three waveforms: a damped sinusoidal monophasic waveform, a damped sinusoidal biphasic waveform, and a truncated exponential biphasic waveform delivered from a 280-μf capacitor and each phase having a 35% tilt. Shocks were delivered from self-adhesive defibrillation electrodes on the left and right chest walls of the animal. PDS curves were determined in an interleaved fashion using an up/down protocol with 10% energy step sizes. Fifteen shocks were delivered for each waveform. The heart was fibrillated for 15 seconds before a test shock was delivered.

The damped sinusoidal biphasic waveform defibrillated with a significantly lower delivered energy, 16.0 ± 4.9J than either the truncated exponential biphasic waveform, 20.3 ± 4.4J, or the damped sinusoidal monophasic waveform, 27.4 ± 6.0J. Delivered energy was significantly lower for both biphasic waveforms than for the monophasic waveform.

Slowing the onset of the defibrillation shock improved defibrillation efficacy. These results suggest that the heart may act as a low pass filter with respect to its response to a defibrillation shock.

965-98 Dominant Frequency of Ventricular Fibrillation Waveforms as Predictors of Cardiopulmonary Resuscitation (CPR)

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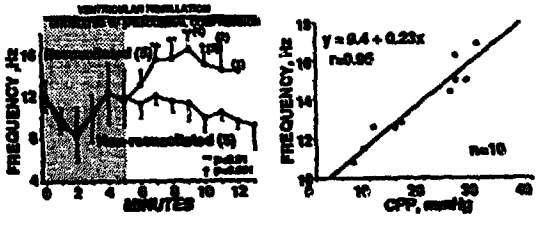
The amplitude of the ventricular fibrillation (VF) signal serves as a quantitative predictor of the success of cardiopulmonary resuscitation (CPR). In the present study, we investigated whether the frequencies of VF signal also serve as indicators and potentially as monitors of the success of CPR. VF was induced in 10 anesthetized pigs. Mechanical ventilation and precordial compression were initiated after 5 min of untreated VF. Defibrillation was attempted after 2 min of CPR and at one min intervals for a total of 6 min. The EKG (lead II) and coronary perfusion pressure (CPP) were continuously recorded. The *dominant frequency* (DF), defined as the frequency which represents the maximum magnitude of the VF signal, was determined using fast Fourier transform analyses. In each of 5 resuscitated animals, the DF was significantly greater than in 5 animals which failed the same resuscitative intervention and DF was highly correlated with CPP during CPR ($r = 0.95$).

The present study demonstrated that the dominant frequency, like coronary perfusion pressure, prognosticate the success of CPR.



965-99 Is Out-Of-Hospital Sudden Cardiac Death an Unexpected Event?

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Early recognition of warning symptoms could lead to a timely alarm of emergency medical services and help to avoid out-of-hospital sudden cardiac death (SCD). In a prospective study, we therefore performed a standardized on-scene interview with eyewitnesses of circumstances of SCD to assess symptoms preceding the collapse, and to evaluate the medical history in all consecutive resuscitation attempts of our physician-operated mobile intensive care unit from January to December 1993.

Of 402 pts (mean age 71 years, 58% male), 149 had ventricular fibrillation (VF), 76 pulseless electric activity and 177 asystole. An interview was obtained in 319 resuscitations. Heart disease was known in 192 pts (61%).The collapse was preceded by one or more symptoms in 216 pts (67%): 96 had angina pectoris (AP), 61 respiratory disstress, 59 other symptoms like vertigo or syncope. Symptom duration was > 1 hr in 47%, 31–60 min in 10%, 6–30 min in 26%, and ≤ 5 min in 15%. Of the pts with AP, 57% had complaints > 1 hr, compared to only 41% of pts with other symptoms ($p < 0.03$). Resuscitation was successful in 101 pts (25%). In a multivariate analysis, eyewitnessed arrests (OR 12.6, 95% CI 2.9–5.4), VF as arrhythmia (OR 2.0, 95% CI 1.3–3.0), an age ≤65 years (OR 2.5, 95% CI 1.4–4.6), and a collapse without preceeding symptoms (OR 2.3, 95% CI 1.2–4.2) proved to be independent factors to predict a successful resuscitation.

Conclusion: SCD frequently occurs after a sustained period of specific warning symptoms and in presence of eyewitnesses (mostly relatives) being aware of the victim's heart disease. Moreover preceding symptoms are associated with a poorer prognosis. These results underline the necessity of designing strategies to educate pts at risk and their relatives to recognize alarming signs early and make immediate use of emergency medical services.

965-100 Chest Wall Electrode Placement Influences Intracardiac Voltage Gradients and Shock Success in Transthoracic Defibrillation

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Achieving transthoracic defibrillation is dependent on delivering a critical amount of current. The spatial distribution of this critical intracardiac (IC) current may be an important determinant of success and may be influenced by electrode placement on the chest wall. To evaluate the effect of chest wall electrode placement on intracardiac current homogeneity and shock success, we administered 50–200 J DC shocks after 15 secs of VF to 7 post-thoracotomy dogs with implanted arrays to measure IC voltage gradients. We used 3 different chest wall electrode configurations: anteroposterior (AP1 and AP2), precordial (PRE); these have been previously described by a 3-D finite element model and tested in our lab. Both AP1 and PRE have one electrode in close proximity to the apex of the heart. AP2 and PRE expose the heart to a wide distribution of current densities; AP1 exposes the heart to a narrower range of current density. Results:

% Shock Success vs. Electrode Configuration

	Energy:			
	50 J	100 J	150 J	200 J
AP1	0	14	55	76†
AP2	0	9	38	37R
PRE	3	33*	75*	81†

*$p < 0.05$ vs. AP1; †$p < 0.05$ vs. AP2 ANOVA

Measured voltage gradients at 50 J from the IC arrays showed that the mean AP2 gradient was 16% higher than PRE and 133% higher than AP1. Conclusion: AP2 exposed the heart to the highest current densities and yet did not perform as well as the other 2 electrode configurations. Excessive intracardiac current density may reduce shock success in defibrillation. Electrode placement on the chest wall influences intracardiac current and shock success; proximity to the apex may be important.

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