Physiologic Pacing in the Elderly

Effects on Exercise Capacity and Exercise-Induced Arrhythmias

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SUMMARY

It is not clear whether hemodynamic and other benefits from dual-chamber pacing also exist in elderly patients.

We studied a group of 18 elderly patients (mean age 74 ± 4 yrs) with exercise testing in DDD and VVI modes in a randomized way to compare the effects of these pacing modes on exercise capacity, atrial rate and exercise-induced arrhythmias. Patients were selected when complete heart block was present without clinical evidence of sinus node dysfunction.

Significant differences were observed: atrial rate was lower during exercise in DDD-mode ($p < 0.01$); exercise time and cumulative load increased ($p < 0.05$); maximal oxygen uptake was improved ($p < 0.05$). Some of these differences were less clear in a subgroup with replacement of a VVI-device by DDD-stimulation.

No differences could be observed in severity of exercise-induced arrhythmias. No evidence of sinus node dysfunction was found during exercise. Reprogramming of atrial sensitivity was required in 3 patients, with reprogramming to DVI because of paroxysmal atrial fibrillation once. Two patients died within a mean follow-up period of 13 months. Sinus rhythm was present at the most recent evaluation in all patients, including the patient stimulated in the DVI mode.

Physiologic stimulation is of value for elderly patients with an active life style and complete heart block. Reprogramming to another pacing mode is only seldom necessary.

Additional Indexing Words:

Arrhythmias Exercise testing Heart block Pacing

IT is becoming accepted that exercise capacity and general well-being in paced patients without atrial arrhythmias are improved with the use of atrial synchronous ventricular pacemakers.¹⁾⁻³⁾ However, it is not entirely clear which patients will get the most benefit from these pacemakers.⁴⁾

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It has been suggested by some investigations that the hemodynamic benefits of atrial triggered pacing will be more pronounced in younger patients.¹⁾

This uncertainty will certainly influence our decision making in implantation of pacemakers in elderly patients presenting with complete heart block. The possibility of associated cardiovascular disease, e.g. angina pectoris and the occurrence of age-related arrhythmias (sinus node disease, atrial fibrillation) may further limit the usefulness of physiological stimulation. Technical problems with the insertion of two leads, the possibility of pacemaker-mediated tachycardia in early devices and the high cost of sophisticated pacemakers limited wide-spread use of physiologic pacing in this age group. Furthermore, biological pacing with a single lead seems to be very attractive.

No systematic study of exercise capacity in geriatric patients with physiological pacemakers has been performed up to now. Nevertheless, it has been stated that age should not be a contraindication for physiologic pacing.³⁾

The purpose of this study was to compare the effects of ventricular demand pacing (VVI) and physiological stimulation (DDD) on exercise tolerance, atrial rate, and exercise-induced arrhythmias in a group of patients with complete heart block, above 65 years of age.

METHODS

Patients 65 years and older with complete heart block and a physically active life style were selected for implantation of a dual-chamber system if a stable sinus rhythm was observed during a 24 to 48 hour post admission observation period before insertion of a permanent pacemaker. Patients with the same conditions needing replacement of a VVI pacemaker, and without atrial arrhythmias during ambulatory control in the past were also considered suitable for insertion of a physiological pacemaker. Our methodology for implantation has been reported elsewhere.⁵⁾ For the atrial position atrial screw-in leads were preferred.

At least 6 weeks after implantation, patients were subjected to two upright bicycle ergometer tests, with 48 hours between each examination. Randomization to VVI or DDD mode for the first testing was performed. Basic programmed rate was 70 bpm for both modes. The upper rate during physiologic pacing was limited to 150 bpm and the AV-interval programmed to 150 ms for all devices, except for Autima II (Teletronics Ltd) where 140 ms was used. Exercise tests were symptom-limited. Initial load was 25 watts, increased every minute by 10 watts. Continuous electrocardiographic recording of leads CM₅, aV_F and V₁ was obtained, with measure-

ment of blood pressure at each step. Maximum oxygen uptake, respiratory quotient and respiratory minute volume were obtained. Ventricular arrhythmias during exercise were classified according to Lown.⁶⁾ Patients were excluded from analysis if AV-conduction resumed during exercise testing in VVI or DDD mode. Further regular follow-up was carried out at 6 month intervals with routine evaluation of pacemaker function and electrocardiogram, after an initial evaluation at 3 months. Statistical analysis was performed with Wilcoxon's test for paired data. Values are expressed as means $\pm$ standard deviation. Approval from the ethical committee was obtained for this study.

RESULTS

A total of 18 patients with a mean age of 74.4 ± 3.7 years were selected for the study. There were 7 patients with replacement of a ventricular demand pacemaker by a physiologic pacemaker with additional placement of an atrial lead, and 11 patients with a first implantation. Coronary artery disease was known in 2 patients and severe hypertension existed in another, but the conduction disturbances were the only cardiac pathology in the remaining patients, all being free of overt myocardial dysfunction.

In 1 patient (a 70-year-old female with a replacement) intermittent atrial fibrillation occurred before the exercise test was carried out, requiring programming in D.V.I. Two patients were excluded because of, respectively, normal AV-conduction or second degree AV-block during the first exercise test.

The mean age of the 15 remaining patients was 74.4 ± 3.9 years (range 65–80). There were 12 male and 3 female patients. Six of these patients had a replacement. Implanted devices were Versatrax 7000, 7000 A, Symbios 7005 (Medtronic) in 6 patients, Autima II (Teletronics) in 7, and Quintech (Vitatron) and Delta (CPI) in 1 patient each.

Results of exercise testing are summarized in Table I. Mean resting heart rate at the time of exercise testing was 70 bpm in VVI and 76 during DDD pacing (Fig. 1). In 6 of the patients it was 70 during DDD. Atrial rate increased to 135 ± 17 during exercise with ventricular demand pacing and with physiologic pacing only to 124 ± 16 bpm (difference: $p < 0.01$). The range of the ventricular response during physiologic stimulation was between 96 and 148, exceeding 130 only in 5 patients. It was limited to 130 in one of these patients because of the programming of the atrial refractory period of the pacemaker.

Resting systolic and diastolic pressures did not differ. Only maximal

Table 1. Results of Comparative Exercise Testing

	VVI-mode	DDD-mode	Statistical significance
Values at rest			
heart rate (bpm)	70± 0	76± 6	<0.01
systolic blood pressure (mmHg)	151± 23	158± 30	NS
diastolic blood pressure (mmHg)	89± 14	92± 17	NS
Maximal values during exercise			
ventricular rate (bpm)	70± 0	117± 25	<0.01
atrial rate (bpm)	135± 17	124± 16	<0.01
systolic blood pressure (mmHg)	187± 34	194± 36	NS
diastolic blood pressure (mmHg)	97± 12	108± 15	<0.02
VO ₂ (ml)	797±150	989±309	<0.05
VO ₂ /kg (ml/kg)	11.2±2.1	14.3±4.6	<0.02
respiratory minute volume (l/m)	30.7±8.4	36.0±8.6	NS
respiratory rate (pm)	32.9±3.3	33.0±4.7	NS
VCO ₂ (ml)	951±276	1208±292	<0.01
RQ	1.29±0.17	1.33±0.27	NS
Cumulative load (watt)	293±204	345±195	<0.05
Total exercise time (min)	5.5±2.6	6.2±2.3	<0.05
ECG disturbances (number)			
Atrial premature beats	?	4	
Atrial fibrillation	1	1	
Lown grade ≥3	5	3	
Sensing problems			
Atrial level	—	3	
Ventricular level	1	2

Fig. 1. Comparison of heart rates at rest, and atrial and ventricular rates at the time of maximal exercise in VVI and DDD modes.

diastolic pressure during exercise reached values that were significantly higher in DDD pacing than in VVI mode (108 mmHg vs 97 mmHg; $p < 0.02$). The mean cumulative load during VVI was 293 watts, compared with 345 watts for physiologic pacing. This corresponded with an increased exercise time for the DDD mode ($p < 0.05$). Complete paired data for oxygen uptake and respiratory parameters were obtained in only 12 patients. Maximal oxygen uptake was significantly improved with physiologic pacing ($p < 0.05$). Respiratory quotient, respiratory rate and respiratory minute volume at maximal level were not different in the two modes.

Lown grade of ventricular arrhythmias during exercise was reduced in 6 patients during DDD, increased in 4 patients and remained unchanged in 5 (Fig. 2). Atrial fibrillation occurred once in the post-exercise phase in VVI; it lasted more than 1 min. A brief episode of atrial fibrillation occurred once in DDD during exercise. Atrial premature beats were observed in 4 patients during physiological stimulation; they were not evident during VVI mode.

Fig. 2. Comparison of ventricular arrhythmias during exercise in VVI and DDD modes (classification modified to Lown). VT=ventricular tachycardia (triplet or more than 3 beats); VC=ventricular couplet; VPB=ventricular premature beat.

Fig. 3. Undersensing of atrial electrogram. This is not evident when the patient was lying (upper left) or sitting (upper right). As AV-dissociation becomes clear during exercise with atrial spikes preceding ventricular stimulation reprogramming of atrial sensitivity is carried out from 1.0 mV to 0.5 mV. Immediate increase of ventricular rate with correct atrial tracking becomes evident.

Muscle potentials during exercise caused short ventricular pauses in 2 patients, once leading to a ventricular couplet. It occurred during DDD, and both patients were completely asymptomatic. Undersensing of ventricular extrasystoles was observed once, in VVI. Atrial sensitivity was reprogrammed to lower values in 3 patients; once the necessity was only clear when exercise was started (Fig. 3).

When data from patients with revisions were analyzed afterwards, it was evident that exercise time remained equal in 3 of 6, increased only slightly in 2, and decreased in the last (Fig. 4). However, atrial responsiveness was maintained in these patients. The data from this subgroup did not influence the overall results.

During follow-up with a mean of 13 months after implantation, 2 of the original 18 patients died, respectively, 5 and 6 months after implantation. Their ages were 78 and 76 years. Maximal level at exercise time of these female patients was 55 watts during DDD. One of them had atrial fibrillation. One died suddenly, and one in cardiac failure. Both were checked and had normal pacemaker analysis 3 months after implantation. The patient was excluded because atrial fibrillation before the exercise test results

Fig. 4. Cumulative load of the study group in VVI and DDD (middle). Comparison of cumulative load in patients with first implantation (left) and patients with replacement of one-chamber by a two-chamber system (right). $\circ$: mean of each group, and of total group of patients (middle).

are still being stimulated in DVI, with digoxin as an antiarrhythmic drug. All other patients still have sinus rhythm and normal sensing and pacing at both the atrial and ventricular levels.

DISCUSSION

Cardiac pacing improves the prognosis considerably in patients with complete heart block.⁷⁾ The value of P-wave synchronous pacing was already recognized in 1963 but difficulties with atrial leads inhibited its general use.⁸⁾ Pacing in geriatric patients is considered of benefit, particularly when complete heart block is present due to conduction tissue fibrosis.^{9), 10)} Actuarial 5-year survival is good, symptomatic improvement is observed and the complication rate is comparable to that in younger groups.⁹⁾ Programmable generators seem to be useful.¹⁰⁾

Dual-chamber pacing is now becoming accepted in active or young patients, or in patients with the pacemaker syndrome.^{1), 3), 11)} Dual-chamber

pacing offers atrioventricular synchrony, preventing disabling symptoms and offering rate variability during exercise, allowing adaptation of cardiac output.¹⁾⁻³⁾ Furthermore, it is claimed that physiologic pacing may be useful in the treatment of ventricular arrhythmias.^{12),13)} When atrial arrhythmias exist, implantation of these devices is not desirable. This is certainly true for atrial fibrillation, which is frequently encountered in the elderly.¹⁴⁾ Other disadvantages of DDD-stimulation are the possibility of pacemaker-mediated tachycardia, the limited longevity of these pulse generators, and the higher price of the devices. Dual-chamber pacing has not been studied in a systematic way in a group of older patients.

Most studies (see Table II) report on groups with a broad range of ages, in contrast to our study and it is not clear whether the results obtained from the other studies hold also for geriatric patients with heart block.^{1)-3),15)} The mean age of our group is above the mean age of other study groups.

We did find an improvement of work capacity of 17%. This is slightly less than the improvement observed by the other investigators. However, we demonstrated that in patients above 65 years, the hemodynamic benefit during exercise also exists, with an enhanced oxygen uptake of the body.

It could be that coexistent sinus node pathology in the elderly is responsible for this relatively small increase. Our patients obtained a mean atrial rate of 124 beats/min, which is not as high as that seen in other studies where pacing systems have been used allowing comparable upper rates (Table II). This may be ascribed to the difference in age. However, during exercise only one patient, taking β -blocking agents, did not reach a cardiac rate of 100 bpm. Overt sinus node disease, judged to be absent based only on

Table II. Comparative Exercise Studies with Dual-Chamber Systems and VVI

Author(s)	Number of patients	Number with age ≥ 70	Mean age (yrs $\pm$ SD)	Age range	Pacing modes	Working capacity	Maximal atrial rate in DC-test
Karlöff (1975)	25	1	55 $\pm$ 11	31-70	VAT vs VVI CO+20%	—	126 $\pm$ 12*
					VAT vs VVIm CO+8%	—	122 $\pm$ 20*
Kruse et al (1982)	16	3	67 $\pm$ 7	57-82	VDD vs VVI	+24%	156 $\pm$ 19
Pehrsson (1983)	14	8	66 $\pm$ 11	44-81	VAT vs VVI	+24%	141 $\pm$ 13
					VAT vs VVIm	+4%	
Perrins et al (1983)	13	4	65 $\pm$ 14	51-87	VDD vs VVI	+27%	135 $\pm$ 18
Jordaens et al (1988)	15	13	74 $\pm$ 4	65-80	DDD vs VVI	+17%	124 $\pm$ 16

Abbreviations: CO=cardiac output; DC=dual-chamber system; VVIm=VVI with frequency matched to rate obtained during VAT. * exercise testing not considered maximal.

clinical and routine electrocardiographical observation, was certainly not found during exercise in this group. The atrial contribution to the increase in cardiac output is considered most important for rates below 110 bpm. This rate was achieved in all patients but one.

Another factor explaining the small difference in exercise tolerance could be the coexistence of coronary or myocardial disease in the elderly, limiting the usefulness of rate adaptation during exercise when atrial rate is used for triggering, e.g. with development of angina pectoris or rhythm disturbances.¹⁴⁾ However, an ischemic etiology was not frequently encountered in our and in one other series.¹⁰⁾ The possible evolution to chronic or paroxysmal atrial fibrillation is certainly a source of concern, and 2 patients had short-lasting atrial arrhythmias during the exercise test. This, combined with the maximal achievable atrial rate supports programming the upper rate limit as low as 135 bpm if possible. Even this could be too high, as it is known that these patients do not reach 120 bpm when ambulatory monitoring during normal activities is carried out.¹⁶⁾ Exercise testing is a safe procedure to select subgroups needing less restriction.

Atrial responsiveness to exercise was maintained in the patients with upgrading. However, the hemodynamic benefit during exercise seemed less impressive. We may suppose that adaptation of cardiac output during activity in these patients was possible with other mechanisms when they were again submitted to ventricular demand stimulation 6 weeks after the implantation of the physiologic pacemaker.

Ventricular rhythm disturbances are important in paced patients, as an important subgroup dies suddenly.¹⁷⁾ Ventricular arrhythmias have been found in more than 50% of patients during exercise testing, even with ventricular demand pacing.¹⁸⁾ It has been claimed that physiologic pacing could reduce the importance of arrhythmias, but only scarce evidence has been reported.^{12),13),19)} We could not demonstrate an excess nor a reduction of ventricular arrhythmias during exercise with physiologic stimulation, in a population prone to the development of ventricular rhythm disturbances and sudden death.^{6),17)}

Implantation of single-chamber systems with the possibility of rate-adaptation during exercise certainly avoids technical problems and remains possible when atrial arrhythmias exist, but programming is not always easy.

It does not seem logical to assume that ventricular demand pacing, even with the additional possibility of a rate increase after sensing of biological parameters, will be able to avoid symptoms arising from asynchrony of atria and ventricles or from retrograde conduction.^{2),3),20)} It seems evident that atrial-synchronous stimulation is preferable during workloads

corresponding to those of usual daily activities. As many elderly patients have a need to cope with such exercise, we think it is not reasonable to withhold atrial synchronous ventricular or physiologic pacing from this age group. When careful implantation is carried out, no important complications are encountered, and the prognosis is good.

Comparative, randomized studies with rate-responsive as well as physiologic pacemakers will certainly be needed to answer several of our questions in elderly patients.

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