Cardiopulmonary Test as Helpful Tool for Optimizing AV-Delay in DDD-Paced Patients

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Summary

The aim of the study is to investigate by noninvasive methods (echocardiography and cardiopulmonary test) the relationship between atrio-ventricular (AV) delay, diastolic filling pattern, homogenization of left ventricular contraction and increase systolic function in patients with DDD pacemaker. It shows that the optimum AV-delay individually determined at the best diastolic profile corresponds to a homogenization of left ventricular systolic pattern, systolic function and oxygen kinetics. Difference between worse and better AV-delay for each patient give a statistically significant difference in stroke volume at rest (33.25 ml vs. 56.7 ml; $p < 0.005$) and in oxygen deficit during cardiopulmonary test (1146.8 ml vs. 612 ml; $p < 0.0005$).

Key Words

Cardiopulmonary test, AV-delay optimization, AV-synchronous pacing

Introduction

Abnormalities of left ventricular diastolic function may precede systolic dysfunction and have been demonstrated with pulsed echo-doppler echocardiography [1]. The doppler pattern of diastolic mitral inflow directly reflects left ventricular filling and it is influenced by factors such as age, heart rate, loading conditions [2]. When impaired relaxation is present the early diastolic pressure gradient between the left atrium and left ventricle is small, resulting in decreased rate of early filling velocity with a prolonged deceleration time as well as a greater residual atrial volume. If it is obtained an increase in early diastolic filling may be obtained a significant reduction in the isovolumic relaxation time, that is the most energy requiring phase of excitation-contraction coupling and it is influenced by sympathetic tone. An increase in myocardial elasticity can contribute to an increase in cardiac output and oxygen supply to skeletal muscles [9]. This mechanism may play a role in explaining the changes in left ventricle diastolic filling in patients with abnormal relaxation [5-8]. A significant doppler predictor of outcome is the early to atrial filling velocity (E/A ratio). In paced patients mean age is often over 60 years and a diastolic dysfunction is a common ("riscontro") find - so it is important to optimize the AV-delay to maximize cardiac output at rest and during exercise by an automatic decrease in AV-delay during higher rates [4, 10].

The use of cardiopulmonary exercise testing is useful in the assessment of ambulatory patients [11-14]. Peak VO_2 is an objective measure of functional capacity and a independent prognostic index, but may be influenced by non cardiovascular factors such as patient's motivation and skeletal muscle characteristics [8-10].

Previous studies demonstrated that oxygen kinetics are delayed in patients with congestive heart failure. Oxygen kinetics at exercise onset with a low work are more dependent on changes of pump function than heart rate, while peak oxygen consumption is more heart rate dependent. So chronotropic incompetence influences peak oxygen consumption while oxygen kinetics are unaffected. Higher the work load, more heart rate dependent oxygen kinetics become.

Oxygen kinetics were assessed during exercise: oxygen deficit was calculated according to the following formula [13,14]:

Patients	Age	Sex	Other Pathologies	NYHA	AV Block
A.M.	64	M	hypertension	II	III degree with narrow QRS
N.B.	71	F	hypertension	II	II degree with LBB
M.G.	73	M	hypertension	II	III degree with narrow QRS
B.I.	75	F	hypertension	III	III degree with narrow QRS
V.G.	81	M	hypertension	III	II degree with RBB
R.L.	66	F	diabetes	II	III degree with narrow QRS
M.G.	77	M		III	III degree with LBB
F.D.	74	M	transient cerebral ischemia	II	II degree
C.G.	65	M	ischemic cardiomyopathy	III	II degree
R.I.	83	F	hypertension	II	III degree
B.L.	84	M		II	II degree
I.G.	77	M	hypertension	II	III degree
S.L.	76	F	hypertension	III	III degree
S.V.	78	F	hypertension; rheumathic mitral insufficiency	III	II degree

Table 1. Investigated patients.

O_2 deficit = t [rest to steady state] x Delta VO_2 -sigma O_2 [rest to steady state].

The mean response time (MRT) of oxygen consumption was calculated using the following formula [13,14]:

MRT = O_2 deficit / Delta VO_2.

Peak oxygen consumption was defined as maximum oxygen uptake during ramp exercise (25 watts x 2 min) by averaging consecutive breaths expressed in ml/min/Kg of body surface.

Methods

15 paced DDD patients, mean age 72 ± 6.3 years, were evaluated. Devices were Physios and Kairos (all Biotronik) with progressive AV shortening programmed for higher frequencies (rate adaptive AV-delay). Baseline echocardiograms were performed in the apical five chamber view. The pulsed wave doppler was oriented into the left ventricular outflow tract parallel to aortic flow. For each programmed atrio-ventricular delay between 100 ms and 200 ms in steps of 50 ms, measurements were determined during a stable heart rate during atrial triggered ventricular stimulation. Measurements of left ventricular end diastolic volume, end systolic volume, stroke volume, deceleration time of E wave velocity, E/A ratio were obtained. Every three months patients were evaluated; for each AV-delay they performed a cardiopulmonary exercise test with analysis of oxygen kinetics. Exercise testing was performed on a treadmill (25 W x 2 min). Gas exchange was assessed breath by breath. Peak oxygen consumption was defined as maximum oxygen uptake during exercise expressed in ml/min/kg body weight. Follow-up was assessed for one year.

Results

No patient had a restrictive pattern of diastolic filling; all but one showed E/A ratio < 1 as an altered compliance pattern with a deceleration time < 155 ms. Optimizing the AV-delay for the best diastolic filling pattern, deceleration time and uniformity of left ventricular contraction, NYHA functional class, echocardiographic measurements (stroke volumes, diastolic and

AV-delay	Average (ml)	SD
200 ms	107.82	± 44.92
150 ms	97.78	± 27.34
100 ms	95.48	± 34.74

Table 2. Diastolic volumes.

AV-delay	Average (ml)	SD
200 ms	58.69	± 31.53
150 ms	50.61	± 29.09
100 ms	47.56	± 19.48

Table 3. Systolic volumes.

AV-delay	Average (ml)	SD
200 ms	45.37	± 16.83
150 ms	47.19	± 15.33
100 ms	40.60	± 18.02

Table 4. Stroke volumes.

systolic volumes: Tables 2-4) and oxygen kinetics improved (Table 5).

Deficit O_2	Average (ml)	SD
pre-optimization	1146.8	± 434.78
post-optimization	612	± 370.66

Table 5. Oxygen kinetics.

	Average (ml)	SD
pre-optimization	33.25	± 7.64
post-optimization	56.71	±14.93

Table 6. Stroke volume after individual optimization.

Stroke volume showed significant improvement for the each optimized AV-delay from the worse value of 33.2 ml to best individual to 56.7 ml ($p < 0.005$) (Table 6). Individual values of stroke volumes for each patient are given in Figure 1. It can be observed a wide inter-individual variation for each AV-delay measured in different steps. For an individual optimization of this interval oxygen deficit also improved from 1146.8 ml to 612 ml ($p < 0.0005$). Mean response time changed from a mean of 78 s to 67 s without significant difference at statistical analysis.

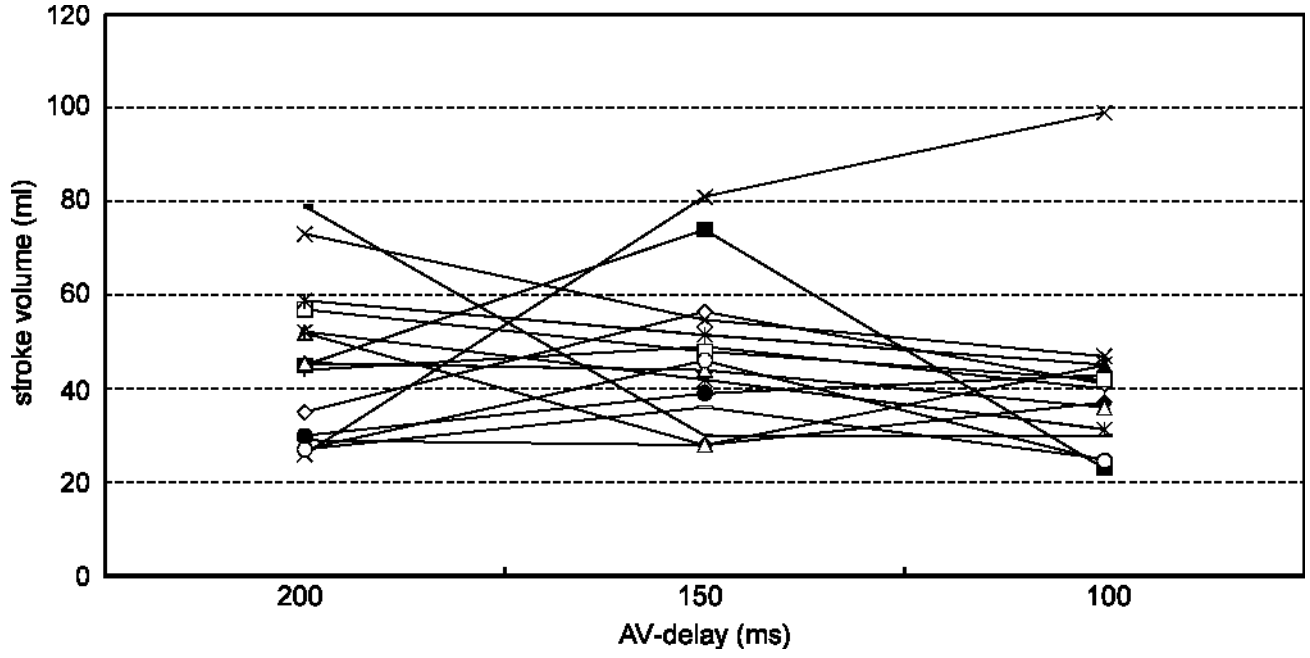

Figure 1. Behaviour ot the stroke volume for different AV-delay (all patients).

Discussion

For a given heart rate there is an individual optimal AV-delay in patients with II and III degree block and during submaximal exercise it's important to shorten that interval. Cardiopulmonary exercise test is an objective and reproducible method for identification of hemodynamic profile; oxygen kinetics are even more sensitive than peak oxygen uptake for older patients that cannot reach anaerobic threshold. We demonstrated an improvement in systolic performance and oxygen kinetics for an individualized AV-delay. Diastolic abnormalities were present in our patients without systolic insufficiency at rest. In older paced patients improvement in exercise capacity may be obtained optimizing increasing peak early filling rate and peak filling rate, decreasing atrial filling rate.

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