Optimal Setting of AV Delay Guided by Thoracic Electric Bioimpedance

L. MELCZER, M. BROLLY, C.S. CSONTOS, M. TEKERES
Institute of Anaesthesiology and Intensive Care, University Medical School of Pécs, Hungary

Summary

The aim of our study was to examine the acute changes in the haemodynamic state of patients at rest at VVI and VDD program of Dromos 03 and/or SL "single lead" pacer with dynamic AV delay (all Biotronik, Germany), respectively. Fifteen patients (6 females 9 males), whose mean age was 61.5 (38-78) years, were examined. Repeated measurement was performed in each minute in VVI mode and then in VDD mode of pacing with three different AV delays by Thoracic Electric Bioimpedance (TEB) developed by ASK Company (Hungary). All measured parameters were recorded and processed. Data analysis of relevant parameters was performed. Mathematical analysis was performed with paired Student's t-test. The fall in stroke volume index was significant in the VVI mode of pacing compared to VDD mode with "medium" and "high" setting of dynamic AV delay ($p < 0.001$). Its decrease was moderate but significant with "low" setting of dynamic AV delay of VDD mode ($p < 0.05$). The cardiac index showed slight but significant increase at VDD mode with "medium" and "high" setting of dynamic AV delay ($p < 0.05$) compared to the VVI mode, despite of the decrease in heart rate. The acute haemodynamic effects of different ways of pacing could be detected by TEB recording. The patient adapted dynamic AV delay of VDD mode of pacing should be individually programmed.

Key Words

Single lead VDD pacing, dynamic AVD, pacemaker haemodynamics, thoracic electric bioimpedance

Introduction

During the 41 years history of pacemaker (PM), therapy has had several remarkable milestones. The first major step was the prevention of Adams-Stokes' attack. Five years later, invasive haemodynamic examinations showed the advantages of physiological heart stimulation over cardiac ventricle stimulation (15). The re-establishment of AV synchrony together with the individual patient adapted pacemaker programming can improve the cardiac output with a 10-30% increase. The development of the pacemaker technology made the single lead VDD AV sequential stimulation possible [1,9]. Dynamic AV delay (AVD) provides a more accurate adaptation to the haemodynamic requirements of frequency modulation. Haemodynamic effects of pacemaker programming could be measured by several non-invasive methods beside the "golden standard" Swan-Ganz method e.g. echocardiography, isotope ventriculography. A new and reliable technique of thoracic electric bioimpedance (TEB) has successfully been applied for monitoring the haemodynamics [4,10-12,14].

The aim of this investigation is to detect the immediate haemodynamic changes related to the operation of the pacemaker and the programming of AV delay by using non-invasive methods with the assessment of the haemodynamic adaptation of pacemaker patients at rest.

Methods

Patients

15 patients (6 women, 9 men) were examined. Mean age was 61.5 years (ranged between the ages 38 and 78). Biotronik Dromos 03 or SL single lead VDD PM with dynamic AVD programs was implanted to patients with normal sinus node function with II-III AV block and/or intraventicular conduction deficiency (Table 1). AVD "low" setting corresponds to the frequency dependent shortening of the PQ time calculated according to the Bazett formula.

Rate range	AVD (in ms) when the dynamic AVD is programmed to low	medium	high	individual
below 70 bpm	170	160	150	
71 - 90 bpm	160	140	120	
91 - 110	150	120	100	
111-130	130	100	75	
above 130	120	75	50	

Table 1. Programmability of dynamic AVD of Biotronik Dromos 03/SL pacemakers.

Non-invasive beat to beat analysis

The basic principle of TEB method is to detect the changes in the impedance when high frequency (100 kHz) and low intensity (0.4 mA) current flows through the chest organs and tissues [3, 5, 13]. The position of the electrodes during the measurements are shown in Figure 1. The changes in the stroke volume were calculated according to the Kubiczek formula (Figure 2).

Protocol

Informed consent of the patients was obtained before the study. The changes in blood pressure were measured and registered with BOSO BC 24 automatic blood pressure recorder. The changes in haemodynamic parameters were determined with ICG M401 Impedance Cardiograph (ICG) developed by ASK Ltd (Hungary). Repeated measurements were performed every minute and each measurement lasted 16 seconds according to the examination protocol (Figure 3).

The last 5 measurements were considered in the statistical analysis. During the examinations all parameters were measured and recorded by the ICG. From all the data the following relevant parameters were evaluated: mean arterial pressure (MAP), heart rate (HR), stroke volume index (SVI), cardiac index (CI), systemic vascular resistance (SVR)). The significance of the data was analyzed with paired Student's t-test.

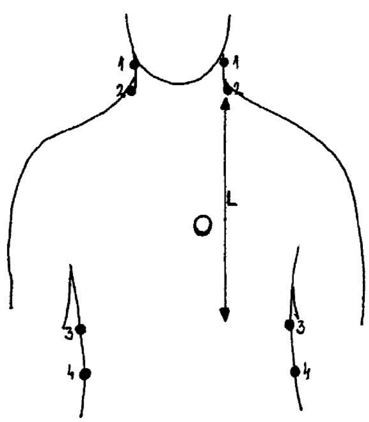

Figure 1. The arrangement of ICG electrodes and the microphone for the detection of heart sounds. 2, 3: pairs of electrodes of te voltage measuring. 1, 4: pairs of electrodes for constant oscillation of the inert current (100 kHz, 0.4 mA). O: The position of the microphone.

$$SV = r * 135 * VET * \frac{L^2}{Z0^2} * \frac{dz}{dt} (max.)$$

Figure 2. The estimation of the stroke volume by TEB recording according to Kubiczek method. SV = stroke volume, r = blood constant, L = electrode distance (cm), Z0 = thoracic impedance, VET = ventricular ejection time (ms), dz/dt (max) = maximum value of the first derivative of the thoracic impedance.

Results

When using AVD "high" or "low" programming, heart rate was significantly lower than in the case of VVI setting ($p < 0.05$ and $p < 0.01$). In the VDD mode, there

Protocol
- 10 minute time rest (adaptation)
- ICG measurement three times in VDD mode
- Programming the pacer to VVI mode
- ICG measurement for 30 minutes in every minute
- Programmming the pacer to VDD AVD "medium" mode
- ICG measurement for 10 minute in every minute
- ICG measurement for 15 minutes in every minute
- Programming the pacer to VDD AVD "high" mode
- ICG measurement for 15 minutes in every minute
- Programmming the pacer to VDD AVD "low" mode
- ICG measurement for 15 minutes in every minute

Figure 3. The protocol for the detection of hemodynamic changes caused by the effect of VVI and VDD mode of pacing with different dynamic AVDs.

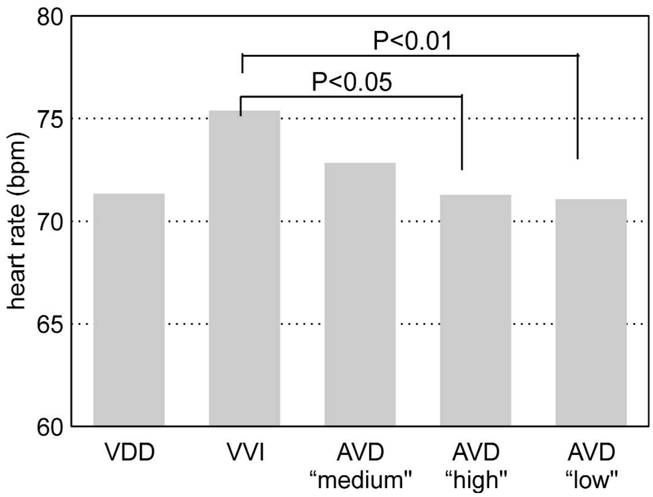

Figure 4. The change of heart rate in the different modes of pacing.

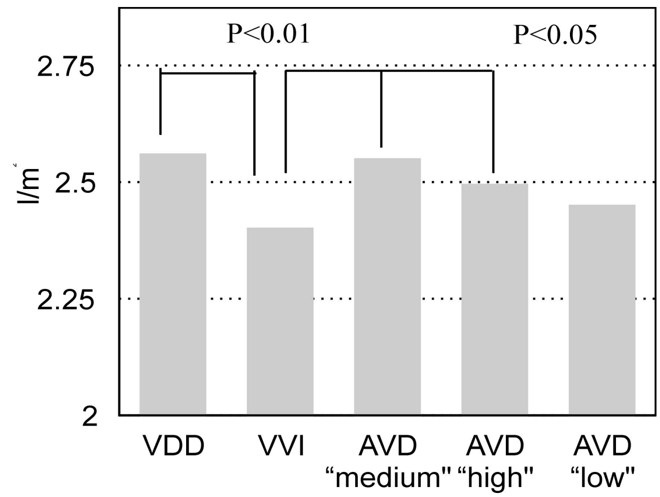

Figure 6. The change of the cardiac index in the effect of different pacing modes.

was no considerable frequency difference between the different AVD settings (Figure 4).

The stroke volume index was significantly higher in case of all dynamic AVD setting of VDD mode than in case of VVI mode. (AVD "medium" and AVD "high": $p < 0.001$, AVD "low": $p < 0.01$). In VDD mode there were no considerable differences between the different AVD settings (Figure 5).

The cardiac index was much higher in case of AVD "medium" and "high" settings of VDD mode than in VVI mode ($p < 0.05$). There were no relevant differences among "low" AVD setting of VDD mode and VVI mode, neither the different AVD settings of VDD mode (Figure 6).

Mean arterial pressure and the systemic vascular resistance did not change significantly during the examinations.

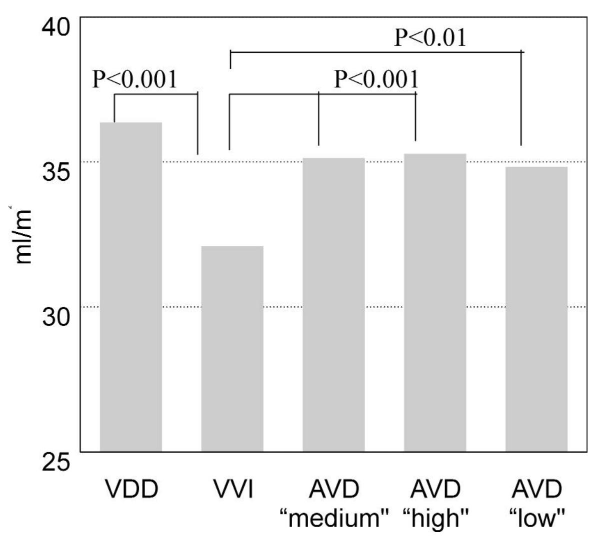

Figure 5. The change of the stroke volume index at the effect of different pacing modes.

Discussion

Single pass VDD stimulation was a remarkable development in pacemaker therapy, even in Hungary. [1, 9]. The frequency dependent AVD made further haemodynamic adaptation possible [9]. TEB recording is widely accepted and used as a non-invasive method based on measurement of the changes in the haemodynamic state with a beat-to-beat analysis in patients living with a pacemaker [4, 11]. TEB recording can be used both at rest and during physical exercise [2, 3, 6, 7, 8, 10, 12]. The significant increase in the heart rate observed in the VVI mode can be explained with effect of the ventricular overdrive. In case of normal AV conduction the program of the basic rate of PM was set at a higher rate than the patient's own sinus rhythm. In patients with persisting AV block the PM had to be programmed to the frequency which corresponds to the P wave.

Results of the stroke volume index in the VVI mode showed an immediate and significant fall as a consequence of lost AV synchrony. The restoration of the

AV synchrony resulted in significant improvement in the stroke volume in all AVD settings of VDD mode. Relevant other alterations could not be observed among the different AVDs settings, because optimal AVD settings are individually depending on age, heart rate and function of the left ventricle (Figure 7). The patients' frequency curves at rest and physical exercise should always be considered whenever a further smooth adjustment is required by applying an individual dynamic AVD program.

The cardiac index unlike in VVI mode shows significant improvement in VDD mode with "high" AVD setting, despite the programmed higher normal frequency in VVI mode. Concerning heart rate, there was no considerable difference between VDD mode with AVD "medium" setting and VVI mode. However, the improvement in cardiac index was significant in VDD mode. The cardiac index increases that during P wave triggered ventricle stimulation (VDD mode) at rest and in case of unchanging afterload, because of the improvement of the ventricular filling, which is ensured by the AV synchrony (Frank-Starling mechanism). Despite the significant increase in stroke volume during AVD "low" setting, the cardiac index does not increase because of the (compared to the other two settings) relatively significant fall in the heart rate ($p < 0.01$) and the moderate increase in SVR.

Conclusion

The haemodynamic changes resulted from the programming of the pacemaker can be easily detected with the beat-to-beat analysis of TEB recording.

When AV synchrony is ceased (VVI stimulation), cardiac index falls significantly causing various complaints and discomfort for the patient.

Restoring AV synchrony, which is similar to the physiological conduction, results in the significant improvement of cardiac output by means of establishment of the optimal ventricular filling.

In general, none of the different AVDs should be "favored". In order to achieve optimal cardiac output, the dynamic AVD programming should be adapted to the individual physical and haemodynamic characteristics of the patient. The Dromos pacemaker family provides the program the dynamic AVD adjusted to the individual requirements, which is another additional tool for improving the quality of life the pacemaker-holder patients.

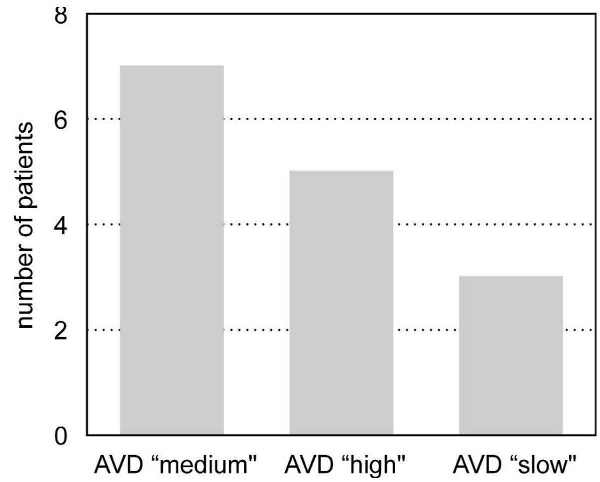

Figure 7. The ratio of patients according to the optimal AV delay (AVD).

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