● Original Article ●

Assessment of Optimal Atrioventricular Delay Using Doppler Index in Atrioventricular Sequential Pacing

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Summary: Optimal atrioventricular (AV) delay (AVD) is important for AV sequential pacing. To verify whether optimal AVD can be determined using only Doppler index (DI), adult mongrel dogs with complete AV block were examined with pulsed Doppler echocardiography and hemodynamics measured by a cardiac catheter. After passive-fixation pacing leads were inserted into the right atrium and ventricle, complete AV block was achieved by radio-frequency catheter ablation. AV sequential pacing was then applied. Cardiac index (CI), isovolumic contraction time (ICT), isovolumic relaxation time (IRT), aortic ejection time (ET), and diastolic filling time (DFT) were measured, and DI was calculated as (ICT+IRT)/ET at AVDs of 50, 80, 100, 120, 150, and 200 ms. DI was minimal when AVD was set at 100 ms, and increased significantly when AVD was set at either above or below 100 ms. Optimal AVD determined from DI was the AVD at which DI was minimal. This optimal AVD was equal to the optimal AVD obtained from CI. On the basis of results in this study, DI is useful in determining optimal AVD in AV sequential pacing.(J. Jpn. Coll. Angiol., 2004, **44**: 103–107)

Key words: AV sequential pacing, AV delay, Doppler index

Introduction

Determining optimal atrioventricular (AV) delay (AVD) is very important, as it greatly affects cardiac function in AV sequential pacing. Numerous studies have utilized echocardiography to determine optimal AVD.[1~8] Doppler index[9] (DI) has provided indications of cardiac function, and can be used to evaluate global cardiac function. One clinical study[1] demonstrated the relationship between optimal AVD and DI, but failed to specify whether optimal AVD is determined using only DI. This study sought to clarify whether optimal AVD could be determined in AV sequential pacing using only DI, and assessed relationship between parameters of Doppler time interval and changes in cardiac function under various settings of AVD.

Subject and Method

Seven adult mongrel dogs (10–28 kg) were used under general anesthesia. All experimental animals were treated in accordance with the Guide for the Care and Use of Experimental Animals at the Faculty of Agriculture, Kagoshima University. General anesthesia was performed by intravenous administration of sodium pentobarbital (25 mg/kg) and xylazine (1 mg/kg). In addition, propranolol (0.04 mg/kg/h) was administered continuously to regulate heart rate. A 5F Swan-Ganz catheter was inserted into the left femoral vein. Passive-fixation leads were inserted into the right ventricle and right atrium from the right internal jugular vein, anchored to the optimal positions, and connected to a programmable stimulator. A 7F ablation catheter was inserted into the right femoral vein to achieve complete AV block. After confirm-

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ing bundle of His potential, radio-frequency ablation was applied. With complete AV block, continuous AV sequential pacing was started. While atrial rate was maintained at 90–100/min, external atrial pacing rate was set at 100–110/min. All measurements were performed at AVDs of 50, 80, 100, 120, 150, and 200 ms. With each change, 3 min were allowed for stabilization before measurements. A Swan-Ganz catheter was placed in the pulmonary artery to measure cardiac output (CO); which was three consecutive measurements were averaged, which came to a result within 15% of one another. Doppler echocardiography was performed using an Aloka SSD 4000 with a 3.5-MHz transducer. The transducer was positioned at the cardiac apex and mitral inflow velocity was recorded from the apical four-chamber view with the sample volume placed at the mitral valve leaflet tips. Left ventricular outflow velocity was recorded from the apical long-axis view with the sample volume placed just below the aortic annulus. Under each AVD pacing state, CO was measured, and Doppler tracings were videotaped. Isovolumic contraction time (ICT), isovolumic relaxation time (IRT), aortic ejection time (ET), and diastolic filling time (DFT) were measured. DI was calculated as (ICT+IRT)/ET, derived as (a–b)/b (**Fig. 1**).[9] DI was defined as the mean of 3 consecutive cardiac cycles. CO was divided by body surface area to obtain Cardiac index (CI). Different researchers independently controlled echocardiography recordings and measurements of each index. Measured variables are provided as mean±SD. ANOVA was repeated to obtain statistical analysis. Values of $P<0.05$ were considered statistically significant.

Results

Representative Doppler recordings of mitral inflow velocity and left ventricular outflow velocity at two different AVDs were demonstrated (**Fig. 2**). Changes in CI occured under various settings of AVD, reaching a maximal value when AVD was set at 100 ms. CI decreased greatly when AVD was set at either above or below 100 ms (**Fig. 3**). ICT gradually decreased from AVD settings of 200 ms to 50 ms (**Fig. 4a**). The sum of ICT and IRT gradually decreased from AVD settings of 200 ms to 80 ms, and increased slightly from AVD settings of 80 ms to 50 ms (**Fig. 4b**). ET gradually increased from AVD settings of 50 ms to 100 ms, and no remarkable change in ET was observed from AVD settings of 100 ms to 200 ms (**Fig. 4c**). Shortening of AVD from 200 ms to 50 ms gradually increased DFT (**Fig. 4d**). DI was minimal when AVD was set at 100 ms, and increased significantly when AVD was set at either above or below 100 ms (**Fig. 5**).

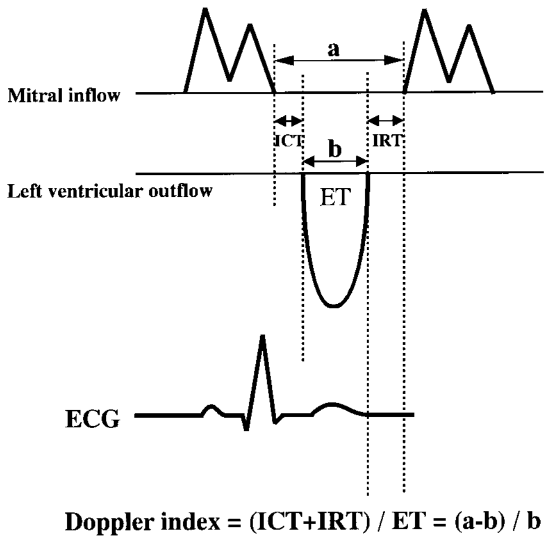

Figure 1 Doppler index was determined as (ICT+IRT)/ET, derived as (a–b)/b.
ECG: electrocardiography, ET: ejection time, ICT: isovolumic contraction time, IRT: isovolumic relaxation time.

Discussion

Cardiac pacing is extremely useful in the treatment of bradyarrhythmia. Physiological pacing has seen wide use in helping to maintain cardiac function; physiological dual-chamber pacing and duration of AVD affect cardiac function. Several methods have been used to determine optimal AVD, including CO and/or CI obtained with cardiac catheterization,[10~12] QT interval,[13~15] and radionuclide ventriculography.[16, 17] However, these are impractical, owing to relatively long examination times, difficulties in monitoring, and high costs. On the other hand, echocardiography can be used at the bedside with a low level of invasiveness. DI offers several advantages[9]: easy measurement, reproducible results, and ability to perform measurements any time after pacemaker implantation.

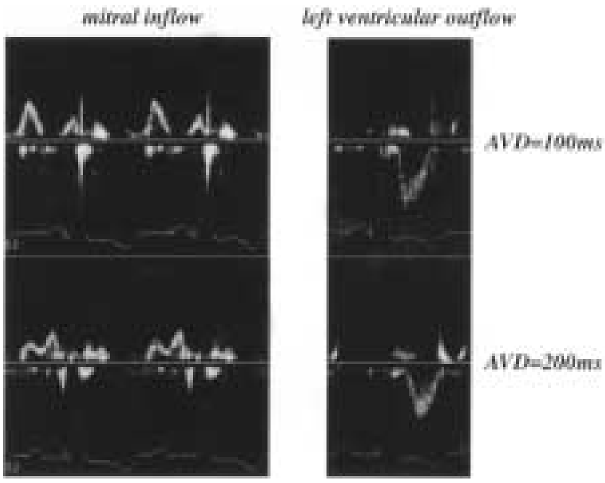

Figure 2 An example of pulsed Doppler echocardiography of left ventricular outflow and mitral inflow at atrioventricular delays (AVDs) of 100 ms (upper) and 200 ms (lower).

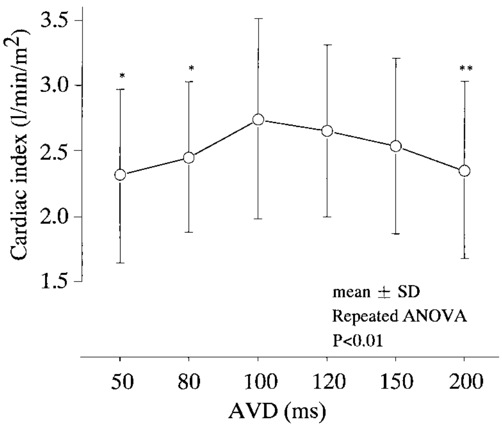

Figure 3 CI changed under various settings of AVD, reaching a maximal value when AVD was set at 100 ms. CI decreased significantly when AVD was set at either above or below 100 ms (P=0.003).
*P<0.05 for AVD=100 ms, **P<0.01 for AVD=100 ms.
CI: cardiac index, AVD: atrioventricular delay.

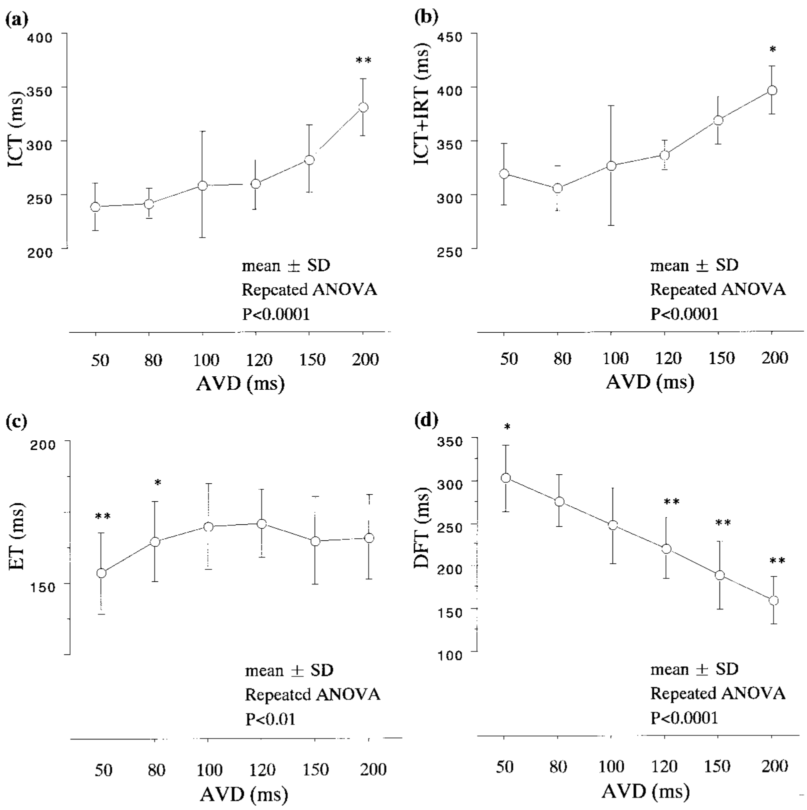

Figure 4
a: ICT gradually decreased from AVD settings of 200 ms to 50 ms.
b: ICT+IRT gradually decreased from AVD settings of 200 ms to 80 ms, and increased slightly from 80 ms to 50 ms.
c: ET gradually increased from AVD settings of 50 ms to 100 ms, and no significant change in ET was observed from AVD settings of 100 ms to 200 ms.
d: DFT gradually increased from AVD settings of 200 ms to 50 ms.
*P<0.05 for AVD=100 ms, **P<0.01 for AVD=100 ms.
ICT: isovolumic contraction time, AVD: atrioventricular delay, IRT: isovolumic relaxation time, ET: ejection time, DFT: diastolic filling time.

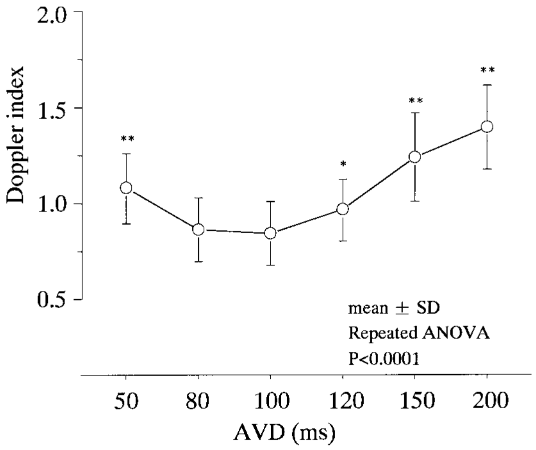

Figure 5 DI was minimal when AVD was set at 100 ms, and increased significantly when AVD was set at either above or below 100 ms (P<0.0001).
*P<0.05 for AVD=100 ms, **P<0.01 for AVD=100 ms.
DI: Doppler index, AVD: atrioventricular delay.

We then investigated whether optimal AVD could be determined using only DI under various settings of AVD in AV sequential pacing. In the present animal experiment, CI peaked when AVD was set at 100 ms, decreasing when AVD was set at either above or below 100 ms. Skinner et al.[18] showed that CO changed with varying AV intervals and was reduced by either shortening or lengthening AV interval. DI, measured simultaneously with CI, was minimal when AVD was set at 100 ms, and increased when AVD was set at either above or below 100 ms. Similarly, changes in CI and DI under various settings of AVD may indicate changes in hemodynamics. In addition, optimal AVD obtained from hemodynamic index is consistent with the values of AVD obtained from DI. Toda et al.[1] reported that DI was improved by prolonging DFT to optimize AVD. In this study, DI was improved in the range of 200 ms AVD to optimal AVD. This was attributed to shortened the sum of ICT and IRT, and prolonged DFT. However, shortening AVD from optimal value to 50 ms prolonged DFT and decreased the sum of ICT and IRT, resulting in worsened DI. Kataoka[19] reported that 50 ms AVD resulted in decreased ET, and that overstretching muscle fibers at an AV interval of 50 ms causes an inappropriate increase in preload that may contribute to worsened left ventricular function. The findings of this study indicate that shortening ET caused worsened DI because ET decreased from optimal AVD to an AVD setting of 50 ms. When AVD was set at above optimal value, there was no significant change in ET. On the contrary, shortening of DFT and prolongation of the sum of ICT and IRT were observed. So worsened DI when AVD was set at above optimal value was due to shortening of DFT and prolongation of the sum of ICT and IRT.

In conclusion, optimal AVD as obtained by DI is consistent with optimal hemodynamic AVD, and DI is therefore useful in determining optimal AVD in AV sequential pacing.

Limitations

DI as obtained in this animal experiment was generally greater than that observed in typical clinical situations. This may be due to suppression of cardiac function by xylazine as an anesthetic and β-blockers to regulate heart rate. Further clinical studies are required with the following in mind: the results of animal experiments are not necessarily applicable to humans.

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