

Impedance Cardiography for Atrioventricular Interval Optimization During Permanent Left Ventricular Pacing

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TSE, H-F., ET AL.: Impedance Cardiography for Atrioventricular Interval Optimization During Permanent Left Ventricular Pacing. Left ventricular (LV) pacing is increasingly used in the management of congestive heart failure. Optimization of the atrioventricular (AV) interval is essential to maximize the hemodynamic benefits of this therapy. Although Doppler echocardiography (echo) is the most widely used method, it is time-consuming, expensive, and operator-dependent. We examined the value of an impedance cardiography (IC)-based method of cardiac output (CO) measurement to optimize the AV interval in 5 men and 1 woman (mean age = 72 ± 11 years) during permanent LV pacing with a 4.8 Fr unipolar coronary sinus pacing lead. Simultaneous measurements of CO by IC and echo were performed at AV intervals of 50, 80, 110, 150, 180, and 225 ms during DDD pacing at 85 beats/min. The optimal AV interval varied between 110 and 180 ms. In 5 of 6 patients (83%), the optimal AV interval by echo and IC was identical. While CO measurements were higher with IC than with echo (6.1 ± 0.4 L/min vs 4.7 ± 0.3 L/min, $P < 0.05$), CO measurements by IC and echo were closely correlated ($r = 0.87$, $P < 0.001$). In conclusion, our initial experience suggests that IC is a reliable method of AV interval optimization during LV pacing. IC and echo measurements of CO during LV pacing were closely correlated. (PACE 2003; 26(Pt. II):189-191)

atrioventricular interval, impedance cardiography, echocardiography, congestive heart failure, cardiac output

Introduction

The site of ventricular stimulation^{1,2} and the programming of the atrioventricular (AV) interval³ both influence cardiac hemodynamics during cardiac resynchronization therapy for treatment of congestive heart failure. The AV interval during AV sequential pacing influences left ventricular (LV) systolic performance by modulating preload.⁴ Therefore, incorrect programming of the AV interval during cardiac pacing may result in suboptimal hemodynamics.⁵ Although Doppler echocardiography (echo) is an established method to optimize the AV interval during dual chamber pacing, it is time-consuming, expensive, and operator-dependent. Prior studies have demonstrated that impedance cardiography (IC) is a useful alternate noninvasive technique to optimize the AV interval,⁶ and correlates well with Doppler echo in patients with standard DDD pacemakers.⁷ However, the value of IC to optimize the AV interval during LV pacing remains unclear. The aim of this study was to compare IC with Doppler echo to optimize the AV interval during permanent LV pacing.

Methods

Patients

The study population included 5 men and 1 woman with sick sinus syndrome (mean age = 78 ± 11 years) who had received DDDR pacemakers and a permanent Medtronic 1055K LV pacing lead (St. Jude Medical, Sylmar, CA, USA), via the coronary sinus lead as described previously.⁸ Patients with a history of coronary artery diseases, significant valvular disease, congestive heart failure, chronic atrial tachyarrhythmias, or left ventricular ejection fraction $< 50\%$ on a baseline screening echo were excluded from this study. The mean LV ejection fraction (EF) by echo was $62\% \pm 12\%$. The study protocol was approved by the local Ethics Committee and informed consent was obtained from all patients.

Study Protocol

Throughout the study, the pacemakers were programmed to DDD mode at a lower pacing rate of 85 beats/min to ensure continuous atrial pacing. Cardiac output (CO) at rest was measured simultaneously by Doppler echo and IC at AV intervals of 50, 80, 110, 150, 180, and 225 ms, in random order. At least 5 minutes were allowed for stabilization between measurements. At each AV interval, mean CO was calculated by averaging three consecutive measurements obtained by each technique. All

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patients were studied by the same operator under standardized conditions, and all measurements of CO were made in the left lateral position after at least 15 minutes of inactivity.

Impedance Cardiography

IC was performed with a commercially available device (BioZ.com, CardioDynamics International Corporation, San Diego, CA, USA) which allows the noninvasive measurement of CO by monitoring the change in impedance of an alternating current applied across the thorax.⁹ A pair of patches was placed anterior to the ear lobes. The chest leads were placed as recommended by the manufacturer. Measurements of CO were made from 10-beat averages. A default central venous pressure value of 8 mmHg was used.

Doppler Echocardiography

The echo studies were performed with a VingMed System V (GE Medical System, USA) using a 2.5 or 3.5 MHz transducer. The Doppler study was performed with the patient in the left lateral decubitus position and with the transducer placed at the apex to obtain apical 4 chamber views. Transmitral pulsed Doppler inflow velocity was recorded with the sample volume positioned between the edges of the mitral leaflets during quiet respiration. Peak velocities of the early filling and atrial filling waves were determined, as were their velocity time integrals. The CO was calculated from the stroke volume measured by using the aortic valve flow velocity integral and the cross-sectional area of left ventricular outflow tract. All echo data were digitally stored in a Macintosh PowerPC computer for later off-line analysis.

Statistical Analysis

All data are expressed as mean \pm 1 standard deviation. Analysis of variance with repeated measures was used for multiple comparison of CO measurements at different AV intervals, followed by post-hoc test. The Pearson correlation test was used to test the correlation between CO measured by Doppler echo versus by IC. P values <0.05 were considered statistically significant.

Results

The optimal AV interval and CO determined by IC and Doppler echo in each patient are presented in Table I. There was no significant difference between the mean AV interval determined by impedance cardiography and that determined by Doppler echo (153.3 ± 23.5 ms vs 158.3 ± 25.4 ms). In 5 of 6 patients (83%), the optimal AV intervals measured by the two methods were identical (Table I).

The mean CO at different AV intervals measured by IC and Doppler echo is presented in Figure 1. The mean CO measured by IC at each AV interval was significantly higher than when measured by Doppler echo. The mean CO at the optimal AV interval determined by IC was significantly higher than when determined by Doppler echo (6.1 ± 0.4 L/min vs 4.7 ± 0.3 L/min, $P < 0.05$). However, a close correlation was found between CO measured by IC and CO measured by Doppler echo ($r = 0.67$, $P < 0.001$, Fig. 2).

Discussion

The results of the present study suggest that IC is a reliable method to optimize the AV interval during LV pacing. Although CO measured by IC

Table I.

Optimal Atrioventricular Interval Using Cardiac Output Measured by Impedance Cardiography and Echocardiography

| Patient # | Impedance Cardiography | | Echocardiography | |
|---------------|--------------------------|-----------------------------------|--------------------------|-----------------------------------|
| | Optimal AV Interval (ms) | Maximum CO at Optimal AV Interval | Optimal AV Interval (ms) | Maximum CO at Optimal AV Interval |
| 1 | 180 | 5.4 ± 0.3 | 180 | 5.02 ± 0.37 |
| 2 | 150 | 6.1 ± 0.4 | 150 | 5.06 ± 0.51 |
| 3 | 150 | 5.5 ± 0.1 | 150 | 4.59 ± 0.28 |
| 4 | 110 | 7.0 ± 0.3 | 110 | 5.34 ± 0.47 |
| 5 | 180 | 6.8 ± 0.4 | 180 | 5.08 ± 0.20 |
| 6 | 150 | 5.1 ± 0.2 | 180 | 3.19 ± 0.10 |
| Mean \pm SD | 153.3 ± 23.5 | 6.1 ± 0.4 | 158.3 ± 25.4 | $4.7 \pm 0.3^*$ |

AV = atrioventricular; CO = cardiac output. *p < 0.05 compared with cardiac output measured by impedance cardiography

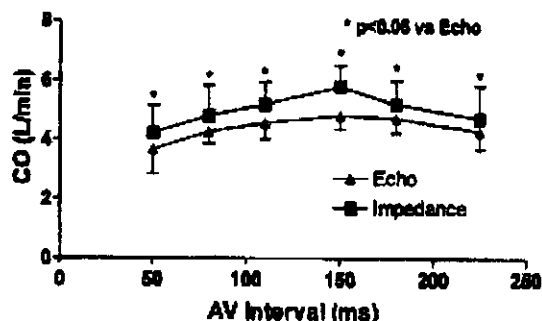


Figure 1. Cardiac output measured by impedance cardiography and Doppler echocardiography at various atrioventricular intervals.

was higher than when measured by Doppler echo, a close correlation between the two measurements was observed. In the majority of recipients of dual chamber pacemakers the AV interval is usually programmed empirically. However, optimization of the AV interval during dual chamber pacing optimizes the timing of atrial contraction contributing to ventricular preload.⁵ Previous studies have shown that optimization of the AV interval can contribute up to 40% of the CO.^{5,10,11} Therefore, it is an important step to maximize the hemodynamic benefits of cardiac pacing, especially during cardiac resynchronization therapy for congestive heart failure.³

IC has been found useful to measure CO non-invasively, and to be closely correlated with invasive technique.⁹ Prior studies have demonstrated that it is a useful alternative to Doppler echo to optimize the AV interval during standard dual chamber pacing with permanent right ventricu-

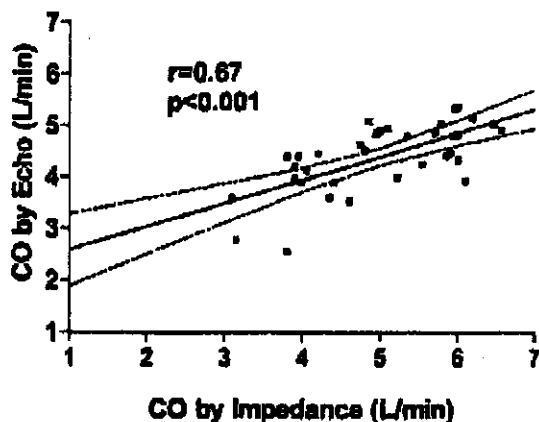


Figure 2. Scatterplot comparing cardiac output measured with impedance cardiography versus Doppler echocardiography.

lar stimulation.^{6,7} LV pacing is being increasingly used in the management of congestive heart.¹ This study demonstrates the feasibility and ease of this impedance technique to determine CO during LV pacing with a close correlation with Doppler echo.

Limitations of the Study

The main limitation of AV interval optimization by either technique was their performance in the supine position and at rest. Therefore, the findings of this study may not be applicable during upright posture or during exercise. Another important limitation was the small number of patients studied. Larger studies validating IC are needed before its clinical application can be recommended.

References

1. Leclercq C, Kass DA. Retiming the failing heart: Principles and current clinical status of cardiac resynchronization. *J Am Coll Cardiol* 2002; 39:194-201.
2. Butter C, Auricchio A, Stellbrink C, et al. Effect of resynchronization therapy stimulation site on the systolic function of heart failure patients. *Circulation* 2001; 104:3028-3026.
3. Auricchio A, Ding J, Spinnelli JC, et al. Cardiac resynchronization therapy restores optimal atrioventricular mechanical timing in heart failure patients with ventricular conduction delay. *J Am Coll Cardiol* 2002; 39:1182-1189.
4. Chevalier S, Basta M, Leitch JW. The importance of the left atrioventricular interval during atrioventricular sequential pacing. *PACE* 1997; 20:2956-2960.
5. Druvert C, Mabo P, Gras, et al. Physiological cardiac pacing: An individual objective. The importance of AV synchrony optimization. In AE Aubert, H Hector, R Stroobandt (eds): *Cardiac Pacing and Electrophysiology*. Dordrecht, The Netherlands, Kluwer Academic Publishers, 1994, pp. 238-247.
6. Crystal E, Ovseyshcher E. Cardiac output-based versus empirically programmed AV interval- how different are they? *Eurpace* 1999; 1:121-126.
7. Kindermann M, Frohlig C, Dorr T, et al. Optimizing the AV Delay in DDD pacemaker patients with high degree AV Block: Mitral valve doppler versus impedance cardiography. *PACE* 1997; 20:2453-2462.
8. The HF, Yu C, Lee KL, et al. Initial clinical experience with a new self-retaining left ventricular lead for permanent left ventricular pacing. *PACE* 2000; 23:1738-1740.
9. Rosenberg F, Yancy CW. Noninvasive assessment of hemodynamics: An emphasis on biimpedance cardiography. *Curr Opin Cardiol* 2000; 15:151-153.
10. Mortelmans L, Vanhecke W, Mertens D, et al. Assessment of the optimal atrioventricular delay in dual chamber paced patients by a portable scintillation probe (VRST). *J Nucl Cardiol* 1996; 3:321-326.
11. Ovseyshcher IE. Toward physiological pacing: Optimization of cardiac hemodynamics by AV delay adjustment. *PACE* 1997; 20:861-865.