Background  Atrioventricular (AV) delay optimization may be important in patients with biventricular pacing and the optimal AV delay can be predicted using Doppler echocardiography and the formula: optimal AV delay = AV delay – the interval between the end of A wave and complete closure of the mitral valve when the AV delay is set at slightly prolonged AV delay.

Methods and Results  In the present study the efficacy of this method was evaluated in 5 patients (67.4±8.0 (SD) years old) with biventricular pacing. Cardiac output (CO) and diastolic filling time were measured by Doppler echocardiography. When the AV delay was set at the predicted optimal AV delay –25 ms, the predicted optimal AV delay (133±66 ms) and predicted optimal AV delay +25 ms, the respective CO were 4.5±0.9, 5.3±1.0, 4.8±1.0 L/min (p<0.05, ANOVA) and the diastolic filling times were 364±100, 373±105, 335±84 ms (p<0.05, ANOVA). Congestive heart failure improved from New York Heart Association class 3.6±0.5 to 1.4±0.5 (p<0.001).

Conclusions  AV delay optimization is important in patients with biventricular pacing and can be easily achieved by the new method.  (Circ J 2005; 69: 201–204)

Key Words:  Atrioventricular delay; Biventricular pacing; Cardiac resynchronization therapy; Congestive heart failure; Doppler echocardiography

The efficacy of a short atrioventricular (AV) delay in patients with severely impaired cardiac function has been reported, but right ventricular pacing during AV sequential pacing has deleterious effects. It has been reported that biventricular pacing can improve the hemodynamics in patients with congestive heart failure and as both AV delay optimization and shortening of the ventricular activation sequence are important in patients with severely impaired cardiac function, AV delay optimization may also be important during biventricular pacing. However, the optimal AV delay may not be a fixed value in each patient and may need to be frequently calculated.

Diastolic mitral regurgitation (MR) is observed in patients with elevated left ventricular end-diastolic pressure and can be induced by prolonging the AV delay in patients with DDD pacemakers. Cardiac function may be improved by AV sequential pacing and setting the AV delay under the critical PQ interval for the appearance of diastolic MR when diastolic MR is observed in patients with intrinsic AV conduction. We have determined a formula for predicting the optimal AV delay using Doppler echocardiography: optimal AV delay = slightly prolonged AV delay – the interval between the end of the atrial kick and complete closure of the mitral valve (duration of diastolic MR) at the AV delay setting (Fig 1).

In this study, we evaluated the efficacy of our method of AV delay optimization using Doppler echocardiography in patients with biventricular pacing.

Methods  The study included 5 consecutive patients ranging in age from 60 to 77 years (67.4±8.0; mean±SD) with severe congestive heart failure and an implanted biventricular pacemaker selected between December 1999 and September 2001. New York Heart Association (NYHA) class was III–IV before biventricular pacemaker implantation. Two (40%) of the 5 patients were taking angiotensin-converting enzyme inhibitors, 2 (40%) were receiving angiotensin-receptor blockers, 3 (33%) were receiving digitals, 1 (20%) was receiving nitrates, and 5 (100%) were receiving diuretics. Beta-blockers were not prescribed in any patient because of the severe hyperpotension and bronchial asthma. Patients with chronic atrial fibrillation were excluded. Four patients had idiopathic dilated cardiomyopathy and one had ischemic cardiomyopathy. The LV ejection fraction was 23.6±7.1%.

Optimal AV delay was predicted by our method. Cardiac output (CO) and diastolic filling time were measured by Doppler echocardiography when the AV delay was set at the predicted optimal AV delay, the predicted optimal AV delay –25 ms and the predicted optimal AV delay +25 ms.

The follow-up period was 2.3±1.1 (0.8–3.8) years after biventricular pacemaker implantation. We evaluated the severity of congestive heart failure by NYHA class and the optimal AV delay was estimated every 3–6 months. When the end of the A wave on transmitral flow coincided with complete closure of the mitral valve, there was no need to change the AV delay setting. Only when the atrial kick was interrupted or there was a gap between the end of
Fig 1. The atrophicventricular (AV) delay setting at which the end of the A wave on transmitral flow coincides with complete closure of the mitral valve is optimal. AV delay (long) is optimal AV delay + interval between the end of the atrial kick and the ventricular spike + interval between the ventricular spike and complete closure of the mitral valve caused by ventricular contraction (Interval Y). The optimal AV delay can be predicted by our simple formula: slightly prolonged AV delay – the interval between the end of the atrial kick and complete closure of the mitral valve (Interval X; duration of diastolic mitral regurgitation) at the AV delay setting.

Fig 2. (a/Left) Male patient, 60 years old, with idiopathic dilated cardiomyopathy. Marked diastolic mitral regurgitation (arrow) was observed (Upper panel). During 80/min AV sequential pacing, diastolic mitral regurgitation was observed when the AV delay was set at 110 ms (arrow). The interval between the end of the atrial kick and complete closure of the mitral valve (interval X; duration of diastolic mitral regurgitation) was 30 ms. The predicted optimal AV delay was 110–30=80 ms (Middle panel). Diastolic mitral regurgitation disappeared when the AV delay was set at 80 ms (Lower panel). When the AV delay was set at the predicted optimal AV delay –25 ms, the predicted optimal AV delay, and the predicted optimal AV delay +25 ms, the CO was 4.2, 6.0, 5.1 L/min, respectively, and the diastolic filling times were 305, 320, 260 ms. (b/Right) AV delay was optimized (70–100 ms) by our method during follow-up of 3.8 years. Congestive heart failure improved from New York Heart Association (NYHA) class III to II.
the atrial kick and complete closure of the mitral valve (ie, diastolic MR) was the AV delay adjusted. When the atrial kick is interrupted, the AV delay is prolonged until the atrial kick is not interrupted and when the gap between the end of the atrial kick and complete closure of the mitral valve is observed, the AV delay was shortened until the gap disappears.18,19,22 There was no need to detect diastolic MR. All examinations were performed by the same observer, and measurements were made by an observer who was unaware of the clinical data.

Measured variables were expressed as mean±SD. Statistical analysis was performed by paired Student’s t-test and repeated analysis of variance (ANOVA). Values of p<0.05 were considered to be statistically significant.

Results

Three of the 5 subjects were able to receive β-blockers after biventricular pacemaker implantation. The predicted AV delay by our method was 133±66 ms. A representative case is shown in Fig 2. When the AV delay was set at the predicted optimal AV delay –25 ms, the predicted optimal AV delay, and the predicted optimal AV delay +25 ms, the CO was 4.5±0.9, 5.3±1.0, and 4.8±1.0 L/min, respectively (p<0.05, ANOVA, Fig 3) and the diastolic filling time was 364±100, 373±105 and 335±84 ms (p<0.05, ANOVA, Fig 3).

The optimal AV delay at the latest visit was 131±68 ms. Congestive heart failure improved from NYHA class 3.6±0.5 to 1.4±0.5 (p<0.001, Fig 4) and all patients remained in good condition.

Discussion

Although the efficacy of a short AV delay in patients with severely impaired cardiac function has been reported1–5 conventional DDD pacing with AV delay optimization is not always effective for congestive heart failure. In fact, right ventricular pacing during AV sequential pacing has deleterious effects.6 Biventricular pacing can improve the hemodynamics in patients with congestive heart failure5,7–9.
but the importance of optimizing the AV delay is still controversial1–4,20 in DDD pacing for congestive heart failure. The optimal AV delay may change with changes in cardiac function, but has been fixed in previous reports1–20. The optimal AV delay may not be a fixed value in each patient and may need to be adjusted constantly. Both AV delay optimization and shortening of the ventricular activation sequence are important in patients with severely impaired cardiac function and thus AV delay optimization may also be important during biventricular pacing.

In patients with an implanted DDD pacemaker, the atrial kick may be interrupted by a truncated AV delay, and filling time may be shortened by a prolonged AV delay. The optimal AV delay allows completion of end-diastolic filling flow prior to ventricular contraction, providing the longest diastolic filling time.21 The AV delay at which the end of the A wave on transmural flow coincides with complete closure of the mitral valve may be optimal19.

In our previous studies, diastolic MR was detected during the interval between the end of the A wave and complete closure of the mitral valve, and the critical PQ interval that induces diastolic MR may represent the upper limit of the optimal PQ interval.5,6,12–19 The optimal AV delay can be predicted by our simple formula: slightly prolonged AV delay – interval between the end of the atrial kick and complete closure of the mitral valve (duration of diastolic MR) at the AV delay setting.19 The AV delay should be prolonged only slightly because biventricular pacing will not function if the AV delay setting is too long in patients with intrinsic AV conduction.

The results of this present study indicate that biventricular pacing with AV delay optimization is useful for patients with severe congestive heart failure and that our method of optimizing the AV delay using Doppler echocardiography can be applied to patients with biventricular pacing.

Although hemodynamic assessments by catheter examination provide the most reliable measurements of CO and intracardiac pressures, it is invasive and difficult to repeat. Easy and noninvasive methods to optimize the AV delay are required in patients with reduced cardiac function.18,19,21,22 Our method is easy and not time-consuming (usually less than 5 min) and thus can be easily repeated. This method is useful for the follow-up of patients with congestive heart failure and with biventricular pacing.

Study Limitations

Our present study enrolled a small number of patients and we did not cross over the fixed AV delay setting and the optimized AV delay setting for ethical reasons. A randomized control study including many patients may be required.

Conclusion

Optimization of the AV delay during biventricular pacing is important for keeping patients with severe congestive heart failure in good condition and can be easily done using our simple method.

References