Original Articles: Clinical Science

Echocardiographic Study of LV Function in Patients with Ventricular and AV Sequential Pacing

Majid Maleki, MD; Majid Haghjou, MD

Abstract

Objectives- This research was performed to assess systolic and diastolic left ventricular function in patients with ventricular and AV sequential pacing, placing particular emphasis on the long-term evaluation of left ventricular function in ventricular and AV sequential pacing.

We also compared the short-term effects of different modes of pacing on LV function.

Methods- We conducted a prospective one-year echocardiographic study on 40 patients with ventricular and AV sequential pacemakers at our center in Tehran. Echocardiography was done before and 1 week, 2, 6 and 12 months after pacemaker implantation. Systolic and diastolic functions were assessed as well.

Results- 12 (30%) women and 28 (70%) men aged 65.32±13.11 years were recruited in the study. 32 (80%) had advanced AV block and 8 (20%) had sick sinus syndrome. End diastolic volume, stroke volume, and ejection fraction were significantly decreased (p<0.01) in ventricular pacing group in short and long–term evaluations. In AV sequential pacing group, end diastolic volume, end systolic volume, and stroke volume were significantly decreased (p<0.01 for both).

Conclusion- In spite of a decreased ejection fraction, ventricular pacing can improve cardiac output both in short and long-terms, but AV sequential pacing improves cardiac output by increasing both ejection fraction and the heart rate. Diastolic function assessment by echo is not as reliable as in systolic function. **(*Iranian Heart Journal.* 2002; 2(4)&3(1): 6-10)**

Key words: Ventricular pacing < AV sequential pacing < left ventricular function < echocardiography

Although several studies have evaluated acute hemodynamic effects of various pacing modalities and heart rates on left ventricular function and cardiac outputs, little information is available about chronic hemodynamic effects of cardiac pacing.[1] Moreover, recent studies have shown hemodynamic benefits of AV sequential pacing versus ventricular pacing.[2,3,4] The evaluation of left ventricular function used to be performed by invasive and time-consuming studies[2,3,4] but recently the reliability of noninvasive methods such as echocardiography has been confirmed.[6,7,13] Until now, the hemodynamic effect of cardiac pacing has been evaluated only for a short time by mode switching from VVI to DDD or VDD.[8,13] This study was designed to evaluate left ventricular systolic and diastolic functions during one-year ventricular and AV sequential pacing.

Material & Methods

Study population

During a one-year prospective and before/after study, 40 pacemaker patients,

From the Department of Cardiology, Shaheed Rajaie Cardiovascular Medical Center, Mellat Park, Vali Asr Avenue, Tehran, Iran
Correspondence to M. Maleki, MD, Shaheed Rajaie Cardiovascular Medical Center, Mellat Park, Vali Asr Avenue, Tehran, Iran
Email: Maleki@rhc.ac.ir Fax: + (9821) 2042026

including 20 with ventricular pacemakers and 20 AV sequential pacemakers, were evaluated serially for left ventricular systolic and diastolic functions by echocardiography. The 40 patients included 12 (30%) males and 28 (70%) females. The average age of the patients in the groups was 65.32±13.11. 30% of the ventricular pacing group and 30% of the AV sequential pacing group were male and 70% in each group were female. Indication for pacing was AV block in 80% and sick sinus syndrome in 20%. In this study, patients with previous pacemaker, poor window for echo and sick sinus patients with tachy-brady syndrome were excluded.

Study design

Information was obtained by the echocardiography machine, *VINGMED*. This machine with a 3.5 Mhz transducer is capable of M-mode, 2D and Doppler study. Simultaneously, ECG monitoring was shown on the echo monitor. For all patients, a complete echo study, including M-mode, 2D and Doppler was performed in the parasternal long axis, apical 4-chamber and apical 2-chamber views before pacemaker implantation. The same echo study was repeated 1 week, 2, 6, and 12 months after the implantation. In each session, the echo study was begun with M-mode in the parasternal long axis. In this view, end diastolic diameter and end systolic diameter were calculated according to the criteria of American Society of Echocardiography. Automatically by this measurement, basal ejection fraction was calculated by the hardware of the echo machine. In the second step, apical 4-chamber and 2-chamber views were obtained from the patients and by Simpson's rule, end diastolic volume, end systolic volume, stroke volume, and global ejection fraction were calculated. Because of simultaneous ECG monitoring, cardiac output was calculated by echo as a product of HR x SV. For the evaluation of diastolic function, sample volume was placed on the tip of the mitral valve in apical 4 chamber view and by activating PW button on the echo machine, pulse Doppler study was done and E-wave and A-wave were shown on the echo monitor. E and A-wave velocities and E-wave deceleration time were calculated. Finally a CW Doppler study was performed on apical 5-chamber view by simultaneous recording of the aortic and mitral Doppler flow. From this tracing, isovolumic relaxation time was measured. All these parameters were measured on different occasions as mentioned before.

Statistical analysis

After obtaining the required data in predetermined intervals, a statistical analysis was performed for each independent variable as mean±SD and their trend over a one-year period was evaluated by the lower–bound test. These calculations were done separately for ventricular and AV sequential pacing groups. For the comparison of systolic and diastolic LV functions in the short-term, the independent variables of 2 months after pacemaker implantation were compared with the variables of preimplantation state. This comparison was tested by paired T-test. All the statistical calculations were done using the SPSS v. 9.01 and *p*-value less than 5% was reported as statistically significant.

Results

40 patients entered this study, including 12 (30%) males and 28 (70%) females with an average age of 65.32±13.11. In the ventricular pacing group, 20 patients, including 6 (30%) male and 12 (70%) females, were included. The average age of this group was 62.30±14.95 years. In the AV sequential pacing group, 20 patients entered, 6 (30%) males and 14 (70%) females. Indications for pacing in the ventricular pacing group were AV block (75%) and sick sinus syndrome

(25%) and in the AV sequential pacemaker group, AV block (85%) and sick sinus syndrome (15%).

An evaluation of LV systolic function in the ventricular pacing group showed a statistical decrease in end diastolic volume, stroke volume, and ejection fraction as well as an increase in cardiac output both in short–term (2 months after pacing) and long-term (up to 12 months after pacing). Changes of end-diastolic diameter, end- systolic diameter, and end-systolic volume were not statistically significant. From the diastolic function parameters, only the increase of E-wave deceleration time over a one-year period was significant statistically. An evaluation of LV systolic function in the AV sequential pacing group showed a statistically significant decrease in end-diastolic volume, end-systolic volume, and stroke volume and an increase in cardiac output and ejection fraction both in the short and long-terms. Changes in end-systolic diameter and end-diastolic diameter were not significant. An assessment of diastolic parameters showed only a statistically significant decrease in isovolumic relaxation time, while other parameters had no significant changes (Tables I-IV).

Table I. Mean values of end-systolic diameter, end–diastolic diameter, end-systolic volume, end–diastolic volume, and stroke volume before and after single chamber PPM implantation

Parameter / Time	ESD (mm)	EDD (mm)	ESV (ml)	EDV (ml)	SV (ml)
Before PPM Imp	34.58 ±5.81	52.99 ±7.83	50.92 ±11.58	111.54 ±21.97	609.32 ±14.37
1 week after Imp	33.44 ±5.63	50.03 ±6.46	49.16 ±11.93	106.73 ±19.65	56.75 ±19.65
2 months after Imp	33.67 ±5.14	50.32 ±7.05	52.49 ±9.72	103.74 ±15.33	51.25 ±11.62
6 months after Imp	33.07 ±5.01	48.84 ±6.97	57.72 ±9.65	101.96 ±14.40	50.191 ±10.52
12 months after Imp	32.99 ±4.96	48.62 ±6.89	51.59 ±9.65	101.55 ±14.37	49.91 ±10.53

ESD indicates end-systolic diameter; EDD, end-diastolic diameter; ESV, end-systolic volume; EDV, end-diastolic volume; SV, stroke volume

Table II. Mean values of end-systolic diameter, end-diastolic diameter, end-systolic volume, end–diastolic volume, stroke volume before and after dual-chamber PPM implantation

Parameter / Time	ESD (mm)	EDD (mm)	ESV (ml)	EDV (ml)	SV (ml)
Before PPM Imp	31.95± 7.57	41.5 ±9.29	43.96 ±16.20	100.35 ±30.64	56.40 ±17.21
1 week after Imp	32.37± 7.69	46.09 ±9.10	42.41 ±16.70	93.01 ±28.47	50.49 ±13.93
2 months after Imp	31.57± 6.99	46.22 ±8.18	38.56 ±17.73	87.40 ±24.01	48.87 ±10.70
6 months after Imp	31.30± 6.71	45.50 ±7.62	36.74 ±15.11	85.55 ±22.25	48.75 ±9.86
12months after Imp	31.18± 6.66	45.44 ±7.54	36.39 ±15.20	85.34 ±22.22	48.89 ±9.96

ESD indicates end-systolic diameter; EDD, end-diastolic diameter; ESV, end-systolic volume; EDV, end-diastolic volume; SV, stroke volume

Table III. Mean values of basal ejection fraction, Simpson ejection fraction, cardiac output, deceleration time, isovolumic relaxation time before and after single-chamber PPM implantation

Parameter / Time	B-EF (%)	S-EF (%)	CO	EWV (em/s)	AWV (em/s)
Before PPM imp	60.10 ± 9.40	53.75 ± 5.77	2736.35 ± 1006.86	65.70 ± 24.33	62.84 ± 21.35
1-week after imp	58.15 ±10.35	53.55 ± 7.20	3660.80 ± 911.49	73.65 ± 8.80	70.26 ± 24.02
2-months after imp	56.85 ±11.57	48.90 ± 7.87	3411.35 ± 786.77	71.85 ± 20.36	68.63 ± 30.47
6-months after imp	54.90 ±12.30	48.75 ± 7.49	3399.00 ± 736.19	71.55 ± 15.06	74.63 ± 27.22
12-months after imp	54.60 ±12.45	48.70 ± 7.46	3413.05 ± 735.97	67,75 ± 12.05	76.79 ± 28.18

B-EF indicates basal ejection fraction; S-EF, simpson ejection fraction; CO, cardiac output; DT, deceleration time; IVRT, isovolumic relaxation time

Table IV. Mean values of basal ejection fraction and Simpson ejection fraction and Cardiac output, deceleration time, isovolumic relaxation time before and after dual – chamber PPM implantation

Parameter / Time	B-EF (%)	S-EF (%)	CO ml/mm	DT ms	IVRT ms
Before PPM Imp	60.40 ±15.50	55.39 ±8.38	2497.05 ±685.93	189.30 ±106.66	134.00 ±31.09
One week after Imp	58.65 ±1522	54.80 ±7.81	3706.45 ±855.40	156.20 ±53.42	118.30 ±20.89
Two months after Imp	59.15 ±15.40	57.15 ±7.49	3822.25 ±909.43	148.80 ±33.11	90.80 ±21.35
Sixth months after Imp	58.48 ±16.23	58.35 ±8.51	3795.05 ±875.86	144.55 ±28.10	82.25 ±17.12
Twelve months after Imp	58.55 ±16.21	58.80 ±8.72	3818.70 ±369.97	142.20 ±23.21	81.95 ±19.52

B-EF indicates basal ejection fraction; S-EF, simpson ejection fraction; CO, cardiac output; DT, deceleration time; IVRT, isovolumic relaxation time

Discussion

A one-year follow-up in the ventricular pacing group showed a marked decrease in end-diastolic volume, stroke volume and ejection fraction. These changes can be explained by the fact that bradycardia with a probable low cardiac output is compensated by an increase in end-diastolic volume and stroke volume. After the implantation of the pacemaker and achieving adequate heart rates, this compensatory mechanism disappears and heart sizes decrease toward the normal.[14] These findings have been shown by other investigators.[6] The decrease of ejection fraction may be related to chronic apical pacing, because previous studies have shown that impulse initiation from apex has depressing effects on the intact heart.[12] The increase of cardiac output in these patients can be explained by a higher heart rate. Contrary to other studies,[6] in this investigation, end-diastolic diameter did not significantly decrease in spite of end-diastolic diameter curve showing a decreasing trend, and *p*-valve was 0.05 (not significant statistically). This finding can be related to an inadequate sample size or measurement error at 2 months after pacemaker implantation. Regarding diastolic pacemakers, the deceleration time significantly increased during the one-year study. In patients with VVI pacing, AV dissociation, variable E-wave velocities, and slopes were seen. Thus this finding (deceleration time decrease) can be an unrelated finding. It is suggested that this issue be evaluated more carefully.

An evaluation of left ventricular systolic and diastolic functions in patients with AV sequential pacing over a one-year period revealed that end-diastolic volume, end-systolic volume, and stroke volume had a significant decrease. Similar to VVI pacing, these findings are related to the achievement of higher heart rates and loss of the Frank-Starling mechanism. In AV sequential pacing, atrial contraction increases end- diastolic volume proportionately to ventricular pacing (higher preload achieved). Thus, the heart empties itself more vigorously and a lower end-systolic volume is obtained.[14] Contrary to VVI pacing, EF increases in these patients as cardiac output increases.

The increase in ejection fraction is related to a higher end-diastolic volume and a lower end-systolic volume, resulting in a higher stroke volume. From diastolic pacemakers, only isovolumic relaxation time had a significant decrease. This finding may indicate that AV sequential pacing improves heart relaxation.

Acknowledgments

We would like to thank the pacemaker clinic and echo lab staff of the Shaheed Rajaie Cardiovascular Medical Center for their kind collaboration in this trial.

References

1. Ellenbogen KA, Kay GN, Wilkoff BL: Clinical cardiac pacing and defibrillation. 2nd ed. W.B.Saunders, U.S.A. PP, 374 2001.

2. Faerestrand S, Ohm OJ: "A time- related study of the hemodynamic benefit of atrioventricular synchronous pacing evaluated by Doppler echocardiography" PACE. 8:8389, 1985.

3. Rediker DE, Eagle KA, Homma S, et al: Clinical and hemodynamic comparison of VVS Versus DDD pacing in patients with DDD pacemakers". Am J. Cardiol 61:323.1988.

4. Kruse I. Armman K, Conradson TB, Ryden L: "A comparison of the acute and long-term hemodynamic effects of ventricular inhibited and atrial synchronous ventricular inhibited pacing. Circulation 65:846, 1982.

5. Goldman BS, parsonnet V: " World survey on cardiac pacing" PACE 2:9,1979.

6. Fareasterand S, Ohm OJ: " A time- related study by Doppler and M- mode echocardiography of hemodynamics, heart rate, and AV valvular function during activity sensing rate-responsive ventricular pacing".

7. Labovitz AJ, Williams GA, Redd RM, Kennedy HL: "Noninvasive assessment of pacemaker hemodynamics by Doppler echocardiography: Importance of left atrial size ". J Am coll Cardiol 6: 196, 1985.

8. Pehrsson SK, Astrom H, " Left ventricular function after long-term treatment with ventricular inhibited compared to atrial triggered ventricular pacing". Acta Med scand 214: 295, 1983.

9. Oh JK. Seward JB. Tajik AJ.: "The echo manual ", 2nd ed. Lippincott Williams & Wilkins. U.S.A. PP, 46, 1999.

10. Feigenbaim H.,: "Echocardiography", 5th ed. Lea & Febiger, U.S.A PP, 143, 1994.

11. Fuster V, Alexander RW, O Rourke RA; " The Heart", 10th ed Mc Graw Hill, U.S.A, PP, 855, 2001.

12. Karpawitch PP, J ustice CD, Cavitt DL, et al.: " Developmental sequel of fixed – rate ventricular pacing in the immature canine heart: an electrophysiologic, hemodynamic, and histopathologic evaluation. Am Heart J. 119: 1077, 1990.

13. Stojnic BB, Stajaanov PL, angelkov L, et al: "Evaluation of asynchronous left ventricular relaxation by Doppler echocardiography during ventricular pacing with AV synchrong (VDD): comparison with atrial pacing (AAI) PACE 6: 940. 1996.

14. Ellenbogen KA, Kay G.N., Wilkoff BL, " Clinical cardiac pacing and Defibrillation", 2nd ed. WB Saunders PP, 338, 2000.

15. Braunwald E.Zipes DP. LIBB y P,: " Heart Disease", 6th ed W, B Saunders, U.S.A, PP, 776, 2001.

16. Paxinos G, Katritsis D, Kakouros S, et al,: Long – term effect of VVI pacing on atrial and ventricular function in patients with sick sinus syndrome". PAE 4: 728, 1998.