Clinical Investigation

The Relationship between P Wave Dispersion and Diastolic Dysfunction

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We investigated the relationship between P wave dispersion, which is easily measured on the surface electrocardiogram and may be used in evaluating the risk of atrial fibrillation, and left ventricular diastolic function.

There were 133 patients: 73 with diastolic dysfunction and 60 without. P wave dispersions were calculated by measuring minimum and maximum P wave duration values on the surface electrocardiogram. The relationships between P wave dispersion and the presence, cause, severity, and echocardiographic measurements of diastolic dysfunction were investigated.

P wave dispersion was 53 ± 9 ms in patients with diastolic dysfunction and 43 ± 9 ms in the control group (P <0.01). When patients were grouped according to stage of diastolic dysfunction, P wave dispersion was 48 ± 7 ms in stage 1, 54 ± 8 ms in stage 2, and 58 ± 9 ms in stage 3. As the severity of diastolic dysfunction increased, P wave dispersion increased but the difference did not reach statistical significance (P <0.05). When the cause of diastolic dysfunction was considered, P wave dispersion was 53 ± 8 ms in patients with ischemic heart disease and 52 ± 9 ms in patients with left ventricular hypertrophy (P >0.05).

We conclude that P wave dispersion increases in diastolic dysfunction, but that this increase is not related to the severity or cause of diastolic dysfunction. When clinical and echocardiographic variables are taken into account, there is a weak but significant correlation only between P wave dispersion and left ventricular ejection fraction. ***(Tex Heart Inst J 2005;32:163-7)***

Key words: *Atrial fibrillation; diastole; electrocardiography; hypertrophy, left ventricular; ischemia; myocardial contraction; P wave dispersion; ventricular dysfunction, left*

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There is growing recognition that congestive heart failure caused by a predominant abnormality in left ventricular (LV) diastolic function (that is, diastolic heart failure) is common and causes significant morbidity and mortality.[1] In left ventricular diastolic dysfunction (LVDD), maintenance of sinus rhythm and atrial contractions is vital for stability of cardiac output. If atrial fibrillation occurs, atrial output decreases considerably and results in an increase of LVDD and progression of diastolic heart failure, which worsens the patient's clinical condition.[2]

Today, several noninvasive electrocardiographic (ECG) indicators have been investigated to predict the occurrence of arrhythmia in patients with LVDD. It has been shown, for example, that P wave dispersion (PD)—because of its relation to the nonhomogenous and interrupted conduction of sinusal impulses both intra- and interatrially—is a noninvasive indicator that enables the calculation of atrial fibrillation risk on the 12-lead surface ECG.[3,4]

We investigated the relationship between PD and the presence of LVDD as detected by Doppler echocardiography: the stage, origin, and echocardiographic indicators of LVDD in patients with LV hypertrophy and ischemic heart disease.

Patients and Methods

From May 2001 through June 2003, we enrolled 133 patients in our prospective study: 73 with LVDD as determined by transthoracic echocardiography (TTE) (39 men and 34 women; mean age, 60 ± 6 years) and 60 patients without LVDD (27 men and 33 women; mean age, 55 ± 9 years).

We excluded patients with previous acute myocardial infarction, thyroid dysfunction, uncontrolled diabetes mellitus, chronic liver or renal disease, valvular heart disease, cardiomyopathy, electrolyte imbalance, drug use that affects atrial conduction,

or alcohol use. Complete TTE studies were performed in all patients, by use of a commercially available system (Vivid™ 3, GE Healthcare; Haifa, Israel). In all patients, we measured diastolic function indicators such as E and A velocity, E/A ratio, deceleration time, and isovolumetric relaxation time (IVRT). In patients without LVDD, we looked for false normalization patterns by applying the Valsalva maneuver, checking pulmonary venous flow, and performing tissue Doppler echocardiography. In addition, we measured left ventricular ejection fraction (LVEF) by the Simpson method, LV diastolic and systolic diameters with M-mode echocardiography, and segmental wall motion defects with 2-dimensional (2-D) echocardiography. Patients with segmental wall motion defects, a positive exercise stress test, or abnormal myocardial perfusion scintigraphy were separated and checked, by coronary angiography, for coronary artery disease. Patients who had LVDD were classified accordingly: stage 1, prolonged relaxation pattern; stage 2, pseudonormalization pattern; and stage 3, restrictive pattern. They were also grouped according to cause as LV hypertrophy (interventricular septum diastolic diameter >1.3 cm) or ischemic heart disease.

Twelve-lead ECGs of all patients at rest, with 1 mV/cm amplitude and 50 mm/sec rate, were obtained. Measurements were performed on a high resolution monitor after the ECGs were converted to digital form. The beginning of the P wave was defined as the point where the initial deflection of the P wave crossed the isoelectric line, and the end of the P wave was defined as the point where the final deflection of the P wave crossed the isoelectric line. Patients whose measurements could be performed in at least 8 derivations were included in the study. In all patients, derivations were excluded if the beginning or the ending of the P wave could not be clearly identified. P wave dispersion was calculated by subtracting the minimum P wave duration from the maximum P wave duration.

For statistical analysis, the SPSS statistical program, version 10.0 (SPSS Inc.; Chicago, Ill) was used. Qualitative variables of groups were given as arithmetic averages ± SD, whereas quantitative variables were given as percentages. The Mann-Whitney U test was used to compare ECG and echocardiographic values between the 2 groups, and ANOVA analysis was used to compare the qualitative values of more than 2 groups. The differences between 3 groups were evaluated by post hoc analysis. The relationships between PD and clinical and echocardiographic variables in patients with LVDD were evaluated by linear regression analysis. A P value <0.05 was considered to be statistically significant.

Results

In patients with LVDD, the maximum P wave duration was 116 ± 8 ms; the PD was 53 ± 9 ms; the LVEF was 0.53 ± 0.08; and the left atrial diameter was 40.5 ± 5.9 mm. In the control group, the measurements in the same order were 104 ± 9 ms, 43 ± 9 ms, 0.64 ± 0.05, and 34.8 ± 4.7 mm. In each of these instances, the difference between the 2 groups reached the level of significance (Table I).

TABLE I. Comparison of Clinical and Echocardiographic Characteristics and P Wave Durations of Patients with and without Diastolic Dysfunction

Characteristics	All Patients	Control Group	Patients with LVDD	*P* Value
Age (year)	58 ± 9	55 ± 8	60 ± 6	>0.05
Hypertension	54%	31%	74%	<0.01
LVEF (%)	57 ± 9	64 ± 5	53 ± 8	<0.01
Heart rate	70 ± 7	68 ± 9	72 ± 6	>0.05
Left atrial dimension (mm)	39 ± 6.4	34.8 ± 4.7	40.5 ± 5.9	<0.01
E/A ratio	1.3 ± 0.6	1.4 ± 0.2	1.4 ± 0.7	>0.05
IVRT	92 ± 36	90 ± 8	96 ± 41	>0.05
DT	194 ± 52	182 ± 13	201 ± 58	<0.05
Maximum P wave duration (ms)	113 ± 9	104 ± 9	116 ± 8	<0.01
Minimum P wave duration (ms)	61 ± 9	61 ± 9	61 ± 8	>0.05
P wave dispersion (ms)	51 ± 9	43 ± 9	53 ± 9	<0.01

DT = deceleration time; IVRT = isovolumetric relaxation time; LVDD = diastolic dysfunction; LVEF = left ventricular ejection fraction

P <0.05 = significant

TABLE II. Comparison of Clinical and Echocardiographic Characteristics and P Wave Durations According to Stage of Left Ventricular Diastolic Function

Characteristics	Stage 1: Prolonged Relaxation (n=22)	Stage 2: Pseudo-normalization (n=24)	Stage 3: Restrictive Pattern (n=27)	*P* Value
Age (year)	59 ± 6	62 ± 6	60 ± 6	>0.05
LVEF (%)	60 ± 6	53 ± 6	46 ± 8	<0.01
Heart rate	73 ± 4	71 ± 7	69 ± 5	>0.05
Left atrial dimension (mm)	37 ± 4	40 ± 4	44 ± 7	<0.01
E/A ratio	0.64 ± 0.1	1.46 ± 0.2	2.29 ± 0.22	<0.01
IVRT	146 ± 13	80 ± 13	52 ± 6	<0.01
DT	271 ± 26	175 ± 18	144 ± 8	<0.01
Maximum P wave duration (ms)	113 ± 7	118 ± 7	117 ± 8	>0.05
Minimum P wave duration (ms)	61 ± 8	63 ± 9	59 ± 9	>0.05
P wave dispersion (ms)	48 ± 7	54 ± 8	58 ± 9	>0.05

DT = deceleration time; IVRT = isovolumetric relaxation time; LVEF = left ventricular ejection fraction

P <0.05 = significant

When patients with LVDD were staged, PD was 48 ± 7 ms in stage 1, 54 ± 8 ms in stage 2, and 58 ± 9 ms in stage 3. Although PD increased as the severity of LVDD increased, these differences did not reach statistical significance (Table II). On the other hand, the differences in LVEF and left atrial diameter between the 3 groups were statistically significant (Table II). The mean LVEF was 0.60 ± 0.06 in stage 1, 0.53 ± 0.06 in stage 2, and 0.46 ± 0.08 in stage 3; and the mean left atrial diameter was 37 ± 4 mm in stage 1, 40 ± 4 mm in stage 2, and 44 ± 7 mm in stage 3.

When the cause of LVDD was taken in to account, PD was 53 ± 8 ms in association with ischemic heart disease and 52 ± 9 ms in association with LV hypertrophy (Table III). The difference between the 2 groups was insignificant, but the LVEF was 0.51 ± 0.07 in association with ischemic heart disease and 0.57 ± 0.09 in association with LV hypertrophy, which was statistically significant (Table III).

As clinical and echocardiographic characteristics affecting P wave duration were investigated, we noted a weak, indirect relationship between PD and LVEF but no relationships between PD and age, sex, heart rate, left atrial diameter, E/A ratio, IVRT, or deceleration time (Table IV).

Discussion

Thirty to forty percent of patients who show clinical signs of heart failure have normal systolic function but LVDD. Diastolic function usually declines before systolic function, and this precedes clinical signs. Therefore, diagnosis of diastolic dysfunction is very important for early diagnosis, follow-up, treatment, and prognosis evaluation in heart failure patients.[5-8]

Because of increased end-diastolic pressure in LVDD, the maintenance of sinus rhythm and atrial contractions is vital for the stability of cardiac output. If atrial fibrillation occurs, the loss of atrial kick, which accounts for

TABLE III. Comparison of Clinical and Echocardiographic Characteristics and P Wave Durations According to Cause of Diastolic Dysfunction

Characteristics	Patients with IHD (n=41)	Patients with LVH (n=32)	*P* Value
Age (year)	60 ± 6	61 ± 7	>0.05
LVEF (%)	51 ± 7	57 ± 9	<0.01
Heart rate	69 ± 9	70 ± 7	>0.05
Left atrial dimension (mm)	40 ± 5	40 ± 6	>0.05
Maximum P wave duration (ms)	117 ± 8	114 ± 8	>0.05
Minimum P wave duration (ms)	62 ± 9	60 ± 9	>0.05
P wave dispersion (ms)	53 ± 8	52 ± 9	>0.05

IHD = ischemic heart disease; LVEF = left ventricular ejection fraction; LVH = left ventricular hypertrophy

P <0.05 = significant

TABLE IV. The Relationship between P Wave Dispersion, Maximum P Wave Duration, and Clinical, Echocardiographic Characteristics

	P Wave Dispersion			Maximum P Wave Duration		
Characteristics	**β**	***t***	***P* Value**	**β**	***t***	***P* Value**
Age (year)	–0.123	–1.191	<0.24	0.081	0.762	<0.45
LVEF (%)	–0.301	–2.124	<0.04	–0.299	–2.054	<0.04
Left atrial dimension	–0.050	–0.359	<0.72	0.072	0.509	<0.61
E/A ratio	0.043	0.188	<0.85	–0.038	–0.161	<0.87
IVRT	–0.198	–0.638	<0.53	0.026	0.080	<0.94
DT	0.033	0.127	<0.90	–0.018	–0.066	<0.95

DT = deceleration time; IVRT = isovolumetric relaxation time; LVEF = left ventricular ejection fraction

$P < 0.05$ = significant

40% of atrial output, results in an increase of LVDD and in progression of diastolic heart failure.[2]

Hypertension and ischemic heart disease are among the most important causes of atrial fibrillation. Left ventricular diastolic dysfunction in a hypertrophic or ischemic ventricle results in an increase in left ventricular end-diastolic (LVED) pressure and in left atrial dimensions. The increase in left atrial dimensions as a result of rising intra-atrial pressure changes the geometry of atrial fibrils; this, in combination with nonhomogenous fibrosis of the left atrial wall, interrupts the conduction of sinus impulses. As a result, reentry focuses appear, which can start atrial fibrillation.[9-12]

P wave dispersion is related to the nonhomogenous and interrupted conduction of sinus impulses intra- and interatrially. Currently, PD is described as a noninvasive indicator of atrial fibrillation risk, which can be calculated easily on a 12-lead surface ECG.[3,4]

In the literature, no study investigates the relationship between PD and each stage of LVDD or between the PD values of patients with LV hypertrophy and those with ischemic heart disease. Dogan and colleagues[13] compared hypertensive patients who had stage 1 LVDD with hypertensive patients who did not have LVDD and found PD to be higher in LVDD patients. In our study, we used transthoracic echocardiography to measure diastolic function variables and then compared the PD values of LVDD patients with the values of patients who did not have LVDD. In addition, we divided LVDD patients into 3 groups according to stage and into 2 groups according to cause.

Our results showed that maximum P wave duration, P wave dispersion, left atrial diameter, and deceleration time were significantly higher, while LVEF was significantly lower when compared with those values in the control group. Therefore, it can be said that the presence of LVDD is an important factor affecting PD.

As LVDD progresses from an "impaired relaxation" pattern to a restrictive pattern, increases in left atrial pressure and dimensions are expected. In our study, as the LVDD stage of patients progressed, left atrial dimensions increased significantly, but the increase in PD was unrelated to the stage of LVDD.

It is known that PD increases in ischemic heart disease and hypertension.[12,14-16] Therefore, an increase in PD is expected in patients whose LVDD is associated with ischemic heart disease or hypertensive LV hypertrophy. As a matter of fact, in our study, the PD in ischemic heart disease patients was 53 ± 8 ms, and the PD in LV hypertrophy patients was 52 ± 9 ms—values that were significantly higher than those for the control group (43 ± 9 ms, $P < 0.01$). This finding, that the PD value associated with LV hypertrophy is similar to the PD value associated with ischemic heart disease, leads us to speculate that the cause of diastolic dysfunction does not affect PD; however, our study results might have been skewed by our exclusion of patients with a history of acute myocardial infarction or advanced systolic dysfunction.

Limitations of the Study. Most of our hypertensive patients were on antihypertensive medications. Although we excluded patients who were using drugs that might affect atrial conduction and PD, there are no good data on the effect of antihypertensive agents on PD.

Isovolumetric relaxation time and deceleration time were measured by means of Doppler echocardiography. Interobserver and intraobserver variability in these measurements can be relatively high, so our Doppler measurements were done by a single investigator who had no knowledge of the status of the patients.

In our patients with LVDD, PD increased; but this increase was not related to the severity of LVDD. However, our number of patients was relatively low, and our data need support by larger studies. In addi-

tion, we did not investigate the relationship between P wave duration and the number and location of coronary lesions in patients with ischemic heart disease, because the ischemic heart disease group was too small for statistical analysis on this topic.

Conclusion

In a study investigating the clinical variables that affect PD, Aytemir and colleagues[17] found that—among age, sex, and heart rate—only age was related. In our study, none of those variables had an effect on PD.

Although it has been stated that left atrial diameter is not an important predictor for atrial fibrillation and that P wave duration is unrelated to left atrial diameter,[3,18] other studies have reached contrary conclusions.[19,20] Our finding that an increase in PD is unrelated to left atrial diameter or to stage of LVDD supports the idea that other factors—such as decrease in LV systolic function, increase in sympathetic activity,[21] improper inter- and intra-atrial conduction, and conduction blocks—have an important role in PD.

Also, it is said that a decrease in LVEF is an important predictor of paroxysmal atrial fibrillation.[16] In our study, we found that patients with LVDD also displayed decreased LVEF and that the relationship between LVEF and PD was significant but weakly inverse. As a result, PD—a variable easily measured on the surface ECG—increases significantly in patients with LVDD. This increase is apparent from the 1st stage of diastolic function. Among clinical indicators, only LVEF is related to PD. P wave dispersion can be used in predicting the risk of atrial fibrillation in LVDD patients.

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