

Evaluation of P-Wave Dispersion, Ventricular Functions, and Atrial Electromechanical Coupling in Children with Type 1 Diabetes Mellitus

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ABSTRACT

Objective: The present study aimed to evaluate ventricular diastolic function, inter- and intra-atrial conduction delay, and P wave dispersion in pediatric patients with type 1 diabetes mellitus (DM).

Methods: This study comprised 30 pediatric patients with type 1 DM and 30 healthy children served as the control group. P wave dispersion (Pd) was measured on a 12-channel ECG. Both systolic and diastolic functions of both ventricles were evaluated using conventional and tissue doppler imaging (TDI) echocardiography (ECHO). Atrial electromechanical delay was measured using TDI accompanied with electrocardiography (ECG).

Results: On conventional transthoracic echocardiography (ECHO), the mitral E/A ratio and isovolumetric relaxation times (IVRT) were different between the patients with type 1 DM and the control group (1.67 ± 0.46 vs. 1.95 ± 0.43 , $p=0.017$ and 74.5 ± 7.0 vs. 63.3 ± 5.2 , $p<0.001$, respectively). On TDI, LV septal peak systolic (S_m) and early diastolic (E_m) velocities and E_m/A_m ratio were found to be significantly lower in the patients with type 1 DM than in the control group ($p=0.047$, $p=0.003$, and $p=0.001$, respectively). Regarding atrial electromechanical conduction, prolongation was detected in PA lateral, PA septal, PA tricuspid, and inter-atrial (PA lateral-PA tricuspid) and intra-atrial (PA septal-PA tricuspid) conduction delay ($p<0.001$, $p<0.001$, $p<0.001$, $p<0.001$, and $p<0.05$, respectively).

Conclusion: Our findings suggest that intra- and inter-atrial conduction delay, p wave dispersion, and ventricular diastolic functions are abnormal in patients with type 1 DM.

Keywords: Atrial electromechanical delay, children, diastolic function, left atrial mechanical function, type 1 diabetes mellitus

INTRODUCTION

Type 1 DM is one of the most common chronic diseases in adolescents and children. Poorly controlled type 1 DM is associated with many complications such as nephropathy, neuropathy, retinopathy and cardiovascular diseases. There is an increased risk of cardiovascular diseases such as ischemic heart diseases, systolic and diastolic heart failure, conduction system abnormalities and arrhythmias in patients with type 1 DM (1, 2). Atrial fibrillation, which is associated with high mortality and morbidity, is frequently encountered in daily practice (3). It is known that prolonged intra- and inter-atrial conduction delay and non-homogenous distribution of sinus impulses increase predisposition to Atrial fibrillation (AF). Risk of this predisposition can be determined by noninvasive methods such as P wave dispersion (Pd) and tissue doppler imaging (TDI) (4, 5).

There are a few studies conducted on pediatric cases in the literature. Similar to the methodology and design of the previous study conducted by İrdem et al. (6) on pediatric patients with

hypothyroidism, we aimed to evaluate ventricular diastolic function, inter- and intra-atrial conduction delay and P wave dispersion in pediatric patients with type 1 DM.

METHODS

Thirty pediatric patients (18 females, 12 males, mean age 9.6 ± 2.4 years) who have been diagnosed with type 1 DM in accordance with the criteria of the American Diabetes Association (7), who have received insulin therapy for at least one year and have been followed for a mean time period of 3.0 ± 1.2 years in our clinic, as well as 30 healthy children (16 females, 14 males, mean age 8.4 ± 3.6 years), as the control group, were enrolled in this study. Pediatric cases with hypertension, cardiomyopathy, valvular heart disease, branch block in ECG, atrioventricular conduction disorders, thyroid function disorder, kidney disease, lung disease, hypercholesterolemia and a bad presentation in ECG and Transthoracic echocardiography (TTE) in both type 1 DM and control groups were excluded from the study. In addition, individuals in both groups were not using any drugs that could affect heart

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rhythm and they had sinusoidal heart rhythm. P wave dispersion was measured as described by Dilaveris et al. (8) in resting ECG. Individuals in both groups provided written informed consent was obtained before the study. Ethics committee approval was not received. The current research was performed in accordance with the principles of the Helsinki Declaration as revised in 2008. We used the method from our previous study on pediatric patients with subclinical hypothyroidism while planning this study (6).

Transthoracic echocardiography (TTE) (Vivid S5 Pro device, GE, Horten, Norway, 2-4MHz phased-array transducer) was performed with 2-dimensional, M-mode, pulse and color flow Doppler imaging on all cases. A recording was made with one lead ECG throughout the TTE. Using conventional TTE, the mean values of the mitral and tricuspid early diastolic E wave, late diastolic A wave, isovolumetric relaxation times (IVRT), deceleration time (DT) and E/A ratio were calculated from three cycles obtained with Doppler and evaluated according to the American Echocardiography Association guidelines (9). Left atrial (LA) diameter was measured from the parasternal long axis, whereas left ventricular end diastolic diameter (LVEDd) and left ventricular end systolic diameter (LVESd) as well as ejection fraction (EF) were measured using M-mode.

Atrial Electromechanical Coupling and tissue Doppler imaging assessments were performed using minimal optimal gain and adjusting spectral pulse Doppler signal filters until reaching Nyquist limit 0.15-0.20 m/s with transducer frequencies between 3.5-4 MHz in Tissue Doppler echocardiography. LV lateral mitral annulus, septal mitral annulus and RV tricuspid annulus TDI measurements were obtained using pulse Doppler in the Apical 4 chamber. Atrial electromechanical delay (PA), the time interval from the onset of P wave to the beginning of the late diastolic (A_m) wave on surface ECG was measured in milliseconds from the LV lateral mitral annulus (PA lateral), septal mitral annulus (PA septal) and RV tricuspid annulus (PA tricuspid) (10). Values were calculated by averaging the measurements from 3 sequential beats. The difference between lateral and tricuspid PA (lateral PA-tricuspid PA) was defined as inter-atrial electromechanical delay, and the difference between septal PA and tricuspid PA (septal PA - tricuspid PA) was defined as intra-atrial electromechanical delay.

In calculating the P wave in 12-lead resting ECG, the beginning of the first positive wave deflecting upwards from the isoelectric line or the beginning of the first negative wave deflecting downwards from the isoelectric line was determined as the beginning of the P wave. The point where the wave returned to the isoelectric line was determined as the end of the P wave. The longest (P_{max}) and shortest (P_{min}) P wave in any derivation of the twelve-derivation ECG were measured in milliseconds in order to calculate P wave dispersion (P_d) ($P_d = P_{max} - P_{min}$). All measurements were performed by two experienced investigators who did not have any information about the clinical condition of the patients. Among the variables measured by two investigators, only those with less than 5% difference were included in the study.

Statistical Analysis

All analyses were performed using Statistical Package for the Social Sciences 11.0 (SPSS Inc.; Chicago, IL, USA) software. All continuous

variables were described as mean±standard deviation, and categorical variables as percentage. Categorical variables were compared with the Chi-square test. The relationship between the two variables was analyzed using the Pearson Correlation analysis. Student t test was used in comparing continuous variables between the two groups. $P < 0.05$ was accepted as statistically significant.

RESULTS

Age, gender, body weight, height, body mass index, systolic and diastolic pressures, LA diameter, LVEDd, LVESd and LV EF were similar in both groups ($p > 0.05$) (Table 1). Maximum P wave duration and P_d values were found to be significantly higher in patients with type 1 DM ($p < 0.001$) (Table 1). The mean HbA_{1c} level was $8.1 \pm 0.7\%$ and the mean duration of the disease was 3.0 ± 1.2 years in patients with type 1 DM.

Isovolumetric relaxation times was higher in the type 1 DM group as compared to the control group ($p < 0.001$) (Table 2). Mitral and tricuspid E, A wave velocities and DT were similar in both groups ($p > 0.05$) (Table 2). Mitral E/A ratio was significantly lower in the type 1 DM group as compared to the control group ($p = 0.017$) (Table 2).

LV septal S_m , E_m velocities and E_m/A_m ratio were significantly lower in the type 1 DM group as compared to the control group ($p = 0.047$, $p = 0.003$, $p = 0.001$, respectively) (Table 2). A_m velocity and E/E_m ratio, on the other hand, were significantly higher in patients with type 1 DM in comparison to the control group ($p = 0.010$, $p = 0.038$, respectively) (Table 2). LV lateral E_m velocity and E_m/A_m ratio were significantly lower in the type 1 DM group as compared to the control group ($p = 0.009$, $p = 0.012$, respectively) (Table 2). A_m velocity

Table 1. Clinical and laboratory characteristics of the patient and control groups

	Patients (n=30)	Control (n=30)	p
Age (Years)	9.6±2.4	8.40±3.6	0.120
Female (n, %)	18 (60)	16 (53.3)	0.602
Body mass index (kg/m ²)	16.3±2.2	15.9±3.7	0.615
Height (cm)	130.9±12.0	124.5±19.9	0.136
Systolic pressure (mmHg)	100.2±7.9	97.9±9.8	0.320
Diastolic pressure (mmHg)	61.5±4.7	63.3±5.6	0.200
Heart rate (beats/min)	90.75±13.0	87.1±16.7	0.352
P_{max} (ms)	106.2±12.0	91.3±8.0	<0.001
P_{min} (ms)	77.5±9.9	74.3±7.9	0.173
P_d (ms)	28.6±8.2	16.9±7.3	<0.001
HbA_{1c} (%)	8.1±0.7	-	-
Duration of disease (years)	3.0±1.2	-	-

LVEDd: left ventricular end diastolic diameter; LVESd: left ventricular end systolic diameter; P_{max} : maximum P-wave; P_{min} : minimum P-wave; P_d : P-wave dispersion

Table 2. Comparison of the variables measured using conventional and tissue Doppler imaging between patients and control groups

	Patients (n=30)	Control (n=30)	p
Conventional Doppler parameters			
Ejection fraction (%)	70.9±3.7	70.2±4.8	0.528
LVEDd (cm)	3.9±0.3	3.7±0.5	0.067
LVESd (cm)	2.4±0	2.3±0.3	0.087
Left atrial diameter (cm)	2.3±0.2	2.2±0.3	0.143
Mitral E velocity (m/s)	0.92±0.16	0.99±0.17	0.128
Mitral A velocity (m/s)	0.57±0.09	0.54±0.15	0.406
Mitral E/A	1.67±0.46	1.95±0.43	0.017
DT (ms)	160.4±14.5	154.7±14.2	0.132
IVRT (ms)	74.5±7.0	63.3±5.2	<0.001
Tricuspid E velocity (m/s)	0.70±0.12	0.65±0.10	0.128
Tricuspid A velocity (m/s)	0.46±0.09	0.44±0.10	0.512
Tricuspid E/A	1.45±0.18	1.46±0.29	0.816

Tissue Doppler parameters

Septal LV

S_m (m/s)	0.09±0.02	0.11±0.01	0.047
A_m (m/s)	0.07±0.01	0.06±0.01	0.010
E_m (m/s)	0.12±0.0	0.14±0.0	0.003
E_m/A_m	1.7±0.6	2.2±0.5	0.001
E/E_m	7.8±1.6	7.0±1.2	0.038

Lateral LV

S_m (m/s)	0.10±0.02	0.08±0.02	0.001
A_m (m/s)	0.07±0.02	0.07±0.02	0.906
E_m (m/s)	0.13±0.04	0.15±0.03	0.009
E_m/A_m	1.8±0.6	2.1±0.4	0.012
E/E_m	7.3±1.7	6.5±1.6	0.068

RV lateral annulus

S_m (m/s)	0.12±0.02	0.12±0.0	0.813
A_m (m/s)	0.10±0	0.11±0.0	0.125
E_m (m/s)	0.13±0.0	0.16±0.02	0.001
E_m/A_m	1.4±0.4	1.5±0.4	0.243

DT: deceleration time; IVRT: isovolumetric relaxation time; LV: left ventricle; S_m : septal systolic velocity; E_m : early diastolic velocity; A_m : late diastolic velocity; RV: right ventricle

Table 3. Atrial electromechanical interval measurement results obtained from tissue Doppler

	Patient (n=30)	Control (n=30)	p
PA lateral (ms)	69.8±4.8	53.2±4.7	<0.001
PA septum (ms)	46.3±2.3	41.1±2.9	<0.001
PA tricuspid (ms)	40.6±3.5	37.8±3.1	0.001
PA lateral–PA tricuspid (ms) ^a	29.1±6.1	15.4±5.5	<0.001
PA septum–PA tricuspid (ms) ^b	5.6±4.4	3.3±3.9	<0.001

Data was provided in mean ± standard deviation. PA; the time interval from the onset of P wave to the beginning of the late diastolic wave (A_m) on ECG measured by tissue Doppler. ^ainter-atrial electromechanical delay. ^bintra-atrial electromechanical delay

and E/E_m ratio were similar in both groups ($p=0.906$, $p=0.068$, respectively) (Table 2). In addition, RV lateral E_m velocity was significantly lower in the type 1 DM group as compared to the control group ($p=0.001$) (Table 2). S_m , A_m velocities and E_m/A_m ratio were similar in both groups ($p>0.05$) (Table 2).

Patients with type 1 DM were found to exhibit a significantly prolonged PA lateral, PA septum, PA tricuspid, inter-atrial (PA lateral-PA tricuspid) and intra-atrial conduction delay (PA septum-PA tricuspid) in comparison to the control group ($p<0.001$, $p<0.001$, $p=0.001$, $p<0.001$, $p<0.001$, respectively) (Table 3).

No correlation was found between the duration of disease and HbA1c, atrial conduction delay ($r=0.003$, $p=0.493$; $r=-0.092$, $p=0.315$, respectively).

DISCUSSION

It is known that type 1 DM constitutes a risk of heart disease. In addition, DM increases the risk of heart failure by directly affecting the heart without the presence of coronary heart disease and also causes functional and structural changes in individuals with impaired glucose tolerance without the presence of microvascular disease (11-13). Cardiac dynamic changes (increased heart rate, arrhythmia etc.) due to autonomic nervous system dysfunction, systolic and diastolic dysfunction in the heart, and cardiomyopathy can manifest in patients with DM (14, 15). Patients with DM can frequently have heart rhythm disorders with advancing age. The most common of such disorders is atrial fibrillation (AF) (16). Previous studies showed that conditions which cause left atrial enlargement lead to inter-atrial conduction delay (4, 5). Filtered P wave analysis is useful in detecting atrial electrophysiological abnormalities in paroxysmal AF. Atrial electromechanical delay can be measured by various methods (17, 18). Today, it is frequently measured by calculating the time interval between the onset of P wave on ECG and the onset of A_m wave in both ventricles on TDI in milliseconds while performing TTE. Studies have shown that patients with paroxysmal AF and mitral stenosis also had intra- and inter-atrial conduction delay (4, 5). There was intra- and inter-atrial conduction delay in our study despite the normal size of the left atrium.

The decrease in mitral or tricuspid early systolic A velocity correlated with reduced atrial contraction. Both parameters are affected by many cardiac conditions such as heart rate, preload and afterload (19). Previous studies have reported different results regarding left ventricular systolic and diastolic function in patients with DM; i.e. some of these studies reported systolic dysfunction whereas others reported diastolic dysfunction (20-23). However, impaired glucose tolerance leads to systolic and diastolic dysfunction in the heart also in the early phase of DM (13, 21, 24). Left ventricular systolic dysfunction may improve by itself if serum glucose concentrations return to normal levels (11). In our study, although ventricular systolic functions were normal in patients with type 1 DM, some parameters of the ventricular diastolic function were moderately impaired. The reason why our patients exhibited diastolic dysfunction in both ventricles and especially in the right ventricle, although mean duration of the disease was short, can be attributed to high HbA_{1c} levels.

Intra- and inter-atrial conduction time can be determined by calculating P wave dispersion and maximum P wave duration in twelve-lead ECG. It is known that non-homogenous sinus impulses constitute a risk factor for AF. It was reported that inter-atrial electromechanical delay measured using TDI has a correlation with P wave dispersion (10, 22). Increased atrial heterogeneous electrical activity facilitates developing atrial fibrillation/atrial flutter by causing atrial reentry. Pd and Pmax have been used to predict the risk of AF development in many studies (3-5, 25). It is known that an increase in the left atrial diameter is significant for AF development. However, studies demonstrated that Pd increased in patients with AF, although the atrial diameter was normal. Our study also revealed that maximum P wave duration and P_d were significantly higher in patients with Type 1 DM, although LA diameter was normal. Consequently, patients with type 1 DM have higher atrial conduction delay in comparison to healthy individuals and this may indicate an increased risk of developing atrial rhythm disturbance in patients with type 1 DM.

Our study has more than one limitation. The limiting factors of this study include the low number of cases in the study, short duration of follow-up, lack of LV posterior wall thickness measurements and lack of LA mechanical measurements.

CONCLUSION

In our study, it was seen that there was atrial electromechanical delay, i.e. left atrium was affected in patients with type 1 DM. In addition, we found in tissue Doppler imaging that systolic and diastolic functions of the left ventricle were sub-clinically affected in patients with type 1 DM.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects", (amended in October 2013).

Informed Consent: Written informed consent was obtained from patients and healthy children and their parents who participated in this study.

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REFERENCES

- Rydén L, Standl E, Bartnik M, Van den Berghe G, Betteridge J, De Boer M, et al. Guidelines on diabetes, pre-diabetes, and cardiovascular diseases: executive summary The Task Force on Diabetes and Cardiovascular Diseases of the European Society of Cardiology (ESC) and of the European Association for the Study of Diabetes (EASD). *Eur Heart J* 2007; 28: 88-136.
- Villanova C, Melacini P, Scognamiglio R, Scalia D, Campanile F, Fasoli G, et al. Long-term echocardiographic evaluation of closed and open mitral valvulotomy. *Int J Cardiol* 1993; 38: 315-21. [\[CrossRef\]](#)
- Brand FN, Abbott RD, Kannel WB, Wolf PA. Characteristics and prognosis of lone atrial fibrillation. 30-year follow-up in the Framingham Study. *JAMA* 1985; 254: 3449-53. [\[CrossRef\]](#)
- Omi W, Nagai H, Takamura M, Okura S, Okajima M, Furusho H, et al. Doppler tissue analysis of atrial electromechanical coupling in paroxysmal atrial fibrillation. *J Am Soc Echocardiogr* 2005; 18: 39-44. [\[CrossRef\]](#)
- Cui QQ, Zhang W, Wang H, Sun X, Wang R, Yang HY, et al. Assessment of atrial electromechanical coupling and influential factors in non-rheumatic paroxysmal atrial fibrillation. *Clin Cardiol* 2008; 31: 74-8. [\[CrossRef\]](#)
- Irdem A, Aydın Şahin D, Kervancıoğlu M, Baspınar O, Sucu M, Keskin M, Kilinc M. Evaluation of P-wave Dispersion, Diastolic Function, and Atrial Electromechanical Conduction in Pediatric Patients with Subclinical Hypothyroidism. *Echocardiography* 2016; 33: 1397-401. [\[CrossRef\]](#)
- Genuth S, Alberti KG, Bennett P, Buse J, Defronzo R, Kahn R, et al. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Follow-up report on the diagnosis of diabetes mellitus. *Diabetes Care* 2003; 26: 3160-7. [\[CrossRef\]](#)
- Dilaveris PE, Gialafos EJ, Sideris SK, Theopistou AM, Andrikopoulos GK, Kyriakidis M, et al. Simple electrocardiographic markers for the prediction of paroxysmal idiopathic atrial fibrillation. *Am Heart J* 1998; 135: 733-8. [\[CrossRef\]](#)
- Quinones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA; Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. Recommendations for quantification of Doppler echocardiography: a report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2002; 15: 167-84. [\[CrossRef\]](#)
- Ozer N, Yavuz B, Can I, Atalar E, Aksöyek S, Övünç K, et al. Doppler tissue evaluation of intra-atrial and interatrial electromechanical delay and comparison with P-wave dispersion in patients with mitral stenosis. *J Am Soc Echocardiogr* 2005; 18: 945-8. [\[CrossRef\]](#)
- Grandi AM, Piantanida E, Franzetti I, Bernasconi M, Maresca A, Marnini P, et al. Effect of glycemic control on left ventricular diastolic function in type 1 diabetes mellitus. *Am J Cardiol* 2006; 97: 71-6. [\[CrossRef\]](#)
- Galderisi M, Anderson KM, Wilson PW, Levy D. Echocardiographic evidence for the existence of a distinct diabetic cardiomyopathy (the Framingham Heart Study). *Am J Cardiol* 1991; 68: 85-9. [\[CrossRef\]](#)

13. Zarich SW, Arbuckle BE, Cohen LR, Roberts M, Nesto RW. Diastolic abnormalities in young asymptomatic diabetic patients assessed by pulsed Doppler echocardiography. *J Am Coll Cardiol* 1988; 12: 114-20. [\[CrossRef\]](#)
14. Berg TJ, Snorgaard O, Faber J, Torjesen PA, Hildebrandt P, Mehlsen J, et al. Serum levels of advanced glycation end products are associated with left ventricular diastolic function in patients with type 1 diabetes. *Diabetes Care* 1999; 22: 1186-90. [\[CrossRef\]](#)
15. Taegtmeyer H, Passmore JM. Defective energy metabolism of the heart in diabetes. *Lancet* 1985; 1: 139-41. [\[CrossRef\]](#)
16. Brand FN, Abbott RD, Kannel WB, Wolf PA. Characteristics and prognosis of lone atrial fibrillation. 30-year follow-up in the Framingham Study. *JAMA* 1985; 254: 3449-53. [\[CrossRef\]](#)
17. Merckx KL, De Vos CB, Palmans A, Habets J, Cheriex EC, Crijns HJ, et al. Atrial activation time determined by transthoracic Doppler tissue imaging can be used as an estimate of the total duration of atrial electrical activation. *J Am Soc Echocardiogr* 2005; 18: 940-4. [\[CrossRef\]](#)
18. Kinay O, Nazli C, Ergene O, Dogan A, Gedikli O, Hoscan Y, et al. Time interval from the initiation of the electrocardiographic P wave to the start of left atrial appendage ejection flow: A novel method for predicting atrial fibrillation recurrence. *J Am Soc Echocardiogr* 2002; 15: 1479-84. [\[CrossRef\]](#)
19. Fukunami M, Yamada T, Ohmori M, Kumagai K, Umamoto K, Sakai A, et al. Detection of patients at risk for paroxysmal atrial fibrillation during sinus rhythm by P wave-triggered signal-averaged electrocardiogram. *Circulation* 1991; 83: 162-9. [\[CrossRef\]](#)
20. Peterson LR, Waggoner AD, de las Fuentes L, Schechtman K, McGill JB, Gropler RJ, et al. Alterations in left ventricular structure and function in type-1 diabetics: a focus on left atrial contribution to function. *J Am Soc Echocardiogr* 2006; 19: 749-55. [\[CrossRef\]](#)
21. Karamitsos TD, Karvounis HI, Dalamanga EG, Papadopoulos CE, Didangellos TP, Karamitsos DT, et al. Early diastolic impairment of diabetic heart: the significance of right ventricle. *Int J Cardiol* 2007; 114: 218-23. [\[CrossRef\]](#)
22. Acar G, Akcay A, Sokmen A, Ozkaya M, Guler E, Sokmen G, et al. Assessment of atrial electromechanical delay, diastolic functions, and left atrial mechanical functions in patients with type 1 diabetes mellitus. *J Am Soc Echocardiogr* 2009; 22: 732-8. [\[CrossRef\]](#)
23. Di Cori A, Di Bello V, Miccoli R, Talini E, Palagi C, Delle Donne MG, et al. Left ventricular function in normotensive young adults with well-controlled type 1 diabetes mellitus. *Am J Cardiol* 2007; 99: 84-90. [\[CrossRef\]](#)
24. Holzmann M, Olsson A, Johansson J, Jensen-Urstad M. Left ventricular diastolic function is related to glucose in a middle-aged population. *J Intern Med* 2002; 251: 415-20. [\[CrossRef\]](#)
25. Perzanowski C, Ho AT, Jacobson AK. Increased P-wave dispersion predicts recurrent atrial fibrillation after cardioversion. *J Electrocardiol* 2005; 38: 43-6. [\[CrossRef\]](#)

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