Maximum P Wave Duration and P Wave Dispersion in Adult Patients with Secundum Atrial Septal Defect: The Impact of Surgical Repair

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Background: Patients with atrial septal defect (ASD) have an increased risk for atrial fibrillation (AF). Previously it was shown that maximum P wave duration and P wave dispersion in 12-lead surface electrocardiograms are significantly increased in individuals with a history of paroxysmal AF. We studied P maximum and P dispersion in adult patients with ASD during normal sinus rhythm. In addition, the impact of surgical closure of ASD on these variables within 1 year after surgery was evaluated.

Methods: Thirty-four patients (21 women, 13 men; mean age: 35 ± 11 years) operated on for ostium secundum type ASD and 24 age-matched healthy subjects (13 women, 11 men; mean age: 37 ± 10 years) were investigated. P maximum, P minimum, and P dispersion (maximum – minimum P wave duration) were measured from the 12-lead surface electrocardiography.

Results: P maximum was found to be significantly longer in patients with ASD as compared to controls (115.2 ± 9 vs 99.3 ± 14 ms; $P < 0.0001$). In addition, P dispersion of the patients was significantly higher than controls (37 ± 9 vs 29.8 ± 10 ms; $P = 0.003$). P minimum was not different between the two groups ($P = 0.074$). After surgical repair of ASD, 10 patients (29%) experienced one or more episodes of paroxysmal AF. Patients with postoperative AF were older (45 ± 6 vs 30 ± 10 years; $P = 0.001$), and had a higher preoperative pulmonary artery peak systolic pressure as compared to those without postoperative AF (51 ± 11 vs 31 ± 9 mmHg; $P < 0.0001$). No significant difference in the pulmonary-to-systemic flow ratio was observed preoperatively between the two groups ($P = 0.56$). P maximum and P dispersion were significantly higher in patients with postoperative paroxysmal AF at baseline and at postoperative first month, sixth month, and first year as compared to those without it (for P maximum $P = 0.027$, $P = 0.014$, $P = 0.001$, $P < 0.0001$, respectively; for P dispersion $P = 0.037$, $P = 0.026$, $P = 0.001$, $P < 0.0001$, respectively). In addition, in patients with postoperative AF, no significant changes were detected in both of these P wave indices during postoperative follow-up. However, in the other group, P maximum and P dispersion were found to be significantly decreased at postoperative 6 months and 1 year as compared to baseline. P minimum was similar throughout the postoperative follow-up as compared to baseline in both groups.

Conclusions: Mechanical and electrical changes in atrial myocardium may cause greater P maximum and P dispersion in patients with ASD. Surgical closure of the ASD can regress these pathological changes of atrial myocardium with a result in decreased P maximum and P dispersion. However, higher P maximum and P dispersion at baseline, which have not decreased after surgery, may be associated with postoperative paroxysmal AF, especially for older patients.

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atrial septal defect; surgery; electrocardiography; P wave duration; P wave dispersion

Atrial septal defect (ASD) is the third most common form of congenital heart disease found in adults and frequently associated with atrial arrhythmias, especially atrial fibrillation (AF).[1–5] The incidence of AF increases with the patient's age. Surgical closure of the ASD, however, rarely eliminates chronic AF once it has persisted for more than 1 year.[2] The reason for recommending surgical closure of ASD earlier, besides prevention of cardiac failure and pulmonary hypertension, is to prevent atrial arrhythmias arising when the patients become older.[1–3,5]

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Previous studies have reported that the prolonged intra- and interatrial conduction and inhomogeneous propagation of sinus impulses would be the characteristics of paroxysmal AF during sinus rhythm.[6–11] Recently, two simple electrocardiographic markers, maximum P wave duration (P maximum) and P wave dispersion (P dispersion, defined as the difference between P maximum and P minimum), were evaluated as the reflection of these conduction abnormalities in patients with paroxysmal AF.[12–15]

In a recent study conducted in children with ostium secundum ASD, P maximum and P dispersion were analyzed and P dispersion was found to be significantly increased in children with ASD as compared to age-matched healthy controls.[16] To date, there has been no study performed in adult patients with ASD concerning these P wave parameters in the literature. The purpose of this study was to investigate whether P maximum and P dispersion in adult patients with ASD are increased during normal sinus rhythm as compared to healthy controls. In addition, the impact of surgical closure of ASD on these variables within 1 year after surgery was evaluated.

METHODS

Study Population

This study involved 34 patients (21 women, 13 men; mean age: 35 ± 11 years) operated on for ostium secundum-type ASD in our institution between June, 1999 and December, 2001 and all patients had complete postoperative 1 year follow-up data. Before surgery, all patients underwent two-dimensional echocardiography followed by cardiac catheterization for definite diagnosis. Pulmonary-to-systemic flow ratio (Qp/Qs) was calculated from cardiac catheterization by the Fick method. Individuals over 40 years or who had a history of angina pectoris were also evaluated with coronary angiography. Patients with other congenital cardiac defects associated with ASD, such as pulmonary stenosis, Ebstein's anomaly of the tricuspid valve, or ventricular septal defect were excluded from the study. All patients were in sinus rhythm before surgery and none of them were taking antiarrhythmic medication. Previous clinical and electrocardiography (ECG) recordings were carefully reviewed for the history of paroxysmal AF. None of the patients had a documented AF episode. Surgical closure was by direct suturing in 30 patients and by patch in 4 patients. All patients were followed for 1 year after the surgical closure of the defect. Patients were evaluated with physical examination, 12-lead ECG, chest roentgenogram and 24-hour Holter monitoring, and echocardiography if necessary at follow-up visits. Individuals who had postoperative sustained atrial arrhythmias, such as atrial flutter or AF, were not included in the study. However, 10 patients who had documented paroxysmal AF episode during follow-up were not excluded. Other exclusion criteria were the history of systemic hypertension, diabetes mellitus, hyperthyroidism, chronic obstructive pulmonary disease, chronic pericardial effusion, ventricular preexcitation, abnormal serum electrolytes and presence of significant mitral valve regurgitation assessed with color-flow Doppler echocardiography and left ventriculography during cardiac catheterization, and coronary artery disease detected during coronary angiography.

The control group consisted of 24 healthy subjects (13 women, 11 men; mean age: 37 ± 10 years) without a history of cardiovascular disease. All subjects were evaluated with physical examination, 12-lead ECG, chest roentgenogram, and echocardiography before the inclusion. Each subject gave informed consent to participate in the study.

Twelve-Lead Surface ECG

A 12-lead surface ECG was obtained from all the patients on the day before surgery and repeated at 1 month, 6 months, and finally, 1 year after the surgery. All patients were in sinus rhythm during evaluation. Recordings were obtained at a paper speed of 50 mm/s with 1 mV/cm standardization. Subjects were allowed to breathe freely, but not to speak or cough during recordings. P wave duration was measured manually using a electronic digital caliper and a magnifying lens by two investigators who were blinded to clinical data. The onset of the P wave was defined as the junction between the isoelectric line at the beginning of the P wave deflection and the offset of the P wave was defined as the junction between the end of the P wave and the isoelectric line. If the onset or offset of the P wave were not clearly determined, the lead was excluded from the analysis. This method was performed previously by different investigators.[12–16] Maximum and minimum P wave duration

(P minimum) were both measured from the 12-lead ECG and then P wave dispersion (defined as the difference between P maximum and P minimum) was calculated. Intraobserver and interobserver coefficients of variations were 3.8% and 4.1% for P maximum and 4.1% and 4.5% for P dispersion, respectively.

Statistical Analysis

Continuous variables are presented as mean values ± SD and were compared by Mann-Whitney U test. Categorical variables are expressed as frequency and were compared by means of the chi-square test. Wilcoxon signed ranks test was performed to compare baseline and postoperative P wave measurements. A P value ≤ 0.05 was considered statistically significant. The SPSS 10.0 statistical software package (SPSS Inc., Chicago, IL) was used for all calculations.

Table 1. Clinical and Echocardiographic Characteristics of Study Population

	Patients	Controls	P Value
Number of subjects	34	24	–
Age (years)	35 ± 11	37 ± 10	0.36
Gender (men/women)	13/21	11/13	0.3
Heart rate (beats/min)	80 ± 10	75 ± 11	0.12
Left atrial diameter (mm)	35 ± 5	33 ± 4	0.19
LVEF (%)	70 ± 2	69 ± 2	0.26
PAPSP (mmHg)	37 ± 12	14 ± 4	<0.0001
P maximum (ms)	115.2 ± 9	99.3 ± 14	<0.0001
P minimum (ms)	78.1 ± 11	70.3 ± 14	0.074
P dispersion (ms)	37 ± 9	29.8 ± 10	0.003

LVEF = left ventricular ejection fraction; PAPSP = pulmonary artery peak systolic pressure.

RESULTS

Comparisons Between Patients and Controls

There were no significant differences with respect to age (P = 0.36), gender (P = 0.3), heart rate (P = 0.12), left atrial diameter (P = 0.19), and left ventricular ejection fraction (P = 0.26) between patients and controls. Pulmonary artery peak systolic pressure was significantly higher in patients with ASD as compared to controls (P < 0.0001). Mean Qp/Qs of patients with ASD was 2.6 ± 0.7 (minimum: 1.7; maximum: 4). P maximum was found to be significantly longer in patients with ASD as compared to controls (P < 0.0001). In addition, P dispersion of the patients was significantly higher than controls (P = 0.003). P minimum was not different between the two groups (P = 0.074; Table 1).

Comparisons Between Patients with Postoperative Paroxysmal Atrial Fibrillation and Patients without it

Ten patients (29%) had at least one episode of paroxysmal AF during 1 year follow-up. In seven patients, AF episodes were detected during 24-hour Holter analysis, and because of the self-terminating nature of these paroxysms, these patients were treated by a beta-blocker or a calcium-channel antagonist and warfarin. Two patients who experienced their first AF episodes after the first month of surgery were treated by electrical cardioversion and amiodarone for maintenance of sinus rhythm at different medical centers. The remaining patient was treated by sotalol for the same reason. All these patients were in sinus rhythm during follow-up visits. Patients were divided into two groups according to the presence or absence of postoperative paroxysmal AF. Patients with this arrhythmia were older (45 ± 6 vs 30 ± 10 years; P = 0.001) and had a higher preoperative pulmonary artery peak systolic pressure as compared with the other group (51 ± 11 vs 31 ± 9 mmHg; P < 0.0001). No differences in gender (4 men/6 women vs 9 men/15 women; P = 0.5), heart rate (85 ± 11 vs 78 ± 9 beats/min; P = 0.09), preoperative left atrial diameter (37 ± 3 vs 33 ± 5 mm; P = 0.08), left ventricular ejection fraction (70% ± 2% vs 70% ± 2%; P = 0.56), and Qp/Qs (2.5 ± 0.7 vs 2.7 ± 0.7; P = 0.56) were observed between the groups. Patients with paroxysmal AF were noted to have longer P maximum and higher P dispersion at baseline as compared to those without this arrhythmia (P = 0.027 and 0.037, respectively). P minimum was similar in both groups (P = 0.4). After the operation, P maximum was significantly longer at 1 month (P = 0.014), 6 months (P = 0.001), and at 1 year (P < 0.0001) in patients with paroxysmal AF as compared to patients without it. Moreover, patients with this arrhythmia had higher P dispersion throughout the postoperative 1-year period as compared to patients without it

Table 2. Baseline and Postoperative P Wave Duration Measurements of Patients with Postoperative Paroxysmal AF

		After Surgery		
Variables	**Baseline**	**1 Month**	**6 Months**	**1 Year**
P maximum (ms)	121.1 ± 8	119.6 ± 9	118 ± 6	120.2 ± 7
P minimum (ms)	80 ± 13	78.8 ± 9	78 ± 9	79.7 ± 9
P dispersion (ms)	43.1 ± 9	41.5 ± 5	40.1 ± 5	40.4 ± 6
P1 value*	–	0.6	0.2	0.33
P2 value†	–	0.6	0.14	0.9
P3 value‡	–	0.5	0.14	0.28

*P1 = individual postoperative P maximum versus baseline P maximum; †P2 = individual postoperative P minimum versus baseline P minimum; ‡P3 = individual postoperative P dispersion versus baseline P dispersion.

(P = 0.026 for 1 month, P = 0.001 for 6 months, and P < 0.0001 for 1 year). There were no significant differences in P minimum between the two groups during follow-up (P = 0.4 for 1 month, P = 0.5 for 6 months, and P = 0.1 for 1 year).

Tables 2 and 3 demonstrate baseline and postoperative 1 month, 6 months, and 1 year P wave measurements for the two groups of patients. In patients with postoperative paroxysmal AF, no significant changes were noted in P maximum, P dispersion, and P minimum during the postoperative 1-year follow-up as compared to baseline values. For patients without postoperative AF, there was no significant difference in P maximum between baseline and postoperative 1 month values (P = 0.2). However, P maximum was found to be significantly decreased at 6 months compared to the baseline value (P = 0.002). It was also true for postoperative 1 year P maximum measurement (P = 0.001). In addition, baseline P dispersion of the patients without AF was similar to postoperative 1 month value (P = 0.3). When baseline P dispersion was compared to the postoperative 6 months and 1 year values separately, it was revealed that the baseline P dispersion was significantly higher than the postoperative 6 months (P = 0.009) and 1 year P dispersion (P = 0.001). There was no significant difference in P minimum throughout the follow-up as compared to baseline.

DISCUSSION

We have demonstrated that in adult patients with ASD and normal sinus rhythm, maximum P wave duration is significantly longer and P wave dispersion is significantly increased as compared to age-matched healthy controls. Besides, when patients with ASD were divided into two groups according to the presence or absence of postoperative paroxysmal AF, it was noted that these two P wave indices were significantly longer for both baseline and postoperative 1-year period in patients with postoperative paroxysmal AF as compared to

Table 3. Baseline and Postoperative P Wave Duration Measurements of Patients without Postoperative Paroxysmal AF

		After Surgery		
Variables	**Baseline**	**1 Month**	**6 Months**	**1 Year**
P maximum (ms)	112.8 ± 9	111.5 ± 8	102.9 ± 12	101.7
P minimum (ms)	77.3 ± 10	75.5 ± 8	75.5 ± 9	74.4 ± 8
P dispersion (ms)	34.5 ± 8	33.5 ± 6	28.8 ± 7	27.5 ± 8
P1 value*	–	0.2	0.002	0.001
P2 value†	–	0.22	0.36	0.34
P3 value‡	–	0.3	0.009	0.001

*P1 = individual postoperative P maximum versus baseline P maximum; †P2 = individual postoperative P minimum versus baseline P minimum; ‡P3 = individual postoperative P dispersion versus baseline P dispersion.

patients without it. In the former group of patients, there was no significant decrease in P maximum and P dispersion throughout the 1-year follow-up as compared to baseline values. However, in patients without postoperative paroxysmal AF, P maximum and P dispersion were found to be significantly decreased at postoperative 6 months and 1 year as compared to preoperative values.

Electrophysiological studies have shown that an abnormally prolonged and fractionated atrial electrogram is characteristic of patients with AF, suggesting that the inhomogeneity of electrical activity is related to delayed and nonuniform anisotropic conduction.[8–10] In addition, right atrial mapping studies during sinus rhythm have demonstrated that prolonged, fractionated atrial electrocardiograms were found more frequently, and were more distributed within the entire right atrium in patients with paroxysmal AF.[11] This peculiar atrial electrophysiological feature characterized by slow inhomogeneous conduction of atrial impulse could be reflected by prolongation of P wave duration and P wave dispersion. Previously, prolonged P wave duration in 12-lead surface ECG or in signal-averaged ECG has been used for prediction of paroxysmal AF and considered to represent intra- and interatrial conduction delays predisposing to AF.[12–15,17,18] Moreover, P dispersion is a relatively novel ECG index in noninvasive electrocardiology and seems to be quite useful in the prediction of AF in various clinical settings.[12–15,19] It is believed that increased P dispersion simply reflects inhomogeneous and discontinuous propagation of sinus impulses.[12,13]

A recent study conducted in children with ostium secundum ASD reported that the P dispersion was found to be significantly longer in patients with ASD than the age-matched healthy controls.[16] Although one of the our findings, increased P dispersion in adult patients with ASD, is similar to aforementioned study,[16] we also demonstrated that in adults with ASD, P maximum is significantly longer than in the controls. We believe that the prolongation of P maximum and increased P dispersion simply represent mechanical and electrical changes of atrial myocardium in patients with ASD. These changes could be the results of atrial dilatation, increased atrial stretch, and atrial conduction disturbances, all of which are common in ASD.[2,20] Increased atrial stretch and atrial dilation,[21,22] in response to volume overload, prolong atrial refractoriness heterogeneously and make the atria prone to fibrillation. Furthermore, in older patients, these changes of atrial myocardium may be more prominent because of longstanding pressure and volume overload. This suggestion might explain why individuals with postoperative paroxysmal AF in this study had greater P maximum and P dispersion before surgery and during the postoperative first year.

Although the incidence of AF increases with age even in the general population,[23] the incidence of AF in patients with ASD is strikingly high even after surgical closure.[1,20,24] Recently, Oliver et al.[5] demonstrated that advanced age is the most important condition related to the presence of AF in patients with ASD both before and after surgical closure. Furthermore, they also observed higher systolic pulmonary pressure in patients with AF as compared to the those without it.[5] Another study concerning the risks of late atrial arrhythmias after surgical repair of the ASD in adults has shown that the age at surgical repair and pulmonary hypertension are closely related to the presence of late AF or atrial flutter.[3] Although our study was not designed to investigate the preoperative predictors of postoperative atrial arrhythmias, we found that patients with postoperative paroxysmal AF were older and had higher preoperative pulmonary artery peak systolic pressure as compared to those without it, despite similar Qp\Qs at baseline between the two patient groups. These findings are consistent with previous observations.[1–3,5]

In our study, patients with preoperative atrial arrhythmias including paroxysmal AF were excluded; therefore none of the individuals had a previous history of AF before the surgical closure of the defect. However, during follow-up, 10 patients (29%) experienced one or more episode of paroxysmal AF. Interestingly, no significant decrease was detected in P maximum as well as in P dispersion during the postoperative follow-up in patients with paroxysmal AF. It seems to be related to the established mechanical and electrophysiological changes of atrial myocardium that may not resolve completely with surgical repair of the ASD at older ages. In contrast, progressive decrease in P maximum and P dispersion of the patients with ASD during postoperative follow-up in patients without postoperative paroxysmal AF may reflect the regressions of the pathological changes in atrial macro- and microarchitecture. Earlier closure of the defect might result in more homogeneous and organized conduction of atrial impulse.

It is concluded that in a small group of adult patients with ASD and sinus rhythm, P maximum is significantly longer and P dispersion is significantly increased as compared to the age-matched healthy controls. After surgical closure of the ASD, significant decrease in both of these P wave indices may be related to a lower risk for AF in part, for a relatively short-term follow-up. However, higher P maximum and P dispersion at baseline, which do not decrease after surgery may be associated with postoperative paroxysmal AF, especially for older subjects. Larger studies are needed to further evaluate the clinical importance of these two P wave indices in patients with ASD with or without surgical closure.

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