Analysis of P Wave and P Dispersion in Children with Secundum Atrial Septal Defect

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Background: P maximum and P dispersion are evaluated as predictors of paroxysmal atrial fibrillation in adults. In this study, these variables are being investigated in children with secundum ASD in comparison with that of normal controls and in relation to size of ASD and the presence or absence of atrial dilation.

Methods: Ninety-four children with isolated secundum ASD (33 boys, 60 girls; mean ± SD age at diagnosis 2.9 ± 4.1 years) and 65 age-matched controls (mean ± SD age 4.2 ± 4.2 years) were evaluated. Resting 12-lead ECG was used to measure P waves from which P maximum and P dispersion (difference between maximum and minimum P-wave duration) were derived. ASD children were arbitrarily subgrouped according to ASD sizes (small: 1-3 mm, moderate: 4-7 mm, large: ≥ 8 mm). The presence of right atrial dilation was noted from echocardiography.

Results: Children with ASD had significantly longer mean P dispersion compared to controls (P dispersion: 30.2 ± 11.1 vs 26.4 ± 6.6 ms, $P = 0.008$). Mean P maximum and P dispersion were significantly prolonged with increasing ASD size ($P < 0.001$). Children with right atrial dilation had significantly longer P maximum (102.3 ± 15.2 vs 82.8 ± 13.4 ms, $P < 0.001$) and larger P dispersion (36.1 ± 12.5 vs 27.6 ± 9.4 ms, $P = 0.003$) compared to those without right atrial dilation.

Conclusion: Prolonged atrial conduction time and inhomogeneity of atrial conduction may possibly be present in children with moderate to large sized ASD and in those with atrial dilation.

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P wave; atrial septal defect; children

Signal-averaged P waves have been evaluated in various clinical situations.[1-5] More recently, simple electrocardiographic markers using P wave, P maximum, and P dispersion have been proposed for evaluation of patients at risk of paroxysmal atrial fibrillation or to predict recurrent atrial fibrillation.[6-8]

Prolongation of P wave is thought to be an indicator of interatrial conduction disturbance[9] and is often used to predict paroxysmal atrial fibrillation (PAF).[1-3,10] Maximum P wave (at a value of ≥ 110 ms) derived from a 12-lead surface electrocardiogram (ECG) had a good sensitivity and specificity for the separation of patients with idiopathic PAF from controls.[11] P-wave dispersion (P dispersion) is proposed to quantify the heterogeneity of atrial conduction that can result in variable P-wave duration measured from the different surface electrocardiographic leads. A P dispersion value of 40 ms also separated patients with idiopathic PAF from controls with good sensitivity, specificity and positive predictive accuracy.[11] The combined use of both P maximum and P dispersion appeared to strengthen and complement their roles in this respect.[11]

Left-to-right shunts across the atrial septum in patients with isolated secundum atrial septal de-

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fects (ASD) tend to increase with age in many patients.[12] This can cause stretching of the atria which predisposes these patients to atrial flutter, fibrillation, and tachycardia. While only a small percentage of patients below 18 years of age develop atrial arrhythmias, the proportion may increase to significant magnitude in older adults.[3,14] Chen[15] had suggested that atrial electrophysiological characteristics of a dilated atrium differ from that of a normal atrium.

Our objective was to evaluate maximum P-wave duration and P dispersion in children with isolated secundum ASD in comparison with that of controls and to relate these variables to the size of ASD as well as the presence or absence of right atrial dilation.

METHODS

Study Population

A total of 94 children (34 boys, 60 girls) with isolated ASD and 65 healthy age-matched controls (33 boys, 32 girls) participated in this study. The mean ± SD ages of patients (at time of diagnosis) and controls were 2.9 ± 4.1 years and 3.4 ± 4.3 years, respectively.

Diagnosis of ASD was confirmed by cross-sectional and Doppler echocardiography. The ASD children had no other cardiovascular defects. Echocardiographic measurement of atrial size and presence of atrial dilation were noted. Children with ASD were further arbitrarily subgrouped into those with small (1-3 mm), moderate (4-7 mm) and large (≥ 8 mm) ASD. These children were also classified into those with or without right atrial (RA) dilation.

Measurement of ECG

All patients and controls had resting 12-lead surface ECGs measured while in a supine position. Each ECG was measured in 3-lead sets, at a paper speed of 25 mm/sec and with 10 mm/mV standardization. The ECG recordings were magnified two times for manual measurement of P-wave durations from each of the 12 leads. The onset of P wave was defined as the junction between the isoelectric line and the beginning of P-wave deflection. The offset of P wave was taken at the junction between the end of the P-wave deflection and the isoelectric line. The average P wave of three consecutive beats from each lead was determined. Three variables determined from the P wave measurements were: (1) P-wave duration defined as the average P-wave duration from lead II; (2) P maximum defined as the longest P-wave duration among the 12 leads; (3) P dispersion defined as the difference between the maximum and minimum P-wave durations from the 12 leads.

Measurement of P waves was done by the same observer. Intraobserver variation was determined using the method described by Bland and Altman.[16] Mean ± SD difference between measurements was −0.08 ± 4.09 ms (range -16-10 ms) and 95% confidence interval of the mean difference was between −2.55 to 2.40 ms.

Statistical Analysis

All variables were presented as means and standard deviation (SD). Statistical calculations were performed using SPSS 10 for Windows (SPSS Inc. IL, USA). Independent-samples *t*- tests were used to compare the differences between ASD patients and controls, as well as between those patients with and without RA dilation. One-way ANOVA was used to assess the differences between the ASD subgroups and between the various follow-up intervals in patients who had surgical repair of ASD. Statistical significance was defined as a P value of < 0.05.

RESULTS

Children with ASD were distributed according to size of ASD: 28.7% had small ASD, 33.0% had moderate sized ASD, and 38.3% had large ASD. Mean ± SD size of ASD was 13.6 ± 5.3 mm. None of the children had any history of atrial arrhythmias.

ASD Children versus Controls

Table 1 shows the mean ± SD P-wave duration (lead II), P maximum, and P dispersion of ASD patients and controls. The upper limits (mean + 2SD) of P-wave duration, P maximum, and P dispersion for controls were 104.3 ms, 108.2 ms, and 39.6 ms, respectively. Children with ASD had significantly longer mean P dispersion compared to controls (30.2 ± 11.1 vs 26.4 ± 6.6 ms, P = 0.008).

ASD Subgroups According to Size

The proportions of children with small, moderate, and large size ASD were 29, 33, and 38%,

Table 1. Mean P Wave Duration, P Maximum, and P Dispersion of Controls and Children with ASD

	Control	ASD	P
Number	65	94	
P wave duration (msec)	78.1 ± 13.1	78.5 ± 17.1	0.863
Range	44–105	40–115	
P maximum (msec)	86.2 ± 11.0	88.6 ± 16.5	0.267
Range	60–108	60–135	
P dispersion (msec)	26.4 ± 6.6	30.2 ± 11.1	0.008
Range	15–42	8–62	

respectively. It was noted that mean P-wave duration, P maximum, and P dispersion increased significantly with increasing sizes of ASD ($P < 0.0001$) (Table 2).

ASD With and Without RA Dilation

Of the ASD children, 29.8% had RA dilation while 70.2% did not have dilation of RA. Of those with RA dilation, 89.3% had large ASD, 10.7% had moderate ASD, and none had small ASD. Those who had right atrial dilation had significantly longer mean P-wave duration (90.4 ± 11.4 vs 73.5 ± 16.7 ms, $P < 0.0001$) and P maximum (102.3 ± 15.2 vs 82.8 ± 13.4 ms, $P < 0.0001$) than those without RA dilation. Mean P dispersion of patients with RA dilation was also significantly higher (36.1 ± 12.5 vs 27.6 ± 9.4 ms, $P = 0.003$) than those without RA dilation (Table 3).

DISCUSSION

The mechanism for atrial fibrillation is believed to be intra-atrial conduction abnormalities resulting in fragmentation and prolongation of atrial activation.[17-19] While the simple P-wave duration may represent duration of atrial activation, it cannot reflect regional differences in atrial activation and dispersion in refractoriness. The heterogeneity of atrial conduction plays an important role in the initiation of re-entry circuits[17-19] which may predispose the atria to arrhythmias. Nonuniform electrophysiological characteristics, atrial size (surface area), morphology and anatomic obstacles may contribute to the heterogeneity of atrial conduction and vulnerability to atrial fibrillation.[20]

Table 2. Mean P Wave Duration, P Maximum, and P Dispersion of Controls and Children with Different Sizes of ASD

	ASD Size			
	Small (1–3 mm)	Moderate (4–7 mm)	Large (≥8 mm)	P
Number	27 (29%)	31 (33%)	36 (38%)	
P wave duration (msec)	61.4 ± 11.0	77.1 ± 10.6	92.5 ± 12.8	<0.001
Range	40–83	56–104	52–115	
P maximum (msec)	72.8 ± 5.7	83.7 ± 7.7	104.7 ± 13.1	<0.001
Range	60–85	72–104	80–135	
P dispersion (msec)	25.6 ± 7.0	26.3 ± 10.2	36.8 ± 11.2	<0.001
Range	14–43	8–48	18–62	

Table 3. Mean P Wave Duration, P Maximum, and P Dispersion of ASD Children With and Without Right Atrial (RA) Dilation

	Without RA Dilation	With RA Dilation	P
Number	66 (70.2%)	28 (29.8%)	
P wave duration (msec)	73.5 ± 16.7	90.4 ± 11.4	<0.001
Range	40–109	65–115	
P maximum (msec)	82.8 ± 13.4	102.3 ± 15.2	<0.001
Range	60–120	75–135	
P dispersion (msec)	27.6 ± 9.4	36.1 ± 12.5	0.003
Range	8–49	8–62	

Inhomogeneous atrial conduction may result in highly variable P-wave duration measured from different oriented surface ECG leads.[11] In this study P-wave duration and P maximum are used to quantify atrial conduction time while P dispersion is used as a marker of regional differences in P-wave durations. These variables were found to have a significant positive relation to size of the atrial septal defect and to the presence of atrial dilation. Left-to-right shunting across the atrial septum commonly occurs in ASD. The development and magnitude of the shunt depends on pressure differences between the right and left atria and the relative compliance of the right and left ventricles rather than on the size of the interatrial communication.[12] Large shunts may cause stretching of the atria which may then predispose them to atrial arrhythmias. Large left-to-right shunts have been found to be associated with increased incidence of atrial arrhythmias.[12] The incidence of atrial arrhythmias was also much higher in older patients, particularly in adults. While there is no documentation of atrial arrhythmias in our study cohort, there are already significant increases in P-wave duration, P maximum, and P dispersion in those with right atrial dilation and large ASD sizes.

In adult studies, both P maximum and P dispersion were found to be significantly higher in patients with PAF.[11] A P maximum value of 110 ms and P dispersion value of 40 ms separated patients with PAF from controls with a sensitivity of 88 and 83%, a specificity of 75 and 85%, respectively.[11] However, multivariate analysis of several variables revealed that only P maximum and not P dispersion was a significant independent predictor of recurrent PAF.[8] The study of Chang et al.[7] supported the above opinion that prolongation of P-wave duration ($\geq$ 100 ms) was an independent predictor of postoperative AF while P dispersion did not prove to be a predictor of postoperative AF in patients after coronary artery bypass surgery.

In this study, the children with ASD had no history of atrial arrhythmias. However increased values of P maximum and P dispersion to as high as 135 ms and 62 ms, respectively, particularly in those with large ASD or dilated RA are indicative of prolongation and heterogeneity of atrial conduction which may predispose these children to PAF. The mechanism/s for such conduction defects may be a combination of anatomic, morphologic, and possibly electrophysiological factors that are related to the structural and hemodynamic features of ASD. Although size of ASD does not directly influence the magnitude of left-to-right shunt, their likely association is indicated by the fact that almost 90% of the ASD children with dilated RA have large ASD.

This study revealed that children with ASD had significantly prolonged P dispersion in comparison with normal controls. P maximum and P dispersion which were indicative of atrial conduction time and inhomogeneity of atrial conduction, respectively, were more severe with increase in size of ASD and in the presence of right atrial dilation. Whether such changes in atrial conduction predispose the children to PAF is yet to be proved. The results of this study, however, may have useful prognostic implication in differentiating those who are more predisposed to develop atrial dysrhythmias. Secondly, children with secundum ASD and with abnormal P-wave markers warrant serial ECG assessment and clinical follow-up to detect atrial dysrhythmias. Thirdly, in circumstances where echocardiography is not easily available, the use of simple P-wave markers may be helpful indicators of atrial size and dilation.

REFERENCES

1. Steinberg JS, Zelenkofske S, Wong SC, et al. Value of the P-wave signal-averaged ECG for predicting atrial fibrillation after cardiac surgery. Circulation 1993;88:2618-2222.
2. Villani GQ, Piepoli M, Cripps T, et al. Atrial late potentials in patients with paroxysmal atrial fibrillation detected using a high gain, signal-averaged esophageal lead. PACE 1994; 17:1118-1123.
3. Klein M, Evans SJL, Blumberg S, et al. Use of P-wave-triggered, P-wave signal-averaged electrocardiogram to predict atrial fibrillation after coronary artery bypass surgery. Am Heart J 1995;129:895-901.
4. Kubara I, Ikeda H, Hiraki T, et al. Dispersion of filtered P wave duration by P wave signal-averaged ECG mapping system: Its usefulness for determining efficacy of disopyramide on paroxysmal atrial fibrillation. J Cardiovasc Electrophysiol 1999;10:670-679.
5. Yamada T, Fukunami M, Shimonagata T, et al. Dispersion of signal-averaged P wave duration on precordial body surface in patients with paroxysmal atrial fibrillation. Eur Heart J 1999;20:211-220.
6. Villani GQ, Piepoli M, Rosi A, et al. P-wave dispersion index: A marker of patients with paroxysmal atrial fibrillation. Int J Cardiol 1996;55:169-175.
7. Chang CM, Lee SH, Lu MJ, et al. The role of P wave in prediction of atrial fibrillation after coronary artery surgery. Int J Cardiol 1999;68:303-308.
8. Dilaveris PE, Gialafos EJ, Andrikopoulos GK, et al. Clinical and electrocardiographic predictors of recurrent atrial fibrillation. Pacing Clin Electrophysiol 2000;23:352-358.
9. Josephson ME, Kaster JA, Morganroth J. Electrocardiographic left atrial enlargement: electrophysiologic, echocardiographic, and hemodynamic correlates. Am J Cardiol 1977;39: 967-971.

10. Stafford PJ, Turner I, Vincent R. Quantitative analysis of signal-averaged P waves in idiopathic paroxysmal atrial fibrillation. Am J Cardiol 1991;68:1662-1668.
11. Dilaveris PE, Gialafos EJ, Sideris SK, et al. Simple electrocardiographic markers for the prediction of paroxysmal idiopathic atrial fibrillation. Am Heart J 1998;135 (5 Pt 1): 733-738.
12. Vick GW III. Defects of the Atrial Septum, Including the Atrioventricular Septal Defects. In: Garson A Jr, Bricker TJ, Fisher DJ, et al. The Science and Practice of Pediatric Cardiology. 1997, pp.1023-1051.
13. Rrandenburg RO Jr, Holmes DR Jr, Brandenburg RO, et al. Clinical follow-up study of paroxysmal supraventricular tachyarrhythmias after operative repair of a secundum type atrial septal defect in adults. Am J Cardiol 1983;51: 273-276.
14. Boelkens MT, et al. Dysrhythmias after atrial surgery in children. Am Heart J 1982;106:125-130.
15. Chen YJ, Chen SA, Tai CT, et al. Electrophysiologic characteristics of a dilated atrium in patients with paroxysmal atrial fibrillation and atrial flutter. J Interv Card Electrophysiol 1998;2:181-186.
16. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;i:307-310.
17. Tanigawa M, Fukatani M, Konoe A, et al. Prolonged and fractionated electrocardiograms during sinus rhythm in patients with paroxysmal atrial fibrillation and sick sinus node syndrome. J Am Coll Cardiol 1991;17:403.
18. Niwano S, Aizawa Y. Fragmented atrial activity in patients with transient atrial fibrillation. Am Heart J 1991;12:62.
19. Misier ARR, Opthof T, van Hemel NM, et al. Increased dispersion of "refractoriness" in patients with idiopathic paroxysmal atrial fibrillation. J Am Coll Cardiol 1992;19: 1531.
20. Allessie M, Kirchhof C. Termination of Atrial Fibrillation by Class Ic Antiarrhythmic Drugs, a Paradox? In: Kingma JH, van Hemel NM, Lie KI (eds): Atrial Fibrillation: A Treatable Disease? Boston, Kluwer, 1992. p. 265.