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Original Article

Duration and dispersion of the P wave after the Senning operation

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Abstract We studied the duration and dispersion of the P wave in patients after a Senning operation, assessing its value in detecting the risk of atrial tachycardias.

We measured the duration and dispersion of the wave in surface 12 lead electrocardiograms obtained from 18 patients with sinus rhythm, having a mean age of 12.8 years, with 13 being males and 5 females, who had undergone a Senning operation, comparing the values obtained in 35 age and gender-matched healthy people. The patients had undergone repair at a mean age of 13.4 months, and had a mean duration of follow-up of 12.8 years after the procedure. We also made 24 hour Holter recordings.

The maximal duration of the P wave, at a mean of 129.3 milliseconds, and dispersion with a mean of 78 milliseconds, were both significantly increased in the patients compared with their controls, the mean values for the normal subjects being 103.7 and 54 milliseconds. Supraventricular tachycardia was detected in 1 of 3 patients with dispersion greater than 100 milliseconds, and in 2 of 15 patients (13%) with dispersion less than 100 milliseconds as measured from the Holter recordings ($p > 0.05$).

Thus, the maximum duration and dispersion of the P wave were increased in patients after a Senning operation, but we were unable to establish any relationship between these measurements and atrial tachycardias as observed using Holter monitoring.

Keywords: Electrocardiogram; atrial tachycardia; transposition of the great arteries

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Dispersion of the P wave is the difference between the longest and shortest duration of the wave as recorded from surface 12 lead electrocardiograms.[1–4] Such measures of dispersion and duration have been used to evaluate the discontinuous propogation of the sinus impulse, and the prolongation of the atrial conduction time. Slow and inhomogeneous conduction has been suggested to cause prolongation of the duration of the P wave, and increase its dispersion. Many clinical studies in both adults and children have shown the benefit of these values in determining the risk of atrial tachycardias.[1–18] Atrial arrythmias are common after the Senning operation, occurring in more than half of all cases, and underscoring subsequent death in up to one-twentieth.[19–22] Our purpose in this study was to evaluate the duration and dispersion of the P wave in patients who had undergone the Senning operation, assessing their value in detecting the risk of atrial tachycardias.

Materials and Methods

We recruited 18 patients who had undergone the Senning operation for correction of discordant ventriculo-arterial connections from the population regularly attending the Division of Pediatric Cardiology, Cerrahpaşa Medical Faculty Hospital (Table 1). So as to ensure the homogeneity of our study group, we excluded patients with significant tricuspid regurgitation and congestive cardiac failure,

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Table 1. Demographic and clinical characteristics of the subjects.

Characteristics	18 Patients	35 Controls	p
Age (year)	12.8 (5)	12.3 (6)	0.586
Gender (Male/Female)	13/5	22/13	0.495
Height (centimeters)	147.3 (25)	142.4 (26)	0.567
Weight (kilograms)	47.9 (7.5)	39.8 (20)	0.306
Body-mass index (kg/m^2)	20 (5.5)	18.2 (3.7)	0.542
Systolic blood pressure (mmHg)	101.9 (13)	105.8 (9.9)	0.284
Diastolic blood pressure (mmHg)	58 (11)	63.8 (7.3)	0.055
Heart rate (beats per minute)	86.1 (25)	78 (13)	0.254

Values are means with (standard deviations).

along with any patients in whom we found evidence of supraventricular tachycardia from the history, physical examination, and Holter monitoring. All patients were in sinus rhythm, and none of the patients was taking medications which were known to modify the P wave. As a control group, we recruited 35 healthy subjects, matched for age and sex, who were undergoing investigation of innocent murmurs, all known to have normal echocardiograms (Table 1). As with the patients, none of our control patients was taking medications known to modify the P wave. Informed written consent was obtained from all participating patients or their parents. The study was performed according to the principles of the Declaration of Helsinki, and was approved by the Ethical Committe of İstanbul University Cerrahpaşa Medical School.

After assessment of the histories and physical examinations, we obtained standard 12 lead resting electrocardiograms from the patients and their controls. Measurements were performed on a high resolution monitor after the electrocardiograms were converted to the digital form. All electrocardiograms were evaluated for rhythm, rate, QRS axis, PR, QRS, QT, and RR intervals, evidence of atrial dilation or ventricular hypertrophy, and any evidence of abnormal repolarization. All the measurements were compared with normal values for age.[23]

The onset of the P wave was defined as the junction between the isoelectric line at the beginning of the deflection, and the offset was defined as the junction between the end of the wave and the isoelectric line.[1–4] Duration of the wave was measured at 3 consecutive cardiac cycles for each lead, using the mean of these values for analysis. P maximum was defined as the longest duration among the 12 leads, with P minimum defined as the shortest duration. Dispersion was calculated as the difference between the maximal and minimal durations from 12 leads. The measurements were performed by two investigators who were unaware of the clinical data. Intraobserver and interobserver coefficients of variation were 3.9% and 4.2% for the maximal duration, and 4.2% and 4.5% for the dispersion, respectively. All patients underwent 24 hour Holter monitoring. The records were evaluated to establish rhythm, conduction, maximal, minimal and mean heart rates, atrial premature beats, supraventricular tachycardia, ventricular premature beats, ventricular tachycardia, and pauses.

All variables are presented as means and standard deviation. Statistical calculations were performed using SPSS 10 for Windows (SPSS Inc. IL, USA). The comparison of measurements of age, weight, and height between groups were done using the Mann-Whitney U test for abnormally distributed values. The comparison of body-mass index, heart rate, and parameters of the P wave between the groups were done using the independent sample Student's t-test for normally distributed subjects. We used the Chi-square test to compare patients with and without increased dispersions to assess the significance of the presence of supraventricular tachycardia revealed by Holter monitoring. We considered p values lower than 0.05 to be statistically significant.

Results

Demographic and clinical characteristics of the patients and their controls are shown in Table 1. No significant difference was found between groups for age, sex, height, weight, body-mass index, systolic and diastolic blood pressure, and heart rate. The patients had undergone repair at a mean age of 13.3 months, and the mean duration of follow-up was 12.8 years after surgery. Of the 18 patients, 10 had mild, 3 had moderate, and 5 had no tricuspid regurgitation on the echocardiographic examination.

The electrocardiograms of all patients were in sinus rhythm. Right axis deviation was seen in 14 patients, with 1 patient having a long PR interval, 3 wide QRS complexes, 1 having right and left atrial enlargement, and 16 patients having evidence of right ventricular hypertrophy. All control subjects had sinus rhythm, and normal QRS axis,

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PR intervals, and QRS durations. None of them were detected to have atrial enlargement, ventricular hypertrophy, ST-T changes, or arrhythmias.

The maximal durations of the P wave, at means of 129.32 milliseconds and 103.77 milliseconds, respectively, and dispersions of the P wave, at 78 milliseconds and 54.02 milliseconds, respectively, were found to be significantly higher in the patients than in their healthy controls ($p = 0.003$ and $p = 0.006$, respectively – Table 2). No significant difference was found between groups for the minimal duration and RR duration ($p = 0.769$ and $p = 0.750$, respectively).

In the controls, the highest value for dispersion was 90 milliseconds. It proved impossible to determine a cut point for dispersion because of the small number of patients. If the threshold for dispersion was taken as 100 milliseconds, we detected supraventricular tachycardia in one of 3 patients with values above 100 milliseconds, and 2 of 15 patients (13%) with values below 100 milliseconds as detected using the Holter electrocardiogram. No statistical difference was seen. The findings from Holter monitoring are summarized in Table 3. We found wide QRS complexes in 3 patients, with 1 patient having a long PR interval. We identified attacks of supraventricular tachycardia of 3 beats 18 times in the our 12th patient, of 3 beats once in the 14th patients, and 13 times, the longest of 110 beats, in the 16th patient.

Discussion

Dispersion of the P wave is a new and simple electrocardiographic marker that has been reported to be associated with inhomogeneous and discontinuous propagation of sinus impulses.[1–4] It has been defined as the difference between the longest and shortest durations of the wave as measured in any of the 12 electrocardiographic leads. Many studies have been performed on duration and dispersion of the wave in adults,[1–17] studying conditions such as hypertension,[7–15] rheumatic mitral stenosis,[9] aortic stenosis,[17] congestive heart failure,[8,10] dilated cardiomyopathy,[16] hypertrophic cardiomyopathy[14] and paroxysmal atrial fibrillation.[1–6] Prolonged durations, and increased dispersion, have been reported to carry an increased risk for atrial tachycardias. The atriums work against pressure and volume afterload in various diseases, and this causes slow and inhomogeneous conduction in and

Table 2. Electrocardiographic findings of the patients and controls.

Measurements	18 Patients	35 Controls	p
RR (milliseconds)	751.11 (240.21)	734.57 (150.71)	0.750
P maximum (milliseconds)	129.32 (30.92)	103.77 (12.14)	0.003
P minimum (milliseconds)	51.38 (21.60)	49.74 (12.78)	0.769
P wave dispersion (milliseconds)	78 (31.42)	54.02 (13.74)	0.006

Values are means with standard deviations.

Table 3. Holter findings of the patients.

Patient	Basic rhythm	Highest heart rate (beats per minute)	Lowest heart rate (beats per minute)	Mean heart rate (beats per minute)	SVPB	VPB	SVT	VT	Pause
1	Sinus	144	42	68	44	–	–	–	–
2	Sinus	146	40	72	1	5	–	–	–
3	Sinus	157	40	65	17	10	–	–	–
4	Sinus	150	54	74	–	–	–	–	–
5	Sinus	164	84	108	2	–	–	–	–
6	Sinus	124	37	64	194	66	–	–	–
7	Sinus	159	41	60	8	5	–	–	–
8	Sinus	182	39	76	–	1	–	–	–
9	Sinus	167	49	82	125	–	–	–	–
10	Sinus	120	48	73	23	–	–	–	–
11	Sinus	154	36	55	28	–	–	–	–
12	Sinus	176	42	80	9191	–	+	–	–
13	Sinus	149	53	84	2	–	–	–	–
14	Sinus	145	55	78	8	571	+	–	–
15	Sinus	159	49	94	3	–	–	–	–
16	Sinus	161	36	69	3098	85	+	–	–
17	Sinus	145	46	68	12	35	–	–	–
18	Sinus	138	39	61	3	–	–	–	–

SVPB, supraventricular premature beat; SVT, supraventricular tachycardia; VPB, ventricular premature beat; VT, ventricular tachycardia.

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between them.[1–3] The polongation of intraatrial and interatrial conduction times, and the inhomogeneous propagation of sinus impulses, are well-known electrophysiologic characteristics of the atriums prone to develop tachycardia.[2] Both bradyarrhythmias, primarily sinus nodal dysfunction, and tachyarrhythmias, primarily atrial flutter and fibrillation, are common after the Senning operation.[19–22] Electrophysiologic studies have shown frequent electrophysiologic abnormalities such as abnormal sinus nodal automaticity, sinus nodal dysfunction, and sinoatrial and intraatrial conduction defects.[24] Direct trauma or injury to the artery to the sinus node, multiple atriotomies, long suture lines, pericardial inflammation, implanted pericardial or artificial patches, and abnormal atrial anatomy are all seen after the Senning operation, resulting in sinus bradycardia with a variety of slow atrial or junctional escape rhythms, atrial flutter, or fibrillation.[19–22] The degree of sinus nodal dysfunction may worsen over time, suggesting some ongoing fibrotic processes related to the initial trauma or chronic haemodynamic abnormalities. The likehood of a patient developing atrial flutter or fibrillation becomes significantly increased in this setting. Atrial arrythmias, therefore, are common after the Senning operation, occurring in more than half of patients undergoing the procedure, and being responsible for death in up to one-twentieth.[19–22] A history of atrial tachycardia is said to be the best predictive factor for late sudden death.[25]

To date, to the best of our knowledge, no study has been carried out regarding the duration and dispersion of the P wave in these patients. We compared these parameters, therefore, between our patients and healthy subjects. We purposely chose our group of patients to be homogenous, all having stable and good clinical conditions, exluding any who might have biased our sample. The maximum duration and dispersion of the P waves were both increased in the patients compared to their healthy controls. We used 24 hour Holter monitoring to establish the presence of supraventricular tachycardia. In healthy subjects, the highest value for dispersion was 90 milliseconds. Due to the small number of our patients, however, we were unable to establish a cut-off value for dispersion. When we took a threshold for dispersion as 100 milliseconds, we detected supraventricular tachycardia in 1 of 3 patients with dispersion above 100 milliseconds, and in 2 of 15 (13%) patients with dispersion below 100 milliseconds. These differences were not statistically significant. Thus, maximal duration and dispersion of the P wave were both increased in patients after a Senning operation, but we were unable to establish any relation with atrial tachycardia.

Measurements of the duration of the P wave have been made using a cursor on a high resolution computer screen, by calipers, by a magnifying glass on paper, and using a high resolution digitizing board. Low onset and offset amplitudes have been the main source of error in manual measurements. On screen manual evaluation has been proven to be more precise than on-paper evaluation.[3] In our study, therefore, we used a high resolution computer screen for measurement.

Several groups have studied the duration and dispersion of the P wave in children.[12,13,18] One study[13] showed that children with atrial septal defect had significantly prolonged dispersion in comparison with normal controls, with changes being more severe with increasing sizes of the atrial septal defects. These changes were suggested to carry useful prognostic implications in differentiating those who were more prone to develop atrial arrhythmias. The second group[12] showed that dispersion was significantly higher in patients with atrial tachycardia inducible by electrophysiological study than in postoperative patients with tetralogy of Fallot free of arrhythmias. Children with tetralogy of Fallot had significantly prolonged dispersion and maximal duration of the P wave in comparison with normal controls. The third group[18] showed the maximal duration and dispersion of the wave to be longer in patients late after conversion to the Fontan circulation compared with healthy subjects.

In conclusion, we have shown the maximal duration and dispersion of the P wave to be increased in patients after the Senning operation, but we have failed to show any relation between these measurements and the presence of atrial tachycardias on Holter monitoring. Follow up of these patients, and further studies with larger numbers of patients, are now needed to establish any relationship of the increased values with atrial tachycardia.

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