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ORIGINAL ARTICLE

Corrected QT dispersion as a predictor of the frequency of paroxysmal tachyarrhythmias in patients with Wolff–Parkinson–White syndrome

Eid M. Daoud, Ayman Ahmed Abdelaziz *, Ayman A. Abd Elsamad

Cardiology Department, Mansoura Faculty of Medicine, Egypt

Abstract *Background:* Patients with Wolff–Parkinson–White (WPW) syndrome are prone to develop a variety of tachyarrhythmias which may lead to unpleasant, disabling symptoms and in extreme, sudden cardiac death (SCD). The aim of our study was to evaluate the clinical significance of corrected QT dispersion (QTcd) as a noninvasive predictor of paroxysmal tachyarrhythmias in patients with WPW syndrome.

Patients and methods: The study population comprised 40 patients with WPW syndrome presented to the emergency department by paroxysmal tachyarrhythmias. They were classified into 3 groups; group I: 18 patients presented with regular narrow QRS complex tachycardia, group II: 10 patients presented with regular wide QRS complex tachycardia, group III: 12 patients presented with irregular wide QRS complex tachycardia. All patients were subjected to clinical evaluation, 12-lead electrocardiography (ECG) analysis during the attack of paroxysmal tachyarrhythmia to define its type and after reversion to sinus rhythm for the measurement of QTcd, echocardiography, laboratory investigations and 24-h ambulatory electrocardiographic monitoring.

Results: There was a significant increase of QTcd, QTmax, QTmin, Delta wave duration, QRS duration, and QRS amplitude in patients with group III compared to either group I and group II

* Corresponding author. Address: Cardiology Department, Mansoura Faculty of Medicine, Mansoura University, Egypt. Mobile: +20 01117787833, home: +20 0502374373.
E-mail address: aaaene@yahoo.com (A.A. Abdelaziz).

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($P < 0.05$). There was a significant increase in QTcd when compared to patients with WPW syndrome with frequent attacks of tachyarrhythmias with those with infrequent attacks (93.08 ± 14.68 versus 67.47 ± 7.03, $P < 0.001$).

Conclusion: Calculation of QTcd in patients with WPW syndrome presented with paroxysmal tachyarrhythmias is a simple noninvasive clinical test for risk stratification of those patients and hence detecting patients at higher risk for frequent and recurrent tachyarrhythmias.

Introduction

In 1930, Wolff, Parkinson, and White described a series of young patients who had a bundle branch block pattern on ECG findings, a short PR interval and paroxysm of tachycardia. WPW syndrome is currently defined as a congenital abnormality involving the presence of abnormal conductive tissue between the atria and the ventricles in association with supraventricular tachycardia (SVT). It involves preexcitation which occurs because of conduction of an atrial impulse not by means of the normal conduction system, but via an extra atrioventricular (AV) muscular connection, termed an accessory pathway (AP), that bypasses the AV node [1].

Wolff–Parkinson–White syndrome is usually an uncommon but potentially serious form of ventricular preexcitation. It is thought to occur in 0.1–3% of the population and to account for 2.4% of cases of SVT seen in the emergency department [2]. The patients with WPW syndrome have a risk of SCD < 1 per 1000 patients-years of follow up. Almost all survivors of SCD with WPW syndrome have had symptomatic arrhythmias before the event, but up to 10% experience SCD as their first manifestation of the disease [3].

QT dispersion (QTd) has been proposed as a reflector of ventricular repolarization inhomogeneity and as well as potential prognostic tool in detection of future ventricular tachyrhythmic events and death [4,5]. The usefulness of heart rate QTcd compared to QTd in predicting arrhythmic events in exercise test remain contradictory [6]. Greater QTcd has been found in patients with neurohumoral activation, myocardial ischemia, myocardial fibrosis and myocardial hypertrophy [7].

The aim of the current study is to evaluate the clinical significance of QTcd as a predictor of paroxysmal tachyarrhythmias in patients with WPW syndrome.

Patients and methods

The study population comprised 40 patients (31 males and 9 females) with documented diagnosis of WPW syndrome (Figs. 1 and 2) on the surface ECG and presented to our emergency department by paroxysmal tachyarrhythmias on the period from January 2011 to March 2013, Mansoura Medical Specialized Hospital, Mansoura University, Egypt.

The patients of the present study were classified into 3 groups:

Group I: 18 patients presented with regular narrow QRS complex tachycardia (Fig. 3).
Group II: 10 patients presented with regular wide QRS complex tachycardia (Fig. 4).
Group III: 12 patients presented with irregular wide QRS complex tachycardia (Fig. 5).

Patients with valvular heart disease, ischemic heart disease, cardiomyopathies (dilated, hypertrophic and restrictive), bundle branch block and electrolyte disturbance were excluded from the study.

The protocol was approved by our ethics committee, and a written consent was taken from the study subjects.

All patients were subjected to:

Clinical evaluation: included complete history and physical examination with special focus on the history of recurrence of the attacks of tachyarrhythmia and emergency room presentation in the last year. According to the frequency of tachyarrhythmias patients were classified into Group A: 25 patients with frequent attacks, and Group B: 15 patients with infrequent attacks.

Twelve lead ECG

- During paroxysmal tachyarrhythmias for diagnosis of the type of tachyarrhythmia.
- During sinus rhythm: for electrocardiographic features to characterize WPW syndrome and measurements of QT interval, QTc, QTcd, Delta wave duration, QRS duration, and QRS amplitude.

ECG features of WPW syndrome

(1) A PR interval less than 0.12 s during sinus rhythm; (2) A slurring of initial phase of the QRS complex, called a delta wave; (3) QRS complex duration greater than 0.12 s; (4) Secondary ST-segment T-wave changes directed opposite to the major delta wave and QRS complex changes [2,8].

Measurement of the QTcd

The QT interval was measured manually on basal ECG by two study investigators using calipers which form the onset of the QRS to the end of the T wave defined as the return to the TP baseline. When U waves were present the QT interval was measured to the nadir of the curve between the T and U waves. Three consecutive cycles were measured in each of the standard 12 leads and from the three values a mean QT interval was calculated. When the end of the T wave could not be identified the lead was not included. A minimum of seven leads including at least three precordial leads, were required for QT dispersion which is to be calculated. The QTd was defined as the difference between the maximum and minimum QT interval occurring in any of the 12 ECG leads. Heart rate correction
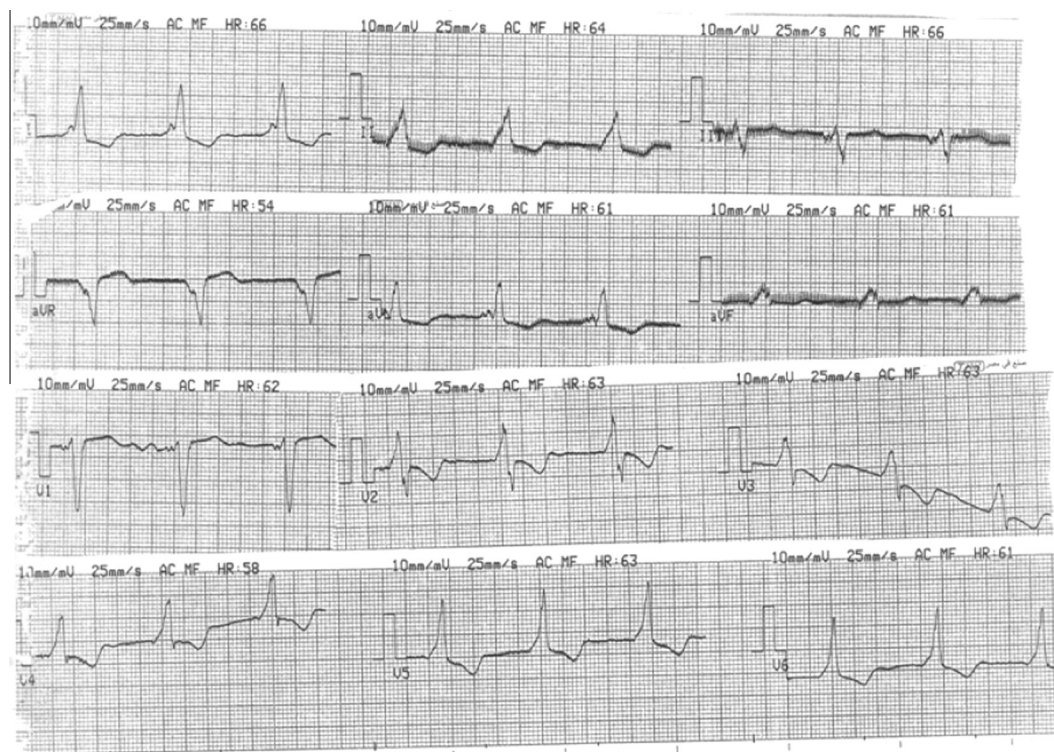
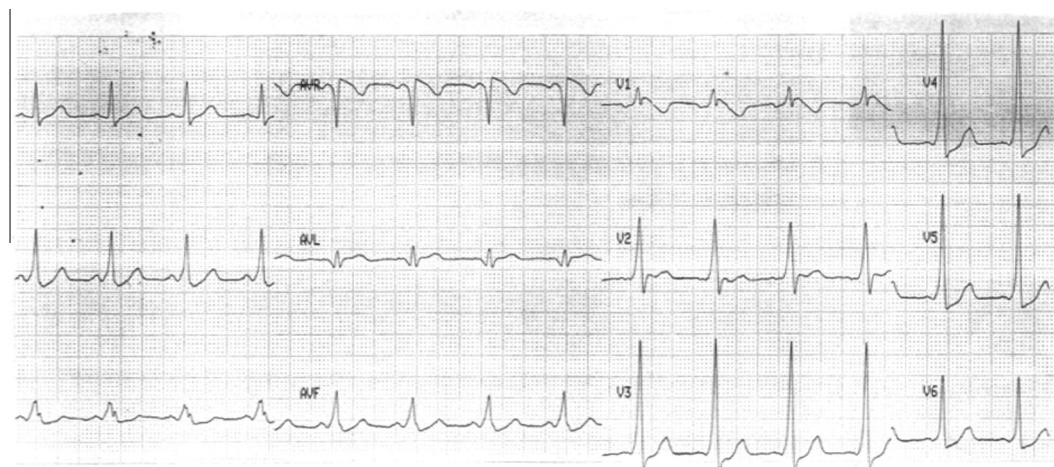**Figure 1** Patient with WPW syndrome type B (negative V1).

Figure 2 Patient with WPW syndrome type A (positive V1).

of the measured QT dispersion was done using Bazett's formula and corrected QTd was calculated by measuring the difference between maximum and minimum corrected QT intervals in each ECG tracing [9].

24-h ambulatory electrocardiographic monitoring (Holter) for recording of maximum and minimum heart rate was performed.

Echocardiography

Transthoracic Doppler-echocardiographic recordings were obtained using a real time phased array sector scanner (vivid 3 model) for the measurement of the left ventricular ejection fraction (EF), fractional shortening (FS) and left atrial dimension.

Laboratory investigations of serum creatinine, and electrolyte profile (potassium, calcium, magnesium and sodium) were obtained.

Statistical analysis

Data was analyzed using SPSS (Statistical Package for Social Sciences) version 17. Qualitative data was presented as number and percent. Quantitative data was tested for normality by the Kolmogrov–Smirnov test. Normally distributed data was presented as mean ± SD. Student's *t*-test
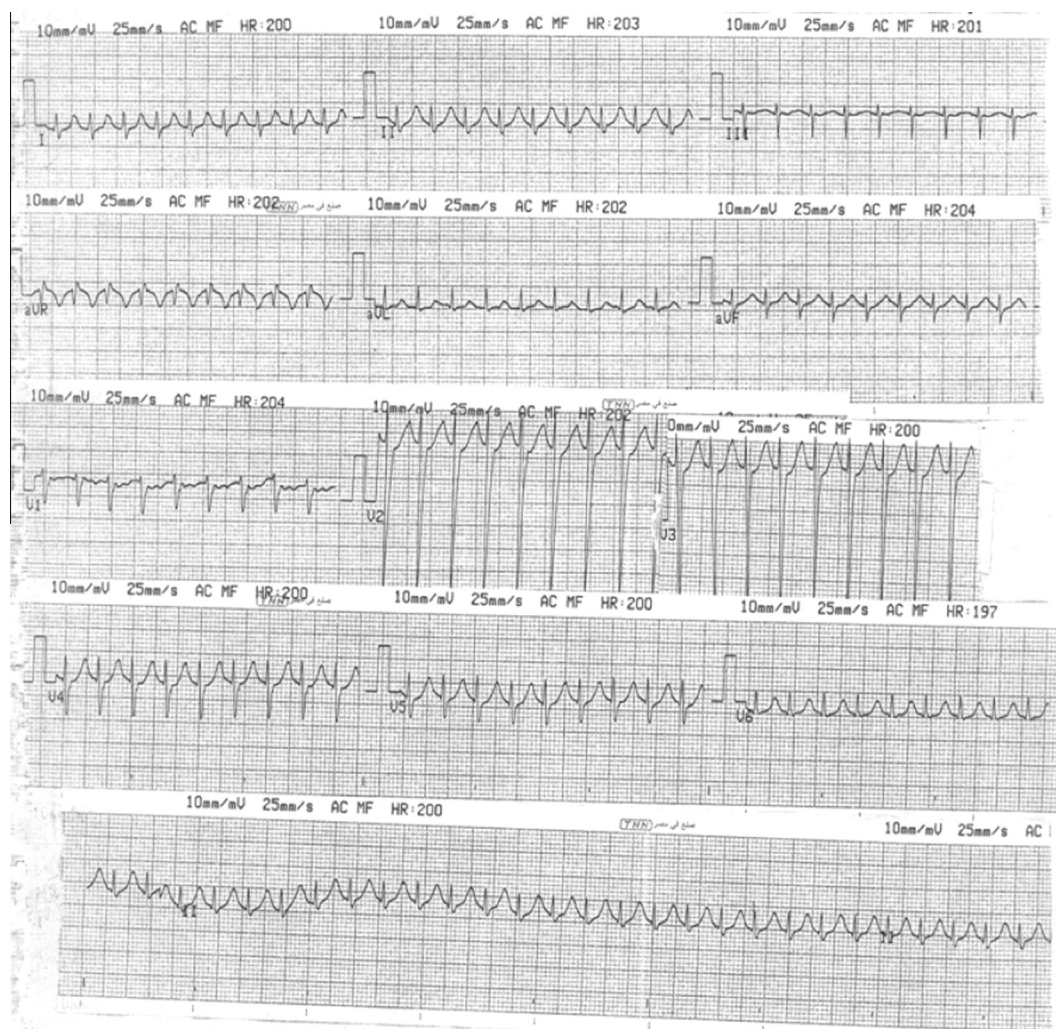
Figure 3 Patient with WPW syndrome with regular narrow QRS complex tachycardia (orthodromic circus movement tachycardia).

Figure 4 Patient with WPW syndrome with regular wide QRS complex tachycardia (antidromic circus movement tachycardia).

was used to compare between two groups and paired t-test was used within the group. F-test (One Way Anova) was used to compare between more than two groups. Pearson's correlation coefficient was used to test correlation between variables. $P < 0.05$ was considered to be statistically significant.
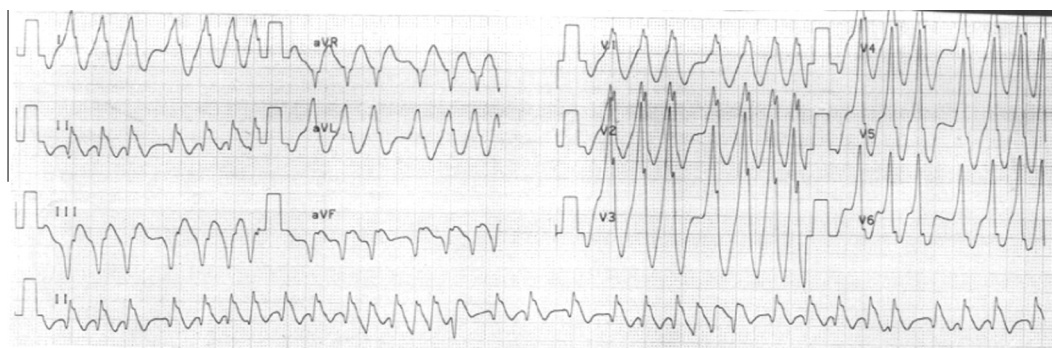
Figure 5 Patient with WPW syndrome with irregular wide QRS complex tachycardia (atrial fibrillation with WPW syndrome).

Results

There was no significant difference as regards age and sex between patients with WPW syndrome with frequent attacks of tachyarrhythmias and those with infrequent attacks ($P = 0.390$, 0.625, respectively). The age of the patients with regular wide QRS complex tachycardia (group II) was significantly higher compared with group I and group III ($P = 0.016$).

There was a significant increase in QTcd, QTmax and LAD and a significant decrease in EF and FS when compared to patients with WPW syndrome with frequent attacks of tachyarrhythmias with those with infrequent attacks ($P < 0.05$, Table 3).

There was a significant increase in QTcd, QTmax, QTmin, Delta wave, QRS duration, and QRS amplitude in patients with WPW syndrome and irregular wide QRS complex tachycardia (group III) compared to group I and group II ($P < 0.05$, Table 4).

QTcd in patients with WPW with either frequent or infrequent attacks of tachyarrhythmia had significant positive correlation with QTmax, delta wave duration, QRS duration and QRS amplitude ($P < 0.05$). While QTcd had positive correlation with QTmin only in patients with frequent attacks ($P < 0.05$, Table 5).

Table 6 showed a significant positive correlation between QTcd and QTmax and QTmin in both group I and group III. There was a significant positive correlation between QTcd and delta wave duration QRS duration and QRS amplitude in both group I and group II. There was a significant negative correlation between QTcd and EF and FS in both group I and III. There was a significant positive correlation between QTcd and LAD in group I. There was no correlation between the QTcd and maximum and minimum heart rate in holter monitoring ($P > 0.05$).

Discussion

This study represents a study of QTcd parameters in patients with WPW syndrome admitted to the emergency department, Mansoura Medical Specialized Hospital. The QTcd analysis was performed during sinus rhythm after termination of tachyarrhythmias by drugs or DC cardioversion.

The frequency of SVT was not affected by the patients' age or gender as shown in Table 1, however it was found that the frequency of regular wide QRS complex tachyarrhythmias was

Table 1 Age and gender distribution according to the frequency of tachyarrhythmia.

	Group A ($n = 25$)	Group B ($n = 15$)	P value
Age (years) (mean $\pm$ SD)	35.72 ± 8.1	38.07 ± 8.54	0.390
Sex			
Male (n, %)	20 (80%)	11 (73.3%)	0.625
Female (n, %)	5 (20%)	4 (26.7%)	

Group A: patients with frequent attacks, Group B: patients with infrequent attacks.

Table 2 Age and gender distribution according to the type of tachyarrhythmias.

	GI	GII	GIII	F	P
Age (years) (mean $\pm$ SD)	33.67 ± 7.79	42.7 ± 7.2	35.9 ± 7.49	4.658	0.016
Sex					
Male (n, %)	14 (77.8%)	8 (80%)	9 (75%)		0.961
Female (n, %)	4 (22.2%)	2 (20%)	3 (25%)		

GI: patients with regular narrow QRS complex tachycardia, GII: patients with regular wide QRS complex tachycardia, GIII: patients with irregular wide QRS complex tachycardia.

Table 3 Comparison between patients with frequent attacks of tachyarrhythmia and those with infrequent attacks.

	Group A (n = 25)	Group B (n = 15)	P value
QTcd (ms)	93.08 ± 14.68	67.47 ± 7.03	<0.001
QTmax (ms)	430.64 ± 33.22	402.80 ± 26.36	0.009
QTmin (ms)	346.00 ± 19.42	336.53 ± 19.81	0.140
Delta wave duration (ms)	57.7 ± 10.25	55.53 ± 11.27	0.533
QRS duration (ms)	138.32 ± 15.14	133.67 ± 18.94	0.397
QRS amplitude	21.9 ± 4.0	21.2 ± 4.2	0.595
EF	61.12 ± 2.19	67.47 ± 2.4	<0.001
FS	31.16 ± 1.93	36.33 ± 2.8	<0.001
LAD	3.28 ± 0.45	2.76 ± 0.35	<0.001

Group A: patients with frequent attacks, Group B: patients with infrequent attacks. QTcd: corrected QT dispersion, QTmax: Maximum QT, QTmin: Minimum QT, EF: Ejection fraction, FS: Fractional shortening, LAD: Left atrial diameter.

Table 4 Comparison between studied groups according to the type of tachyarrhythmia as regards ECG and echocardiographic parameters.

	GI (n = 18)	GII (n = 10)	GIII (n = 12)	F	P
QTcd (ms)	76.5 ± 11.9	79.0 ± 18.49	97.6 ± 16.5	7.585	0.002
QTmax (ms)	407.6 ± 28.4	405.2 ± 25.9	451.5 ± 24.9	11.688	0.000
QTmin (ms)	334.6 ± 19.0	337.0 ± 17.6	358.7 ± 10.9	8.245	0.001
Delta wave duration (ms)	53.06 ± 10.0	53.3 ± 9.8	65.6 ± 6.4	8.058	0.001
QRS duration (ms)	129.4 ± 15.8	131.0 ± 13.7	151.9 ± 8.2	11.219	0.000
QRS amplitude	19.67 ± 3.55	20.9 ± 3.2	25.25 ± 3.14	10.287	0.000
EF	63.72 ± 4.2	64.10 ± 4.09	62.67 ± 3.14	0.423	0.658
FS	33.4 ± 3.48	34.00 ± 3.86	31.8 ± 2.7	1.292	0.287
LAD	3.12 ± 0.52	2.89 ± 0.5	3.19 ± 0.38	1.169	0.322

GI: patients with regular narrow QRS complex tachycardia, GII: patients with regular wide QRS complex tachycardia, GIII: patients with irregular wide QRS complex tachycardia, QTcd: corrected QT dispersion, QTmax: Maximum QT, QTmin: Minimum QT, EF: Ejection fraction, FS: Fractional shortening, LAD: Left atrial diameter.

Table 5 Correlations between QTcd and some echocardiographic and ECG parameters in studied groups according to the frequency of tachyarrhythmia.

	QTcd (ms)			
	Group A (n = 25)		Group B (n = 15)	
	r	P	r	P
QTcd (ms)	0.800	0.000	0.666	0.007
QTmax (ms)	0.913	0.000	0.374	0.169
QTmin (ms)	0.910	0.000	0.756	0.001
Delta wave duration (ms)	0.903	0.000	0.783	0.001
QRS duration (ms)	0.800	0.000	0.674	0.006
QRS amplitude	0.041	0.845	0.167	0.552
FS	−0.043	0.838	0.100	0.724
LAD	−0.023	0.912	0.423	0.116

Group A: patients with frequent attacks, Group B: patients with infrequent attacks. QTcd: corrected QT dispersion, QTmax: Maximum QT, QTmin: Minimum QT, EF: Ejection fraction, FS: Fractional shortening, LAD: Left atrial diameter.

associated with older age of the patients (group II) than the other two groups (I and III), (P = 0.016) (Table 2).

It was found that patients with frequent recurrent pre-exitation related tachyarrhythmias have highly significant higher QTc dispersion than those with infrequent tachyarrhythmias (Table 3) (P = 0.0001). This group also has higher QT max than those with infrequent tachyarrhythmias. These findings indicate that the more the dispersion of the QTc the more

the frequency of attacks of tachyarrhythmias. These findings were expected because the dispersion of ventricular repolarization is an important factor in the genesis of tachyarrhythmias because it results in non homogenous conduction velocity and variable refractory period, both are substrate of arrhythmia [10]. The concept that QTcd reflects dispersion of repolarization is supported by close correlation between changes in dispersion of repolarization (from ventricular monophasic action

Table 6 Correlations between QTcd and some echocardiographic and ECG parameters in studied groups according to the type of tachyarrhythmias.

| | QTcd | | | | | |
| | Group I (n = 18) | | Group II (n = 10) | | Group III (n = 12) | |
	r	P	r	P	r	P
QTcd (ms)	0.691	0.001	0.614	0.059	0.784	0.003
QTmax (ms)	0.569	0.014	0.469	0.171	0.820	0.001
QTmin (ms)	0.538	0.021	0.844	0.002	0.919	0.033
Delta wave duration (ms)	0.556	0.017	0.741	0.014	0.736	0.109
QRS duration (ms)	0.478	0.045	0.770	0.009	−0.112	0.729
QRS amplitude	−0.594	0.009	−0.574	0.083	−0.623	0.030
FS	−0.440	0.067	−0.569	0.086	−0.540	0.040
LAD	0.538	0.021	0.445	0.198	0.257	0.419

GI: patients with regular narrow QRS complex tachycardia, GII: patients with regular wide QRS complex tachycardia, GIII: patients with irregular wide QRS complex tachycardia, QTcd: corrected QT dispersion, QTmax: Maximum QT, QTmin: Minimum QT, EF: Ejection fraction, FS: Fractional shortening, LAD: Left atrial diameter.

potential) and changes in QTcd produced by ventricular pacing [11].

In patients with frequent tachyarrhythmias; the EF and FS were found to be significantly lower than in patients with infrequent tachyarrhythmias ($P = 0.000$) (Table 3). The lower the EF the larger the LV dimension which leads to more nonhomogenous depolarization and consequently more nonhomogenous repolarization thus more QTcd and arrhythmogenesis.

The increased QTcd in patients with irregular wide QRS complex tachyarrhythmias (group III) than the other two groups (I and II) ($P = 0.002$) (Table 4), can be attributed to the dispersion of ventricular repolarization in these patients which is mainly related to abnormal ventricular depolarization due to asynchronous electrical activation of one or both ventricles via an abnormal (accessory) pathway [12]. This is supported by the finding of Ducceschi et al. [13], who stated that ventricular pre excitation increases regional discrepancies of the repolarization process and hence more QTcd.

Patients with irregular wide QRS complex tachyarrhythmias (group III) had significant increase in QT max, QT min, delta wave duration, QRS duration and amplitude than the other two groups. These were expected findings because the wider the delta wave the wider the QRS duration as it is the initial slurring of the QRS.

It was found that patient with irregular wide QRS complex tachyarrhythmias (group III) have significantly higher QTc, QTmax and QTmin (Table 4) than the other two groups I and II. This significantly higher dispersion of QTc is expected, and can be explained by alternation of conduction along the accessory pathway and the normal pathway so that every beat is considered a ventricular fusion beat as each sinus beat is dichotomized and conducted simultaneously along the normal pathway and along the accessory pathway with variable degree of fusion between these two activations depending mainly on the refractory period of both normal and accessory pathway.

There were significant correlations between QTcd and QT max, delta wave duration, QRS duration and QRS amplitude in patients with frequent tachyarrhythmias versus those with infrequent tachyarrhythmias (Table 5), this group of patients with higher QTcd was significantly affected with irregular wide QRS complex than the other group. These differences can be explained by the differences in the electrophysiologic

mechanisms of both groups of arrhythmias: as the group with irregular wide QRS tachyarrhythmias the main electrophysiologic mechanism is microentry which is triggered by premature atrial impulse that stimulates the atria during the vulnerable period and associated with variable conduction along the normal and the accessory pathway and hence inhomogenous ventricular depolarization [14] which leads to dispersion of ventricular repolarization. As a rule abnormal ventricular depolarization leads to abnormal ventricular repolarization. While the mechanism in the other two arrhythmias is reciprocating impulse with antegrade conduction along the normal pathway (orthodromic circus movement tachycardia, narrow QRS tachycardia) or antegrade conduction along the accessory pathway (antidromic circus movement tachycardia, wide QRS tachycardia) both are associated with more synchronized, homogenous ventricular depolarization and hence less ventricular repolarization dispersion [15].

There was a significantly positive correlation between QTcd and QT max, QT min and delta wave duration in group I and group III (Table 6), these indicate that the main factor in producing a higher QTcd is the maximum QTc rather than the minimum QTc interval, these findings coincide with the finding of Inaba et al. [16] who stated that patients with WPW syndrome abnormalities in local repolarization properties are significantly related to QRS duration, and delta wave during preexcitation.

The finding of larger QRS amplitude was associated with longer delta wave duration and wider QRS duration (Tables 5 and 6) can be explained by the duration of delta wave which is related to the degree of preexcitation; the more the preexcitation the longer the delta wave and QRS duration which lead

Table 7 Correlation between QTcd and maximum and minimum heart rate found by holter monitoring.

| | QTcd | | |
		r	P
Maximum HR	130.13 ± 8.38	−0.172	0.32
Minimum HR	66.30 ± 9.23	0.144	0.40

HR = heart rate.

to more abnormal ventricular depolarization and hence bizarre, large QRS complex and more dispersion of QTc [17]. There was a non significant correlation between QTcd and maximum or minimum heart rate recorded by holter monitoring in our study groups. All these findings indicate that the more the QTcd the more the frequent attacks of tachyarrhythmias in patients with WPW syndrome especially irregular wide QRS tachyarrhythmias (Table 7).

Conclusion

Calculation of QTcd in patients with WPW syndrome presented with paroxysmal tachyarrhythmias is a simple noninvasive, reproducible clinical test for risk stratification of those patients and hence detecting patients at higher risk for frequent and recurrent tachyarrhythmias.

Conflict of Interest

All authors declare that there are no conflicts of interest.

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