Research Article

Interventional Cardiology

Correlation between corrected QT dispersion and left ventricular systolic and diastolic function in patients with first acute myocardial infarction

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Abstract

Background: QT interval is attracting the interest of many investigators. In the last two decades, lengthening in the QT interval has been felt to be associated with electrical instability and Sudden Cardiac Death (SCD). The QT interval is an indirect measure of the duration of action potential depolarization and repolarization of the ventricles.

Aim of the study: The goal of the present study is to correlate between QTc dispersion obtained from standard surface 12 lead ECG and left ventricular systolic and diastolic function obtained from transthoracic echocardiography in the setting of acute STEMI promptly after presentation and prior to revascularization. We also aim to evaluate how accurate is the QTc dispersion as an ECG index in predicting LV function after acute STEMI.

Results: There was a statistically significant difference between patients who developed ventricular arrhythmias-prior to reperfusion strategy-and those who did not suffer ventricular arrhythmias regarding QTcD ($p<0.001$). Mean QTcD in ventricular arrhythmia group was much higher than that in non-arrhythmia group (125.26 ± 28.73 msec. vs. 73.41 ± 23.9 msec.). Also, a strong negative correlation ($r=-0.772$) between LVEF and QTcD ($p<0.001$). Moreover, by correlating LV systolic function with QTcD using logistic regression model, QTcD was a good predictor of LV systolic function. Significant positive correlation ($r=0.536$) between QTcD and the grade of LV diastolic dysfunction ($p<0.001$). 88.6% of prolonged QTcD patients had impaired diastolic function in comparison to 53.3% of normal QTcD patients. There was a statistically significant relationship when associating age of STEMI patients with LV diastolic function ($p<0.001$ vs. $p=0.06$). Patients with normal diastolic function had a mean age 48.55 ± 13.69 while those with restrictive diastolic pattern had a mean age 66.4 ± 5.98 years. There was a statistically significant weak positive correlation between duration of hospital stay in days and value of QTcD ($r=0.24$, $p=0.016$).

Conclusion: The present study concluded that, given the ready availability of ECG, QTc dispersion is an important non-invasive electrocardiographic indicator that is highly correlated with LV systolic and diastolic function in the setting of acute STEMI. It is also an important independent predictor of LV systolic function in such patients.

Keywords: Correlation • Corrected QT • Left ventricular systolic • Diastolic • Acute myocardial infarction

Introduction

Myocardial Infarction (MI) is a major cause of mortality and morbidity not only in the industrialized world but also in the developing countries. Each year, about 785,000 persons will have a new attack in the USA alone. In addition, MI has major

psychological, legal and economic implications for patients and the society and is an important outcome measure in research studies [1].

According to the third universal definition of Acute Myocardial Infarction (AMI), detection of a rise and/or drop of cardiac biomarkers with at least one of the values being elevated (>99th percentile upper reference limit) is central. Cardiac Troponin (cTn) is the preferred biomarker. The vast majority of AMIs result from pre-existing coronary atherosclerosis with superimposed coronary thrombosis. The main trigger for coronary thrombosis is disruption of the atheromatous plaque. This is followed by cascade of events: Platelet activation and aggregation, activation of the coagulation pathway, thrombin generation and vasoconstriction [2].

The resultant thrombus interrupts blood flow and leads to an imbalance between myocardial oxygen supply and demand. If this imbalance is severe and persistent, necrosis will follow [3].

A consensus has emerged that inflammation plays a decisive role in the pathophysiology of these acute thrombotic events [4].

With interruption of antegrade blood flow in an epicardial coronary artery, the zone of myocardium supplied by that vessel immediately loses its ability to shorten and contract normally. Four abnormal contraction patterns develop in sequence; (1) dyssynchrony, (2) hypokinesis, (3) akinesis and (4) dyskinesis. Compensatory hyperkinesia of the surrounding normal myocardium initially accompanies dysfunction of the infarct region. Since the middle of 19th century, the cardiac electrical activity became an important object of scientific inquiry and experimentation. The term QT interval has been introduced by Einthoven and the first measurement of QT interval has been reported in Burchell's review [5].

In spite of its importance remains evasive, QT interval is attracting the interest of many investigators. In the last two decades, lengthening in the QT interval has been felt to be associated with electrical instability and sudden cardiac death [6].

The QT interval is an indirect measure of the duration of action potential depolarization and repolarization of the ventricles. It represents the ventricular refractory period, and consists of two components: The QRS complex, which represents depolarization within the His-Purkinje system and ventricles; and the JT interval, which reflects the duration of ventricular repolarization [7].

The T-wave is generated by repolarization of three layers of the myocardium (subepicardium, subendocardium and midmyocardium). The repolarization process spreads from the apex to the base of the ventricles and driven primarily by the outward movement of potassium [8].

The QT interval on the surface ECG is measured from the beginning of the Q wave (or R wave if there is no Q wave) to the end of the T wave. It has been recognized for years that precise measurement of QT interval is difficult due to inter-lead and intra-lead variations. Therefore, the longest QT interval measured in multiple leads should be considered the true QT interval [9].

A standard 12-lead ECG tracing at 25mm/sec. paper speed at 10 mm/mv amplitude is generally adequate for accurate measurement of QT-interval duration. Higher speeds (e.g., 50mm/sec.) may lead to distortion of low-amplitude waves such as U waves.

The main difficulty is identifying correctly the point where the descending limb of the T wave intersects the isoelectric line, particularly when there are T and U waves that are close together. In 1952, Lepeschkin, et al., [10], described various patterns of T and U wave merges and classified them into 16 patterns. They also suggested methods for determining the end of the T-wave when it is buried within the U-wave.

At least three methods are known for manual and automated measurement of the QT. The simplest method is the visual method that recognizes the point where the T wave returns to isoelectric line [11].

Using the visual method, the T wave termination is identified when its descending limb returns to the TP baseline if it is not followed by a U wave or if it is distinct from the following U wave. When T-wave deflections of equal or near-equal amplitudes result in a biphasic T wave, the QT interval is measured to the time of final return to baseline [12].

If a 2nd low amplitude repolarization wave interrupts the terminal portion of the T wave, it is difficult to determine whether the 2nd deflection is a biphasic T wave or an early-occurring U wave. In such cases, the 2nd deflection can be included within the QT interval, or more better record both the QT interval (T-wave offset measured as the nadir between the T and U wave) and the QTU interval (repolarization offset is at the end of the 2nd wave) [13].

In general, biphasic T waves are frequently present in multiple leads, whereas discrete and separate low-amplitude U waves are best seen in the lateral precordial leads. Moreover, at faster heart rates, the P wave may merge with the T wave, resulting in a TP junction which is not on the baseline. In this instance, the P wave onset should be considered the approximate end of the QT interval.

This method reflects accurately the real duration of ventricular

repolarization, but it has a large degree of subjectivity, particularly when biphasic T waves are present or when large U waves interrupt the return of the T wave to the baseline. The method can be effectively applied for manual measurements, but is less suitable for computer analysis because it requires the definition of a given threshold for the amplitude below which T or U wave potentials return to baseline.

A manual approach has the advantage of more accurately determining the end of the QT but is more time consuming because of the large number of QT intervals that need to be measured in each 12 ECG. Automatic approaches allow the rapid measurement of large numbers of QT intervals but even the best algorithms may be inaccurate in determining the end of the QT interval [14].

The ECG marker of LQTS is prolonged repolarization (i.e., Prolonged QT interval), abnormal T wave morphology and a characteristic polymorphic ventricular tachyarrhythmia called torsade de pointes that is mostly induced by activation of the sympathetic nervous system. It can be divided into idiopathic (congenital) or acquired [15].

The idea of detection and quantification of the ventricular recovery times' dispersion from the standard surface ECG can be traced back decades ago. During 1990s, Campbell resurrected an old idea of the inter-lead differences of the QT interval duration. The range of the QT interval durations was suggested as an index of the spatial dispersion of the ventricular recovery times. It was proposed that the different leads of surface ECG magnify the ECG signal of different myocardial regions and consequently, QT Dispersion (QTD) is an almost direct measure of the myocardial repolarization heterogeneity. The cardiological society welcomed this idea [16].

Since that, the cardiological literature has been flooded by articles about QTD, not only in every cardiac but also in many non-cardiac syndromes and diseases [17].

The QTD was defined as the difference between the maximum and minimum QT interval measurements occurring in any of the standard 12 surface ECG leads. Adjacent QTD is the maximum difference of QT interval between two adjacent leads of a standard surface ECG. Adjacent QTD has been also introduced as a simple method to determine regional variation in repolarization and refractoriness. Regional electrical inhomogeneity is considered the cornerstone for development of reentrant ventricular tachyarrhythmia [18].

Increased repolarization dispersion is widely considered as being arrhythmogenic. One possible mechanism has been thought to be re-excitation of fibers with short Action Potentials (APs) by adjacent fibers with longer APs. The recovery times throughout the ventricular myocardium vary due to both differences in the activation times and the different duration of APs. The range of the activation times is roughly reflected in the QRS duration, which is normally 100msec. or less. The range of the ends of the APs (i.e., the range of the recovery times) is normally about twice smaller, owing to progressive shortening of APD in myocardial areas that are activated later [19].

Therefore, under normal circumstances, the different durations of myocytes' action potentials compensate for the different activation times and hence decrease the range of ventricular recovery times. This is attributed to the electronic interactions at the cellular junctions at different degrees of repolarization, a mechanism that actually diminishes the likelihood of reentry.

MI is considered a difficult area in which to measure QTD, because the ECG is abnormal and changing rapidly. The best time to measure QTD following AMI is not exactly known. The labile nature and dynamicity of QTD during and after AMI has been well confirmed [20].

QTD is believed to be increased in AMI and is associated with increased susceptibility to ventricular arrhythmias and SCD among these patients. According to study conducted by Chintamani, et al., [21], QTD in 50 patients with AMI was found to be highest at the time of admission 108 ± 63.0msec. and was found to decrease with time, 91 ± 64.0msec. at Day 2 and 90 ± 58.6msec. at Day 5.

The study aimed to study the relationship between LV systolic and diastolic function obtained by transthoracic echocardiography and the corrected QT dispersion obtained from a standard surface 12 lead electrocardiogram in the setting of acute myocardial infarction, and to determine how much is the accuracy of QTD-as a simple noninvasive ECG marker–in prediction of LV function in such patients.

Materials and Methods

This study included 100 patients with first acute myocardial infarction and was conducted at Mansoura University Emergency Hospital and department of cardiology at Mansoura University Specialized Medical Hospital.

Inclusion criteria

- Patients presented with the first attack of acute ST segment elevation myocardial infarction.
- Patients presented to the emergency department within 24 hours of onset of their manifestations.

- Age: Adult age, starting from 18 years old and older patients.
- Sex: Both males and females.

Exclusion criteria

- Age: Patients less than 18 years old.
- Patients with previous MI, cardiomyopathy or surgical revascularization.
- Patients with non ST segment elevation myocardial infarction.
- Patients with electrolyte abnormalities or taking medications that may affect QT interval and QT dispersion measurements (e.g. antiarrhythmic, anti-convulsant, antipsychotic or antidepressant drugs).
- Patients with BBB or any other intraventricular conduction abnormalities, pre-excitation on ECG or ventricular pacing rhythm.
- Patients with cardiac arrhythmias (e.g. AF or atrial flutter) that may impair accurate assessment of QT interval.
- If QT interval could not be reliably measured in at least nine leads.

All patients-on arrival to the emergency department-were subjected to full history taking; that includes Personal data; e.g. age and sex etc., Past and present history including; hypertension, DM, dyslipidemia, smoking and any cardiovascular disease, drug history including; antihypertensive medications, antiarrhythmic, antipsychotic, antihistaminic, illicit drugs and others. Family history of hyperlipidemia and CAD, thorough physical examination that includes general examination including.

Vital signs monitoring: Pulse, blood pressure obtained manually from both upper limbs, respiratory rate and random blood glucose, body weight and Body Mass Index (BMI), neck veins, chest auscultation, abdominal examination and lower limb edema.

Local examination: Detailed cardiac examination, 12 lead standard surface ECG: Done immediately in the emergency department, at a paper speed of 25 mm/sec. and amplification of 10 mm/mv, to confirm diagnosis of acute STEMI and to calculate QTcD. QT interval was measured manually-by a single observer-in all 12 leads from the beginning of the QRS complex to the end of the T wave using tangential method. Then, QT interval was corrected for the heart rate using Bazett's formula: QTC=QT/RR [22]. Finally, corrected QTD was calculated by subtracting the minimum QTc interval from the maximum QTc interval. Corrected QTD was considered prolonged if it is>60 msec

Laboratory investigations including: Complete Blood Count (CBC), Cardiac enzymes: LDH, total CPK, CK-MB and troponins, Serum electrolytes (e.g. sodium, potassium and calcium); to define any other medical problems or electrolyte abnormalities that may affect measurements of QTc and QTcD.

Transthoracic echocardiography was performed by a well experienced cardiologist: For evaluation of LV systolic function (ejection fraction) using M-mode echocardiography. It was considered normal when EF is ≥ 55% and impaired when EF is<55%. For evaluation of LV diastolic function using Doppler echocardiography with measurement of: Transmitral E velocity (cm/sec), Transmitral A velocity (cm/sec). E/A ratio, E deceleration time (msec). Isovolumic Relaxation Time (IVRT) in msec. Diastolic function was then classified into: Normal transmitral flow, Grade 1 diastolic dysfunction: Impaired LV relaxation with normal filling pressures, Grade 2 diastolic dysfunction: Pseudo-normal filling, Grade 3 diastolic dysfunction: Restrictive filling. Echocardiography was done prior to thrombolysis or PCI for the findings to be accurately correlated with the calculated QTcD.

The corrected QTD was then correlated with LV systolic and diastolic functions evaluated by transthoracic echocardiography. All patients have been managed by the most appropriate means of treating acute myocardial infarction starting with emergency department care till either thrombolysis or primary Percutaneous Coronary Intervention (PCI) or neither of them in certain cases.

Statistical analysis

All data were collected, tabulated and then statistically analyzed using the computer program SPSS (Statistical Package for Social Science) version 20.0 for windows (SPSS Inc., Chicago, IL, USA) and Microsoft Office Excel 2010 for windows (Microsoft Cor., Redmond, WA, USA) to obtain.

Continuous variables were checked for normality by using Shapiro-Wilk test. Mann-Whitney U test (z) was used to compare two groups of non-normally distributed data. Also, Student's (t) test: Used to compare between mean of two groups of numerical parametric data (quantitative variables).

Inter-group comparison of categorical data (qualitative variables) was performed by using chi square test (χ^2 value). Also, Spearman correlation was done for non-parametric data. Logistic regression was done to evaluate QTD as a predictor of LV function.

P value<0.01 was considered highly statistically significant. (The smaller the obtained P value, the more significant the results)

Results

The present study was carried out on 100 patients with acute

ST segment elevation myocardial infarction who presented to Mansoura University Emergency Hospital and admitted in department of cardiology at Mansoura University Specialized Medical Hospital.

Demographical data

As regarding the age of studied patients, the present study included only adult patients with the mean age (Mean ± SD) was 56.62 ± 10.82 years. The youngest patient was 21 and the oldest patient was 79 years old. Most of the patients (92%) were males and only (8%) were females (Table 1). In the present study, patients were classified into 2 groups: The normal QTcD (A) group (30% of patients) with mean QTcD (mean ± SD) was 53.23 ± 10.63msec., and prolonged QTcD (B) group (70% of patients) with mean QTcD ± SD was 57.93 ± 10.67msec. The statistical analysis shows a significant difference between the two groups when QTcD was associated with age (t=2.019, p=0.046) but it shows a statistically non-significant difference when it was associated with sex as shown in Table 2.

Table 1: Description of demographic characters of participants.

Demographic data	N=100
Age	
(Mean ± SD)	56.62 ± 10.82
Min-Max	21-79
Sex	
Male	92(92)
Female	8(8)

Table 2: Association of QTcD with demographical data.

Characters	QT dispersion		Significance
	Normal n=30 N (%)	Prolonged n=70 N (%)	
Age (mean ± SD)			t=2.019
	53.23 ± 10.63	57.93 ± 10.67	p=0.046*
Sex	N(%)	N(%)	
Male	26(86.7)	66(94.3)	χ^2=1.66 p=0.198
Female	4(13.3)	4(5.7)	

Present history

In the present study, 42% of patients were known to be hypertensive and 58% of patients were normotensive. Among the 100 studied patients, 36% of patients were diabetics. Given the smoking history, 28% of patients were nonsmokers, 4% of patients were ex-smokers and 68% of patients were smokers with the median smoking index was 33 pack-year (Table 3). As shown in Table 4, on studying the relationship between incidence of hypertension and QTcD, there was a statistically significant difference between the two QTc dispersion groups A, B (χ^2=14.46, p=<0.001). While on associating incidence of DM and smoking index with QTcD, there was a statistically non-significant difference between the two groups.

Table 3: Description of present history of studied patients.

Present history	N=100 N (%)
Hypertension	42(42)
Diabetes	36(36)
Smoking	
Nonsmoker	28(28)
Smoker	68(68)
Ex-smoker	4(4)
Median Smoking index: (Min-Max)	33(0-125)

Table 4: Association of QTc dispersion with risk factors of AMI.

Characters	QT dispersion		Significance
	Normal n=30 N (%)	Prolonged n=70 N (%)	
Hypertension	4(13.3)	38(54.3)	χ2 =14.46
			p<0.001*
DM	8(26.7)	28(40)	χ2 =1.62
			p=0.203
Smoking index	40 (0-120)	30 (0-125)	Z=1.324
			P=0.185

Note: Z: for Mann Whitney U test; *: p value is significant ≤ 0.05

Electrocardiographic findings

In the present study, 56 (56%) patients suffered anterior wall STEMI, and 44 (44%) patients had inferior wall STEMI. The mean QTcD (± SD) in all STEMI patients was prolonged (74.35 ± 0msec.) with the minimum QTcD was 32.4msec. and the maximum was 151.1msec. During cardiac monitoring prior to revascularization, only 7(7%) patients developed ventricular arrhythmias, either VF or VT or both as shown in Table 5.

On studying the relationship between the site of STEMI (either anterior or inferior wall STEMI) and QTcD, there was a statistically significant difference between both groups with χ^2=4.453, and p=0.035 as shown in Table 6. As shown in Table 7, the median QTcD in anterior wall STEMI patients (93.25msec.) was higher than that in inferior wall STEMI patients (65.17 msec.) with a statistically significant difference between the 2 groups (z=4.36, p<0.001). All patients who developed ventricular arrhythmias were in group B and had markedly prolonged QTc dispersion. The mean QTcD ± SD in patients who developed ventricular arrhythmias (125.26 ± 28.73msec.) was much higher than in patients who did not suffer ventricular arrhythmias (73.41

± 23.9msec.) with a statistically significant difference between the 2 groups (t=5.47, p<0.001) (Table 8).

Table 5: Description of ECG findings in studied patients.

Characters	N (%)
site of STEMI:	
• Anterior wall	56(56)
• Inferior wall	44(44)
QTc dispersion (mean) (min–max)	74.35(32.4 -151.1)
Ventricular arrhythmia	**N=7**
• VF	1(1)
• VT	4(4)
• VT,VF	2(2)

Note: VF: Ventricular fibrillation; VT: Ventricular tachycardia

Table 6: Association of QTc dispersion with ECG findings.

Characters	QT dispersion		Significance
	Normal n=30 N (%)	Prolonged n=70 N (%)	
Site of STEMI:			• VT
• Anterior	12(40)	44(62.9)	χ^2 =4.453 p=0.035*
• Inferior	18(60)	26(37.1)	
Ventricular arrhythmia			
• VF	0	1(1.4)	
• VT	0	4(5.7)	
• VT,VF	0	2(2.9)	

Note: *: p value significant ≤ 0.05; VF: Ventricular fibrillation; VT: Ventricular tachycardia

Table 7: Comparison of QTc dispersion according to site of STEMI.

STEMI site	Anterior STEMI N=56	Inferior STEMI N=44	Significance
Median QTcD	93.25	65.17	Z=4.36
(Min-Max)	(43.5-151.1)	(32.4-106.89)	p<0.001*

Note: *: p value is highly significant.

Table 8: Comparison of mean QTcD according to ventricular arrhythmia.

Patient group	Ventricular arrhythmia N=7	Non ventricular arrhythmia N=93	Significance
QTc dispersion (Mean ± SD)	125.26 ± 28.73	73.41±23.9	t=5.47 p<0.001*

Echocardiographic findings

Table 9, demonstrates that the mean LV ejection fraction (EF) ± SD of the 100 studied patients was 52.74 ± 9.03%. In the prolonged QTc dispersion group, 50(71.4%) patients had impaired systolic function while 20 (28.6%) patients had preserved function.

On the other hand, only 1(3.3%) patient of the normal QTc dispersion group had impaired systolic function and the other 29(96.7%) patients had preserved function.

Hence, there was a statistically significant difference between the two groups (χ^2=38.97, p<0.001) (Table 9). Among the 100 studied patients, the diastolic function of the LV was normal in 22(22%) patients and impaired with different grades in the other 78(78%) patients as shown in Table 10.

On correlating between the left ventricular systolic function and the QTc dispersion using the logistic regression model, it was found that QTD was a significant independent predictor of LV systolic function (percent predicted 85%) with Odd's ratio=1.113, χ^2=70.3 and p value<0.001 (Table 11). On studying the association between QTcD and LV diastolic function data, it was found that 14(46.7%) patients of the normal QTcD group had preserved diastolic function while the other 16(53.3%) patients had grade 1 diastolic dysfunction. Looking at the other group with prolonged QTcD, 8(11.4%) patients only had normal diastolic function, 32(45.7%) patients had grade 1 dysfunction, 20(28.6%) patients had grade 2 dysfunction and the remaining 10(14.3%) patients had grade 3 dysfunction. Indeed, there was a statistically significant difference between the 2 groups (χ^2=24.96, p<0.001) as shown in Table 10. However, QTD was not a significant predictor of LV diastolic dysfunction (Table 12).

Moreover, when associating LV diastolic function with age, there was a statistically significant difference between the 2 groups (normal and impaired diastolic function) (t=4.24, p<0.001) (Table 13).

On the other hand, there was a statistically non-significant difference when associating age with systolic function (t=1.901, p=0.06).

Table 9: Association of QTcD with echocardiographic findings.

Characters	QT dispersion		Significance
	Normal n=30 N (%)	Prolonged n=70 N (%)	
Systolic function (EF)			
Preserved	29(96.7)	20(28.6)	χ^2 =38.97 p<0.001*
Impaired	1(3.3)	50(71.4)	
Diastolic dysfunction grading			
Normal	14(46.7)	8(11.4)	χ^2 =24.96 p<0.001*
Grade 1	16(53.3)	32(45.7)	
Grade 2	0	20(28.6)	
Grade 3	0	10(14.3)	

Table 10: Description of echocardiographic findings in studied patients.

Characters	N (%)
Ejection fraction (min-max)	52.74 ± 9.03 (30-67)
Diastolic function	
Normal	22(22)
Impaired	78(78)
Diastolic function grading	
Normal	22(22)
Grade 1	48(48)
Grade 2	20(20)
Grade 3	10(10)
0	0

Table 11: Logistic regression of QTD in prediction of LV systolic function.

Parameter	B	p value	OR	95% CI of OR
QTc dispersion	0.107	<0.001	1.113	1.07-1.158
χ^2 (model chi square)	70.3			
P value	<0.001			
percent predicted	85%			
Constant	-7.99			

Table 12: Logistic regression of QTD in prediction of LV diastolic function.

Predictors	B	p value	OR	95% CI of OR
QT dispersion	0.724	0.15	0.485	0.183-1.283
χ2 (Model chi-square)	2.26			
percent predicted	66%			
Constant	-0.47			

Table 13: Association of age with systolic and diastolic functions.

Parameters systolic function	Age	Significance
Preserved	54.45 ± 10.56	t=1.901; p=0.06
Impaired	58.51 ± 10.79	
Diastolic function		
Impaired	58.77 ± 8.73	t=4.24; p<0.001*
Normal	48.55 ± 13.69	
Diastolic function grading		
Normal	48.55 ± 13.69[abc]	F=8.71; p<0.001*
Grade1	58 ± 7.16[ad]	
Grade 2	56.8 ± 11.34[be]	
Grade 3	66.4 ± 5.98[cde]	

Note: F: For one way ANOVA; [a,b,c,d]: Similar letters denote significant difference between groups; *: p value is highly significant.

Hospital stay

In the present study, the mean duration of hospital stays in days (mean ± SD) was 3.94 ± 0.81. Table 14, shows a direct proportional relationship between QTc dispersion and duration of hospital stay in days with a statistically significant value (r=0.24, p=0.016).

Table 14: Correlating QTcD with hospital stay and LV function.

Parameter	QTc dispersion
Hospital stay	r=0.24
	p=0.016*
Systolic function (EF %)	r=-0.772
	p<0.001*
Grade of diastolic function	r=0.536
	p<0.001*

Note: *: p value is significant (≤ 0.05); r=0.24 =A statistically significant weak positive correlation; r=-0.772=A high statistically significant strong negative correlation; r=0.536=A.

Correlation between LV systolic and diastolic function andQTcD

When LV ejection fraction (%) was correlated with QTc dispersion value (msec.) in Table 14, a strong inversely proportional relationship was revealed with a high statistically significant value (r=-0.772, p<0.001). As shown previously in Table 14, there was a statistically significant difference when associating LV diastolic function with the two QTc dispersion groups (the normal and prolonged). Also when correlating grades of LV diastolic dysfunction with QTcD in a linear regression model as shown in Figure 1, there was a statistically significant positive correlation (r=0.536, p<0.001) (Figure 1).

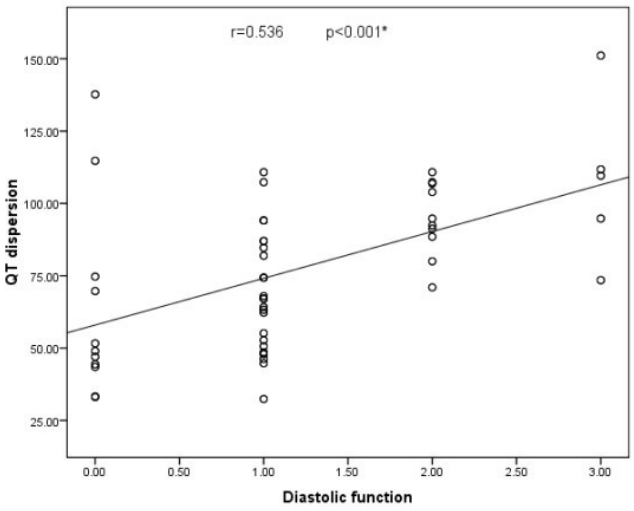

Figure 1: Correlation between LV diastolic function (in grades) and QTcD in msec (Correlation test). **Note:** r=0.536; p<0.001*

Discussion

QT dispersion-the range of QT interval duration in all measurable ECG leads-was used to evaluate degree of myocardial inhomogeneity, which is accompanied by increased dispersion of the ventricular recovery times and prolongation of repolarization [23].

Increased QT interval and QT dispersion values was found to be associated with higher mortality rate in patients with moderate and severe left ventricular dysfunction after AMI [24-34].

Our study was carried out on 100 patients who were presented to Mansoura University Emergency Hospital and admitted in department of cardiology at Mansoura University Specialized Medical Hospital.

The goal of the present study is to correlate between QTc dispersion obtained from standard surface 12 lead ECG and left ventricular systolic and diastolic function obtained from transthoracic echocardiography in the setting of acute STEMI promptly after presentation and prior to revascularization. We also aim to evaluate how accurate is the QTc dispersion as an ECG index in predicting LV function after acute STEMI.

In all patients, careful history taking, examination and risk factor assessment was done. QT interval was measured and corrected using Bazett's formula. QTc dispersion was calculated.

Echocardiography was performed by a well experienced cardiologist. LV systolic function was evaluated several times using M-mode echocardiography (modified Simpson's method). LV diastolic function was evaluated by Doppler echocardiography with measurement of: Transmitral E velocity (cm/sec), transmitral a velocity (cm/sec), E/A ratio, E deceleration time (msec) and Isovolumic relaxation time (msec). Then, LV diastolic function was categorized into one of four groups: Normal function, grade 1, grade 2 or grade 3 diastolic dysfunction.

In the present study, there was a statistically significant difference between the two QTcD groups (normal and prolonged QTcD) and mean age of the studied patients (p=0.046). Patients with normal QTcD value had a mean age (± SD) 53.23 ± 10.63 years while those with prolonged QTcD had a mean age 57.93 ± 10.67 years.

This is in accord to Bortolan et al. [24], who found that age and sex influenced the QT dispersion differently in the three studied patient groups (healthy, hypertensive and patients with cardiac disease). QT dispersion indices were influenced in the healthy group by gender (p<0.01), in the cardiac patient group by age (p<0.01), while in the hypertension group by age (p<0.01) and gender (p>0.01).

This is also in accord to Esen, et al., [25], who compared QT dispersion in 75 elderly and 36 young subjects and found that those over the age of 75 years had higher QTD than those younger than 75. They concluded that QTD increased with age especially over the age of 75 years old.

On the other hand, this is discordant with Mangoni, et al., [26], in their study, QTc interval values progressively increased with advancing age (389 +/- 3 *vs*. 411 +/- 4 *vs*. 418 +/- 3msec. through the three age groups<30, 30-65 and>65 years respectively with P value<0.01). By contrast, no statistically significant differences in QTD were observed across the three groups (36 +/-2 *vs*. 35 +/-3 *vs*. 40 +/- 2msec.). A multivariate regression analysis showed that age is not a predictor of QTD.

In our study, there was a statistically significant difference between the two QTcD groups and incidence of hypertension. In the prolonged QTcD group, 54.3% of patients were hypertensive, while only 13.3% of patients were so in the normal QTcD group (p<0.001).

This is concordant with Gawali, et al., [27], who found that QTD was increased in hypertensive patients compared to control group. Among the different studied groups, significant positive correlation existed between QTD and SBP (p<0.001), DBP (p<0.05), MAP (p<0.05), LV mass (p<0.001) and LVMI (p<0.001).

Abdal-Barr, et al., [28], found that QTcD is significantly increased in hypertensive patients with LVH in comparison with those without, being strongly correlated with the indices of LVH. A QTcD cut-off value of 60msec. predicted LVH in hypertensive patients with high specificity and sensitivity.

In the present study, there was a statistically significant difference between the 2 QTcD groups as regarding the site of STEMI. In the prolonged QTcD group, 62.9% of patients had anterior wall STEMI while 37.1% had inferior STEMI. In the normal QTcD group, 40% of patients suffered anterior and the other 60% suffered inferior STEMI (p=0.035). The median QTcD in anterior STEMI group (93.25msec.) was much higher than that in inferior STEMI patients (65.17msec.) with p value<0.001.

This is in agreement with Aziz, et al., [29], who found that patients of anterior wall MI had significantly greater QTD than non-anterior wall MI (on admission 137.3 ± 16.6msec. *versus* 101.8 ± 13.1msec, p<0.001). This significant difference was maintained even with the declining course of QTD throughout the hospital stay of the patients. Mulay, et al., [30], also demonstrated similar results.

On the other hand, this is in disagreement with George. et al., [31], who showed that there were no statistically significant differences

between anterior and inferior STEMI before reperfusion strategy regarding QT and QTc measurements (QT max, QT min, QTD, QTc max, QTc min and QTcD). They reported that QT and QTc dispersions are dependent on the infarct size rather than the infarct site and the greater values of QT and QTcD associated with anterior MI-that were revealed by other studies can be explained by larger anterior infarctions than inferior ones.

In our study, there was a statistically significant difference between patients who developed ventricular arrhythmias-prior to reperfusion strategy-and those who did not suffer ventricular arrhythmias regarding QTcD (p<0.001). Mean QTcD in ventricular arrhythmia group was much higher than that in non-arrhythmia group (125.26 ± 28.73msec. *vs*. 73.41 ± 23.9msec.).

This is concordant with Aziz, et al., [29], who found that the patients with any ventricular arrhythmic event during hospital stay were found to have QTD of 164 ± 10.4msec. at admission and those without any arrhythmic event were found to have QTD of 119.1 ± 18.6msec. at admission. While comparing these two groups P value was found to be <0.001. Also, Eroglu, et al., [32], found similar results.

On the other hand, Tomassoni, et al., [33], had reported that QTD does not predict early VF during acute MI.

In our study, there was a high statistically significant strong negative correlation (r=-0.772) between LVEF and QTcD (p<0.001). Moreover, by correlating LV systolic function with QTcD using logistic regression model, QTcD was a good predictor of LV systolic function.

This is in accord to Padmanabhan, et al., [34], who declared that increased QTcD was associated with progressively increased LV systolic dysfunction and also associated with an increase in all-cause mortality (P=0.04). QTD mortality impact was most pronounced in the older patients and patients with more severe LV dysfunction.

This is also in accord to Stoickov, et al., [35] who stated that, there was a significant negative correlation of QTD and QTcD with LVEF (p<0.001), and a significant positive correlation of QTd and QTdc with inside dimensions of the left ventricle, in patients with AMI.

Stoickov, et al., [35], studied 290 coronary patients, 72 with angina pectoris and 218 with STEMI. Patients with frequent and complex ventricular arrhythmias had significantly higher values of QTD (71.8 ± 25.5 *vs*. 55.6 ± 21.7msec.; p<0.001), QTcD (81.3 ± 31.5msec. *vs*. 60.3 ± 26.1msec.; p<0.001), LVEDd (56.2 ± 6.9mm *vs*. 53.4 ± 6.2mm; p<0.001) and LVESd (39.5 ± 6.2 *vs*. 36.0 ± 6.3mm; p<0.001), and significantly lower values of LVEF (47.7 ± 13.9 *vs*. 55.9 ± 11.6%; p<0.001) in comparison to those without arrhythmias or with infrequent PVCs.

In the present study, there was a statistically significant positive correlation (r=0.536) between QTcD and the grade of LV diastolic dysfunction (p<0.001). 88.6% of prolonged QTcD patients had impaired diastolic function in comparison to 53.3% of normal QTcD patients.

This is in accord with Gunduz, et al., [36] who found that QTD and QTcD values increase in relation to increasing left ventricular diastolic dysfunctional stage that is determined by echocardiography.

This is in agreement with Enar, et al., [37] who declared similar relationship between QTD and ventricular relaxation abnormalities in patients with AMI. They found that There was a positive correlation between QTD and IVRT (r=0.5, p=0.003). On the other hand, there was a negative correlation between QTD and mitral E/A ratio (r=-0.5, p=0.003), LV flow propagation velocity (r=-0.6, p=0.002), while there was no correlation between QTD and mitral E deceleration time.

This is also in agreement with Moller, et al., [38], who concluded that after AMI, low QTD is associated with preserved LV function, whereas persistently increased QTD is associated with LV dilation and deterioration of diastolic function. However, Moller and his colleagues followed up the relation between QTD and LV diastolic function not only in the acute phase post MI, but also for prolonged periods of time (on presentation, day 5, and after 1, 3, and 12 months).

They divided their patients into group A and B (QTD<52 *vs*. ≥ 52msec. at all measurements). In 26 patients QTD remained increased ≥ 52msec. during the 1st 3 months after MI with a significant increase of LVESV was seen whereas low or rapidly normalized QTD was associated with a marked decrease of LV volumes. After 1 year LVESV (70 ± 32 ml *vs*. 49 ± 16 ml, p=0.006) and LVEDV (138 ± 41 ml *vs*. 105 ± 22 ml, p=0.001) were higher in group B. Group B had significant increase of LVEDV (p=0.01). In group A, diastolic function improved in 8 patients and deteriorated in 2, whereas 1 improved and 9 patients deteriorated from Group B (p<0.01).

In the present study, there was a statistically significant relationship when associating age of STEMI patients with LV diastolic function (p<0.001 *vs*. p=0.06). Patients with normal diastolic function had a mean age 48.55 ± 13.69 while those with restrictive diastolic pattern had a mean age 66.4 ± 5.98 years.

This is in accord to Wang, et al., [39], who showed similar results. They noticed statistically significant decrease in diastolic function in patients>65 years old when compared with those<65 years old. Logistic regression analysis for LV diastolic dysfunction with age showed that, age was an important independent risk factor for LV diastolic dysfunction in STEMI patients (adjusted OR 3.99, p<0.0001).

This is also in accord with Khumri, et al., [40], who found that diastolic dysfunction increased with age with average age 62.5 years (P<0.01).

This is discordant with Fischer, et al., [41]. They concluded that LV hypertrophy, hypertension, diabetes and obesity show strong and independent associations with LV diastolic abnormalities. In the absence of these risk factors, the condition is rare even in those of 50-75 years of age [42].

Limitations

- It is a relatively small and observational study.
- The results were obtained from a single medical center (Mansoura University hospitals).
- The QT interval measurements were not performed in a computerized manner, using a conventional twelve lead ECG at a paper speed of 25 mm/sec. This might reduce their accuracy.
- Although the simplest and most common approach for correcting the QT interval is to divide its value by the square root of the RR interval expressed in seconds, i.e., by using Bazett's formula, several studies have shown that this formula is not optimal in the case of extreme heart rates. However, in the present study the mean heart rate on the hospital admission ECG was normal (86.08 ± 19.99 bpm) and did not reflect significant differences between the patients.
- Lack of long-term clinical follow up.

Conclusion

In the present study, there was a statistically significant weak positive correlation between duration of hospital stay in days and value of QTcD (r=0.24, p=0.016). Mean duration of hospital stay in the prolonged QTcD group was longer than that in normal QTcD patient group (3.98 ± 0.92 *vs*. 3.72 ± 0.51 days). Indeed, it was higher in patients who developed ventricular arrhythmias (4.86 ± 1.68 days). So, the longer the QTcD, the longer is the hospital stay as shown.

This is in fact may be attributed to early complications that can develop after AMI such as malignant ventricular arrhythmias that occur as consequence of increased ventricular myocardial inhomogeneity. Congestive heart failure–another AMI complication which is associated with increased QTD-will lead to increase in duration of hospital stay as well.

The present study concluded that, given the ready availability of ECG, QTc dispersion is an important non-invasive electrocardiographic indicator that is highly correlated with LV systolic and diastolic function in the setting of acute STEMI. It is also an important independent predictor of LV systolic function in such patients.

Ethics Approval and Consent to Participate

It was approved by the ethics committee of Faculty of medicine, Mansoura University and it was started at October 2014 and ended by October 2016. An informed written consent was obtained from the participants. All the investigations done were conformed to the principles outlined in the Declaration of Helsinki.

References

1. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics-2012 update: A report from the American Heart Association. Circulation. 125(1): e2-20 (2012).
2. Finn AV, Nakano M, Narula J, et al. Concept of vulnerable/unstable plaque. Arterioscler Thromb Vasc Biol. 30(7): 1282-1292 (2010).
3. Rajanayagam S. Acute coronary syndromes: Statins and coronary plaque progression. Nat Rev Cardiol. 6(10): 614-614 (2009).
4. Ambrose JA, Singh M. Pathophysiology of coronary artery disease leading to acute coronary syndromes. F1000Prime Rep. (2015).
5. Burchell HB. The QT interval historically treated. Pediatr Cardiol. 4(2): 139-148 (1983).
6. Andrássy G. The effect of different stressors on the QT interval and the T wave. Orvosi Hetilap. 150(10): 447-457 (2009).
7. Harikumar R, Shivappriya SN. A novel approach for different morphological characterization of ECG signal. Lect Notes Electr Eng. (2013).
8. Priest BT, McDermott JS. Cardiac ion channels. Channels. 9(6): 352-359 (2015).
9. Xue JQ. Robust QT interval estimation-from algorithm to validation. Ann Noninvasive Electrocardiol. 14: S35-S41 (2009).
10. Lepeschkin E, Surawicz B. The measurement of the QT interval of the electrocardiogram. Circulation. 6(3): 378-388 (1952).
11. Postema PG, De Jong JS, Van der Bilt IA, et al. Accurate electrocardiographic assessment of the QT interval: Teach the tangent. Heart rhythm. 5(7): 1015-1018 (2008).
12. Goldenberg I, Moss AJ, Zareba W, et al. QT interval: How to measure it and what is "normal". J Cardiovasc Electrophysiol. 17(3): 333-336 (2006).
13. Deshmukh S, Karnad D, Natekar M, et al. Influence of T wave morphology and amplitude on variability in QT interval. Indian Heart J. 60: 448-449 (2008).

14. Hnatkova K, Gang YI, Batchvarov VN, et al. Precision of QT interval measurement by advanced electrocardiographic equipment. Pacing Clin Electrophysiol. 29(11): 1277-1284 (2006).

15. Schwartz PJ, Crotti L, Insolia R, et al. Long-QT syndrome: From genetics to management. Circ Arrhythm Electrophysiol. 5(4): 868-77 (2012).

16. Higham PD, Campbell RW. QT dispersion. Heart. 71(6): 508-510 (1994).

17. Malik M, Batchvarov VN. Measurement, interpretation and clinical potential of QT dispersion. J Am Coll Cardiol. 36(6): 1749-1766 (2000).

18. Ostovan MA, Khosropanah S, Hooshmand S, et al. Adjacent QT dispersion: A good predictor of ventricular arrhythmias after myocardial infarction. Cent Eur J Med. 3(2): 179-182 (2008).

19. Opthof T, Coronel R, Janse MJ, et al. Is there a significant transmural gradient in repolarization time in the intact heart? Repolarization gradients in the intact heart. Circ Arrhythm Electrophysiol. 2(1): 89-96 (2009).

20. Wahab A, Zaheer MS, Rabbani MU, et al. A study of heart rate variability and QT dispersion in patients of acute ST elevation myocardial infarction. Indian Heart J. 61(3): 261-264 (2009).

21. Chintamani SV. A prospective cohort study of the temporal profile of QT dispersion in acute myocardial infarction (Doctoral dissertation, Rajiv Gandhi University of Health Sciences (India). (2011).

22. Bazett HC. An analysis of the time-relations of electrocardiograms. Heart. 7: 353-370 (1920).

23. Hamza O, Azzouz A, Mokhtar OA, et al. CRT-115 QT Dispersion Correlation to St Segment Resolution In STEMI Patients. ACC Cardiovasc Interv. 8(2): S12-S13 (2015).

24. Bortolan G, Bressan M, Golferini F, et al. Gender and age influences in QT-dispersion. (2000).

25. Esen AM, Barutcu I, Melek M, et al. Comparison of QT interval duration and dispersion in elderly population *versus* healthy young subjects. Clin Auton Res. 14: 408-411 (2004).

26. Mangoni AA, Kinirons MT, Swift CG, et al. Impact of age on QT interval and QT dispersion in healthy subjects: A regression analysis. Age Ageing. 32(3): 326-331 (2003).

27. Gawali SM, Shriram V, Jaltade V, et al. QT dispersion and left ventricular hypertrophy in essential hypertensive patients. Int J Med Res. 1(03): (2013).

28. Abdal-Barr MG, Safwat M, Nammas W, et al. Would corrected QT dispersion predict left ventricular hypertrophy in hypertensive patients? Blood Pressure. 21(4): 249-254 (2012).

29. Aziz F, Doddi S, Alok A, et al. QT dispersion as a predictor for arrhythmias in patients with acute ST elevation myocardial infarction. J Thorac Dis. 2(2): 86 (2010).

30. Mulay DV, Quadri SM. QT dispersion and early arrhythmic risk in acute myocardial infarction. Indian Heart J. 56(6): 636-641 (2004).

31. George SK, Waly HM, Abdul Moteleb MT, et al. Assessment of QT dispersion in patients with acute STEMI receiving thrombolytic *versus* those performing primary Percutaneous Coronary Intervention (PCI) therapy. Med J Cairo Univ. 83(1): 1023-1030 (2015).

32. Eroğlu M, Barışık V, Akyurt M. The Relationship between the development of ventricular arrhythmias and QT Dispersion in the early phase of acute myocardial infarction. Kafkas Univ Vet Fak. 3(1): 10-14 (2012).

33. Tomassoni G, Pisanó E, Gardner L, et al. QT prolongation and dispersion in myocardial ischemia and infarction. J Electrocardiol. 30: 187-190 (1998).

34. Padmanabhan S, Silvet H, Amin J, et al. Prognostic value of QT interval and QT dispersion in patients with left ventricular systolic dysfunction: Results from a cohort of 2265 patients with an ejection fraction of ≤ 40%. Am Heart J. 145(1): 132-138 (2003).

35. Stoičkov V, Ilić S. Deljanin-Ilić M, et al. Relation between QT dispersion, left ventricle systolic function and frequency of ventricular arrhythmias in coronary patients. Srpski arhiv za celokupno lekarstvo. 135(7-8): 395-400 (2007).

36. Gunduz H, Akdemir R, Binak E, et al. Relation between stage of left ventricular diastolic dysfunction and QT dispersion. Acta Cardiologica. 58(4): 303-308 (2003).

37. Enar S, Ozkan AA, Pehlivanoğlu S, et al. The relationship between QT dispersion and left and right ventricular diastolic dysfunction in patients with myocardial infarction. Anadolu Kardiyol Derg. 1(4): 266-271 (2001).

38. Møller JE, Husic M, Søndergaard E, et al. Relation of early changes of QT dispersion to changes in left ventricular systolic and diastolic function after a first acute myocardial infarction. Scand Cardiovasc J. 36(4): 225-230 (2002).

39. Wang N, Shah A, Querejeta G, et al. Regional cardiac dysfunction and outcome in patients with left ventricular dysfunction, heart failure, or both after myocardial infarction. Eur Heart J. 34(suppl_1): P662 (2013).

40. Fischer M, Baessler A, Hense HW, et al. Prevalence of left ventricular diastolic dysfunction in the community. Results from a doppler echocardiographic based survey of a population sample. Eur Heart J. 24(4): 320-328 (2003).

41. Khumri TM, Reid KJ, Kosiborod M, et al. Usefulness of left ventricular diastolic dysfunction as a predictor of one-year rehospitalisation in survivors of acute myocardial infarction. Am J Cardiol. 103(1): 17-21 (2009).

42. Bhawani G, Kumar A, Murthy KS, et al. Study of QT interval dispersion in acute myocardial infarction and its relationship with complications. J Pharm Biomed Sci. 32(32): 1425-1431 (2013).