Changes in QTc Interval and QT Dispersion due to Incremental Atrial Pacing in Patients with Ventricular Tachyarrhythmia

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Abstract: This study was conducted to establish the relationship between QT dispersion and QT duration due to incremental atrial pacing. The QT interval and dispersion were measured in 47 patients. Sixteen of the patients had ventricular tachycardia or ventricular fibrillation (VT/VF) [10 with organic heart disease (OHD) and 6 without OHD]. The control group was 31 patients (15 with OHD and 16 without OHD). The QT interval was measured from a surface 12-lead electrocardiogram in sinus rhythm and during incremental atrial paced rates, and was calculated using Bazett's formula. Moreover, the QT interval was divided into the interval between the onset of the QRS and the peak of the T wave (QT peak) and the interval between the peak of the T wave and the end of the T wave (QT end). QT dispersion at rest was markedly increased in the VT/VF with OHD group compared with that in the controls and the VT/VF without OHD group (172 ± 97.2 vs 78 ± 41.1 vs 56.7 ± 39.3 vs 52.5 ± 25.9 p < 0.05). In VT/VF patients with OHD, QT dispersion decreased up to 100 beats per minute (bpm) due to the incremental atrial pacing, but increased beyond 100 bpm. The QTc minimum (QTc min) interval did not change with any of the pacing rates. The interval between QT peak and QT end is a nucleus of the fluctuation of the dispersion by the heart rate. The QT dispersion of the VT/VF with OHD patient group responded to heart rate changes.

Key words: QT interval, QT dispersion, atrial pacing, ventricular tachyarrhythmia

Introduction

The QT interval is a traditional electrocardiographic parameter of the duration of ventricular repolarization. Prolongation of the QT interval is an indicator of an increased risk of ventricular tachyarrhythmias in various clinical conditions. Increased spatial and temporal dispersion of repolarization is believed to be important in the genesis of ventricular arrhythmias. Day et al suggested that the interlead difference in QT intervals, which they call the "QT dispersion", may provide the inhomogeneity in ventricular repolarization. Dispersion of repolarization is considered to be an important electrophysiological factor for

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the initiation of ventricular fibrillation (VF). Recently, Sporton et al reported that inducible QT dispersion by incremental atrial pacing is a more useful indicator than resting QT dispersion in patients with coronary artery disease. QT dispersion changes depending upon atrial pacing rates in OHD with ventricular tachyarrhythmia have not been examined. The aim of this study was to investigate differences in the QT dispersion induced by incremental atrial pacing between OHD patients with or without lethal ventricular tachyarrhythmias.

Methods

Patients

Forty-seven consecutive patients undergoing electrophysiological study (EPS) were studied. Sixteen patients had suffered from ventricular tachycardia (VT) or VF. Thirty-one patients had paroxysmal supraventricular tachycardia (PSVT). These patients were examined by chest X-ray, echocardiogram including doppler image, coronary angiography and left ventricular angiography. None of the patients received any drugs during the EPS. Patients with atrial fibrillation, bundle branch block and unmeasurable T waves were excluded. Informed consent was obtained from all subjects.

Electrophysiological study

Programmed ventricular stimulation was performed at the right ventricular apex or outflow tract at cycle lengths of 600 or 400 ms. A train-of-seven S1 stimuli were presented, followed by up to 3 consecutive extra stimuli and burst pacing with the introduction of VT or VF. Patients were judged to be noninducible if VT could not be induced with 3 extra stimuli and burst pacing from at least 2 right ventricular sites. Next, a multipolar pacing catheter was placed high in the right atrium. The first ECG was recorded at rest, and then atrial pacing was started; the initial pacing interval was just above each individual patient's heart rate. The pacing rate was increased in increments of 10 bpm at 3-min intervals until the appearance of atrioventricular (AV) block.

QT interval measurements

All measurements were made by 2 observers who were blinded to the patients' details and the average values were adopted. The QT interval was measured visually on surface electrocardiograms at a paper-speed of 50 mm/sec and amplitude of 20 mV/cm. The QT interval was taken from the onset of the QRS complex to the end of the T wave, which was defined as a return to the P-P baseline. If a U wave was present, the end of the QT interval was defined as the nadir of the T wave. When the end of the QT interval could not be identified with certainty, the lead was excluded from the analysis. At least 9 measurable leads were required from each electrocardiogram (ECG) recording. The QT dispersion was defined as the absolute value of the difference between the maximum and minimum QT interval in any of the measurable leads. The QT intervals were corrected using a modified version of Bazett's formula: $QTc = QT / \sqrt{RR}$ to obtain the corrected QT interval (QTc) in each lead and hence QTc dispersion. Moreover, in all leads the QT peak interval, (the interval between the start of the QRS and the peak of the T wave), and the QT peak-end interval, (the interval between the peak of the T wave and the end of the T wave) were measured. The QT peak dispersion and QT peak-end dispersion were
Table 1. Clinical characteristics of the study population

<table>
<thead>
<tr>
<th>Patients</th>
<th>Men/women</th>
<th>Age (years)</th>
<th>Heart Rate at rest (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OHD with VT/VF group</td>
<td>10</td>
<td>10/0</td>
<td>58.4± 9.7</td>
</tr>
<tr>
<td>OHD without VT/VF group</td>
<td>15</td>
<td>12/3</td>
<td>63.8±10.9</td>
</tr>
<tr>
<td>No OHD with VT/VF group</td>
<td>6</td>
<td>3/3</td>
<td>44.8±15.0</td>
</tr>
<tr>
<td>No OHD without VT/VF group</td>
<td>16</td>
<td>9/7</td>
<td>61.6±18.9</td>
</tr>
</tbody>
</table>

OHD with VT/VF group: OMI 6, DCM 2, HCM 2
OHD without VT/VF group: OMI 7, DCM 3, DCM 3, Cardiac sarcoidosis 1, AR 1
OHD: Organic heart disease; OMI: Old myocardial infarction; DCM: Dilated cardiomyopathy;
HCM: Hypertrophic cardiomyopathy; AR: Aortic regurgitation

calculated in the same manner.
Respective dispersion was measured in any of the 12 leads, and was further corrected for the effects of heart rate.

Statistical analysis
One-way analysis of variance (one-way ANOVA) was used to compare the groups. A p value <0.05 was considered significant.

Results
The clinical features of the patients are shown in (Table 1). The study group consisted of 34 men and 13 women with a mean age of 59±15 years (range, 22–83 years). Sixteen patients had suffered VT or VF as the first clinical manifestation of ventricular arrhythmia (VT/VF group). Six patients of the VT/VF group had no OHD and the remaining 10 patients had OHD. This included 6 patients with old myocardial infarction (OMI), 2 patients with dilated cardiomyopathy (DCM) and two with hypertrophic cardiomyopathy (HCM). Thirty-one patients with PSVT were used as controls (control group). Sixteen patients in the control group had no OHD and the remaining 15 had OHD. This included 7 patients with OMI, 3 patients with DCM, 3 patients with HCM, 1 patient with cardiac sarcoidosis and 1 patient with aortic regurgitation (AR). In summary, 62.5% of patients in the with VT/VF group had OHD and 48.4% in the without VT/VF group had OHD.

QT interval and QT dispersion at rest
The resting values of the QT dispersion are shown in Fig. 1. The QT dispersion was significantly longer in the OHD with VT/VF group (172±97.2 msec) than in the other 3 groups (OHD without VT/VF, 78±41.1, p<0.01; no OHD with VT/VF, 56.7±39.3, p<0.01; no OHD without VT/VF, 53±25.9, p<0.001). The QT peak dispersion and QT peak-end dispersion also tended to be larger in the OHD with VT/VF group than in the other 3 groups. QT dispersion in the no OHD with VT/VF group was almost in the normal range, similar to the without VT/VF group. The mean QT dispersion in the OHD with VT/VF group was prolonged at each pacing rate. (Fig. 2) shows the QTc maximum and minimum at rest. The QTc minimum in the OHD with VT/VF group was not significantly different from the other groups. In contrast, a significant difference in QTc
maximum was found between the OHD with VT/VF group (620.8 ±93.3 msec) and each of the other groups (OHD without VT/VF, 499.4±41.3, p<0.001; no OHD with VT/VF, 483.7±42.7, p<0.01; no OHD without VT/VF, 460.0±42.7, p<0.001).

Response of QT interval and dispersion to pacing rate

The changes in QT dispersion are presented in Fig. 3. In the OHD with VT/VF group, the QT dispersion decreased with atrial pacing of 70 to 100, but then increased from 110 bpm. Fig. 4 shows that the QT peak dispersion did not change in any of the 4 groups with an alteration in heart rate. Therefore, QT dispersion depends on QT peak-end dispersion (Fig. 5). Fig. 6 shows the QTc maximum (QTc max) and QTc min for each pacing rate in the OHD with VT/VF group. QTc min shows a statistical change at each pacing rate.
In contrast, QTc max decreased up to 100 bpm, but increased at 110 bpm.

Fig. 7 shows the relationship between pacing-induced changes in QT dispersion in OMI patients with VT/VF and non-ischemic patients with VT/VF. There were no significant differences in QT dispersion between OMI patients with VT/VF and non-ischemic patients with VT/VF. Fig. 8 shows the relationship between pacing-induced changes in QT dispersion in patients with VT/VF and in OMI patients with non-VT/VF. In VT/VF group, the QT dispersion increased from 70 bpm to 80 bpm, but decreased from 80 bpm to 100 bpm, and then increased again from 100 bpm to 120 bpm. However, in patients with non-VT/VF in OMI, the QT dispersion increased from 70 bpm to 80 bpm, but then decreased from 80 bpm. The QT dispersion was significantly longer in the patients with VT/VF in OMI group than the patients with non-VT/VF in OMI group in 70 bpm and 80
Fig. 5. Effect of incremental atrial pacing on QT peak-end dispersion

Fig. 6. Effect of incremental atrial pacing on QTc max and QTc min

bpm (70 bpm; VT/VF in OMI, 136.7 ± 35.1 ms, non-VT/VF in OMI, 67.5 ± 27.5 ms, p<0.05, 80 bpm; VT/VF in OMI, 152.0 ± 44.4 ms, non-VT/VF in OMI, 78.6 ± 28.5 ms, p<0.01).

Discussion

It has been reported that the QT interval can identify developing ventricular arrhythmias in long QT syndrome\(^2,5,6\) hypotrophic cardiomyopathy\(^7,8\) and congestive heart failure\(^9-11\). However, QT dispersion did not predict the occurrence of ventricular arrhythmia early after the onset of acute myocardial infarction\(^12,13\), or fatal arrhythmia in the chronic phase of myocardial infarction\(^14\). Exercise or atrial pacing induced QT dispersion and/or QT
duration with a relatively rapid heart rate have been used to identify patients with coronary artery disease. Several studies have shown that the action potential duration shortens in ischemia. This study has shown that QT dispersion and QT duration in the VT/VF group with OHD was longer than in the other groups at a resting heart rate. In addition, QT dispersion on each incremental atrial pacing rate gave similar results. It was interesting that the QT dispersion in the VT/VF group with OHD decreased up to 100 bpm, and then increased at 110 bpm. QTc min did not change significantly during incremental atrial pacing of the heart rate. In contrast, QTc max decreased up to 100 bpm of atrial pacing and increased at 110 bpm. Several studies have demonstrated that the absence of QT interval shortening during exercise could be a sensitive marker of coronary artery disease. Gang
Yi et al observed that exercised-induced prolongation of the QTc interval differentiates patients at high risk of sudden cardiac death from those at low risk. A possible explanation is that ventricular repolarization fails to adapt normally to increases in heart rate in sudden death patients\(^{21}\). It was thought that the OHD with VT/VF group was adaptable to 100 bpm, but that the QTc max could not be adapted from 110 bpm.

**Study limitations**

Bazett's formula

Zabel et al measured action potential duration\(^{90}\) (APD\(_{90}\)) and recovery time (RT) in simultaneous MAP recordings in 18 isolated Langendorff-perfused rabbit hearts\(^{22}\). APD\(_{90}\) and RT shortened continuously throughout all pacing rates, but dispersion of APD\(_{90}\) and RT did not change significantly. Thus, a rate correction of dispersion of repolarization may not be necessary and may even distort the values (and the predictive value) of QT dispersion. The major weakness of Bazett's formula, which is used to correct the QT interval for the influence of heart rate, is that it makes the adjustment unreliable at slow and fast rates as these are based on the predominant heart rates in the studied populations\(^{23,24}\). However, the correction was used uniformly in all leads within the 4 groups, and changes involving the corrected QT dispersion were observed to parallel those of the uncorrected QT duration.

Most previous studies have had to rely on ECG intervals measured manually. Manual measurement may have been subject to errors when the ECG parameters were measured during incremental atrial pacing. It was difficult to measure at a relatively rapid pacing rate (e.g. 100 bpm or 110 bpm) because the end of the T wave overlapped the next pacing spike and the P wave.

In conclusion, QT dispersion of VT/VF patients was more prolonged at rest and at each incremental pacing rate than that of the other groups. QT dispersion in VT/VF patients decreased up to 100 bpm, but increased from 100 bpm, although that of the other groups did not change.

**References**


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