RELATIONSHIP BETWEEN QT INTERVAL AND VENTRICULAR ELECTRICAL AXIS: A NEW SUGGESTION FOR LEAD SELECTION IN QT INTERVAL MEASUREMENT

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Abstract - *Exploration of the interlead QT variation (QT dispersion) introduced cardiologists to some new concepts including the need to define a standard for lead selection in the measurement of QT interval and the reason or factors contributing to QT dispersion. However, still there dose not exist a generally acceptable standard for lead selection and the reason for the QT dispersion has not been given the importance it deserves. Only a few hypotheses have been suggested, none of which have been seriously experimented. Finding important factors causing QT dispersion can lead to a better understanding of its basics and more accurate usage of QT dispersion as an index in clinical practice. This paper examines the "Vector Cancellation Theory" on the basis that if "vector cancellation" affects the QT interval duration in different leads, the nearest lead to the mean QRS axis must have the longest QT interval and vice versa. This was tested on the electrocardiograms taken from 34 people without cardiovascular problems. We came across a statistically significant inverse correlation between the QT interval in each limb lead and its angle to the ECG's mean QRS axis. Thus this study gives weight to the vector cancellation theory. And as the nearest lead to the Mean QRS Axis is likely to have the longest QT interval and given its practicality, it can be suggested as the standard lead for measuring QT interval in an electrocardiogram.*
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Key Words: QT interval, QT dispersion, QRS axis

INTRODUCTION

When the difference between QT interval in various leads of a standard 12 lead surface electrocardiogram (ECG) became apparent, many questions emerged most of which still remain unanswered.

The focus of many studies is on the importance of lead selection in the measurement of QT interval and the need to define a standard for it (1). Some studies have suggested the longest QT among 12 leads as the standard, but in practical terms this did not seem to be easy because it needed QT interval to be measured in all 12 leads. Another group maintains the longest lead among limb leads as the standard. There are also those who are of the opinion that lead II sounds better. Yet a fourth group subscribes to the notion that the lead with the tallest T wave is more appropriate to be the standard lead for the measurement of QT interval in an electrocardiogram. Finally some have proposed a mean QT derived from an arbitrary subset of leads (1,2).

Nevertheless, the aim is to identify a lead which has the closest QT interval to the QTmax and can be easily selected.

Other questions about QT dispersion include causes/factors giving rise to differences between QT interval among leads, and how this new finding (QT dispersion) is practically helpful.

Differences between unipolar and bipolar leads, differential tissue attenuation, vector cancellation and regional differences in repolarisation are considered to be factors causing QT dispersion (3). Of the four, the last one has attracted relatively more attention (1,4) but it should be mentioned that the role of all these suggested factors and even others demand more serious testing.

We tried to test these hypotheses experimentally. Here we focus on "Vector Cancellation Theory". The method of study is built on the notion that if vector cancellation can contribute to differences between QT interval among leads, it means that leads which are closer to the resultant vector of ventricular electrical activity (mean QRS axis), should have longer QT duration because the perpendicular projection of QRS axis on those leads will be more extended (Fig. 1); so they will be recorded as isoelectric later. We examined some electrocardiograms to this end.

MATERIALS AND METHODS

The study population was 34 patients (14 females, mean age 50.6 years, SD 12.54) admitted for elective surgery . None of them had a history of any chronic disease nor had taken any medication affecting cardiac function and/or QT interval. All of them were examined by a cardiologist to rule out any kind of cardiovascular disease. This was done through a physical exam, chest radiograph and ECG.

If any of these tests and/or history taking did not meet the inclusion criteria, the individual was not included in the study.

In each subject a standard 12 lead surface electrocardiogram was taken. All of the ECGs were recorded by one electrocardiograph and by one observer at a paper speed of 25mm/s. Ten minutes before and during the recordings, the subjects were in stationary resting supine position.

Using a scientific magnifier with a 0.1 mm resolution, QT and RR intervals were measured in each ECG limb lead by the same observer for all the 34 ECGs.

QT interval was measured from the onset of the QRS complex to the end of T wave which was the point of return to the TP baseline when there was no U wave, and the nadir between the T and U waves when it existed. When the end of the T wave could not be reliably identified, that lead was not included in subsequent analysis.

The observer also measured the amplitude of the R and S waves in leads I and II for all 34 electrocardiograms.

Mathtematical calculation

The mean QRS axis was calculated for each ECG using the following formulas (5,6) :

$$d = \frac{\sqrt{a^2 + b^2 \;\; 2ab \cos\theta}}{\sin\theta}$$

$$\phi = \cos^{-1}(a/d)$$

"a" is the algebraic sum of the amplitudes of the R and S waves (in mm) in lead I and "b" is the same in lead II, θ is the angle between the leads I and II (60°) and ϕ is the Mean QRS Axis.

QTc was also calculated for every limb leads of all electrocardiograms using standard Bazett's formula ($QTc = QT / \sqrt{RR}$).

Six limb leads of each ECG were ranked on the basis of their proximity to the calculated mean QRS axis in the same ECG. The lead with the smallest angle to the QRS axis or its extension was ranked as 1st and the one with the biggest angle was 6th (Fig. 1).

Statistical Analysis

We wanted to determine if QT interval was longer when the lead was closer to the QRS axis (the lead with smaller rankings). In order to do so, the Spearman correlation coefficient between the QT interval and the rank of leads in each ECG was calculated separately.

So we had 34 Spearman correlation coefficients for 34 ECGs. To establish whether or not the 34 correlation coefficients significantly weigh more heavily on the negative side (leads with smaller rankings have longer QT intervals), these numbers were tested by two different statistical methods :

- Binomial test to show if the number of negative or positive figures among these 34 correlation coefficients were significantly more than the other, regardless of their numerical value.

- Z-test to determine if the mean of these 34 figures differed from zero in a statistically significant way, and if so, whether it was negative.

The same procedure was applied to QTc intervals instead of QT intervals.

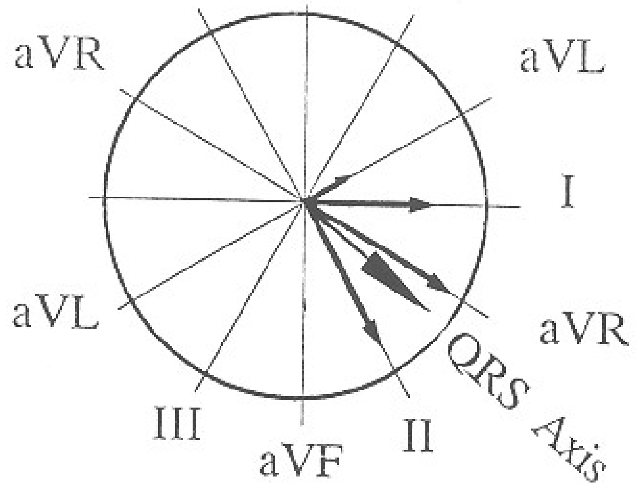

Fig. 1. The vector product of ventricular electrical activity (mean QRS axis) has a perpendicular projection on each lead. When the lead or its extension is nearer to the mean QRS axis, this projection would be longer.
The ranking system in our study is based on this concept. In the above case, aVR is far from the QRS axis but its extension makes an acute angle with the QRS axis and is nearer than any other lead, so it would be ranked as first and is supposed to have the longest QT interval. Lead II would be the second, Lead I third, aVF fourth, etc.

RESULTS

Nine cases had one excluded lead because the end of Twave was not clearly visible in them.

U waves were present in the limb leads of one case out of 34.

The number and numerical value of negative correlation coefficients was significantly more than positive ones for both QT and QTc intervals.

Binomial test results

Observed proportion of negative correlation coefficients for QT interval = 70% ($P<0.03$).

Observed proportion of negative correlation coefficients for QTc interval = 88% ($P<0.0001$).

Z-test results

for QT interval Mean Correlation Coefficient = -0.24
95% Confidence Interval for Mean -0.42,-0.06
for QTc interval Mean Correlation Coefficient = -0.40
99% Confidence Interval for Mean -0.58, -0.23

DISCUSSION

It has been appreciated for many years that estimates of QT interval vary in different leads (1). Many studies have focused on QT dispersion in various physiologic and pathologic states, errors and problems in measuring QT interval and QT dispersion and how to solve these problems, and the need to define a standard for QT interval measurement (1,4,7-10). Our study has focused on its basis and contributing factors.

Results of QT measurement in different limb leads of single ECG showed a tendency for leads nearer to the mean QRS axis to have longer QT intervals by both statistical methods. This was predictable on the basis of ECG basic principals and by the application of mathematical laws of vectors (Fig. 1) and underscored vector cancellation as a factor in QT dispersion.

The validity of Vector Cancellation Theory does not necessarily reject other hypotheses regarding the influence of other factors in QT dispersion. Different contributing factors and degree of their influence will help better use of QT dispersion as an index in clinical practice.

At this stage the study also has been of practical use. As mentioned earlier, many studies have shown that lead selection in QT interval measurement is important. There exists a variety of suggestions. However there is not one which is acceptable to all.

We think the nearest limb lead to the mean QRS axis of each ECG could be a better measure for determining QT interval. Regarding the results of this study, the nearest limb lead to the mean QRS axis tends to be the longest and nearest to the genuine QT interval among all limb leads. One prime benefit of this is the ease with which it can be used in clinical practice because in ECG interpretation we use to estimate the mean QRS axis so the lead for measuring QT interval will be easily selected.

This would be easier than measuring QT interval or Twave in all or a subset of leads (first, second, fourth and fifth above mentioned proposed methods) but less accurate, and is more accurate than selecting lead II in all ECG's (second mentioned method). It should be noted that, because precordial leads are not used for the calculation of mean QRS axis they are not contributed for measuring QT interval in our proposed method (like second and third above-mentioned proposed methods) so the normal range for QT interval should be determined according to this point.

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