Comparison of Manual and Automatic QT Dispersion Measurements in Clinical Groups

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Abstract

We investigated whether automatic QT dispersion measurements are more discriminating than manual measurement in three clinical groups: myocardial infarction; arrhythmia; normals. Four automatic techniques of QT interval measurement, based on models of T wave shape, were used: i) intersection of maximum slope of T wave with baseline (QTsi), ii) intersection of linear best fit over the region 30% to 70% of peak T wave amplitude with baseline (QT30/70), iii) intersection of linear best fit over the region 10% to 30% of peak T wave amplitude (QT10/30) with baseline, and iv) minimum/maximum of 2nd order polynomial best fit over a 0.1 s interval commencing at 50% peak amplitude (QT2nd). There were no significant differences between dispersion in the groups when measured manually. There were significant differences between normal and infarct groups for all automatic techniques ($p < 0.05$), and between normal and arrhythmia groups for QT30/70 and QT2nd ($p<0.05$). Automatic techniques were better able to discriminate between normal and cardiac patient groups.

1. Introduction

QT dispersion is a measure of the variability of QT interval across the 12-lead ECG, usually expressed as the range of QT intervals, which is thought to be related to dispersion of repolarisation [1]. It is known that large dispersion of repolarisation is arrhythmiogenic, and QT dispersion in groups of patients with diagnosed arrhythmias and groups known to be at high risk of developing arrhythmias is increased [1,2]. There is, however, a high level of variability in the manual measurement of QT interval [3]. The characteristic wide range of T wave shapes across the 12 leads and the abundance of low amplitude T waves in some cardiac patients may contribute to increased QT dispersion in these subjects due to measurement uncertainty.

Techniques were developed to facilitate automatic QT interval analysis, and these techniques use features of T wave shape to determine T wave end [4,5]. There is evidence that QT dispersion measured using these automatic techniques is better able to discriminate between normal subjects and cardiac patient groups [6]. We have investigated this with four automatic QT interval measuring techniques and have compared QT dispersion from the automatic techniques with that measured manually.

2. Method

2.1. Data collection

Data were obtained from a database of 12-lead ECGs held within the Medical Physics Department of Freeman Hospital. Single artifact-free beats were extracted from recordings of 10 s duration, captured to computer via a 12-lead ECG amplifier (0.05 to 100 Hz bandwidth, gain of 1000) at 500 Hz and voltage resolution of 4.88 μV. A total of 75 subjects from three clinical groups were assessed: group 1, 25 subjects with no known heart disease (normal group); group 2, 25 subjects with previous myocardial infarction; group 3, 25 subjects with arrhythmias, excluding atrial fibrillation. Prior to analysis leads were filtered with a notch filter at 50 Hz to suppress mains interference, and a low pass filter with a cut off frequency of 40 Hz to remove high frequency atrifact.

2.2. Automatic QT measurement

Q wave start was automatically identified in individual leads as the time instant at which the gradient of the lead exceeded 20% of the maximum gradient of the R wave. The isoelectric baseline was calculated as the average voltage from a stable section of the T to P baseline which was identified manually. Four algorithms for automatic determination of T wave end were investigated:

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i) QTsi — T wave end defined as the intersection of the line tangential to the steepest gradient of the T wave downslope with the isoelectric baseline (Figure 1a).

ii) QT30/70 — T wave end defined as the intersection of the line of best fit between 30% and 70% of peak T wave amplitude with the isoelectric baseline (Figure 1b).

iii) QT10/30 — T wave end defined as the intersection of the line of best fit between 10% and 30% of peak T wave amplitude with the isoelectric baseline (Figure 1c).

iv) QT2nd — T wave end defined as the minimum/maximum of the 2nd order polynomial best fit over a 0.1 s interval starting at 50% peak amplitude (Figure 1d).

2.3. Manual QT measurement

The same data were measured manually (QTm) using computerised interactive QT measurement software. Single leads were displayed on a computer screen at an equivalent paper speed of 70 mm/s and amplitude scale of 25 mm/mV [7]. Q wave start and T wave end points were identified manually using a mouse to control a cross hair on the screen.

2.4. Lead and subject exclusions

For all techniques, leads with T wave amplitudes less than 100 μV were excluded from the analysis as low amplitude T waves are known to increase measurement error [8]. Leads greater than this threshold which were unable to be measured manually were also removed from the analysis of automated measurements, ensuring that the same leads were analysed for all techniques. After lead exclusion, subjects with fewer than 4 remaining leads were excluded from the study.

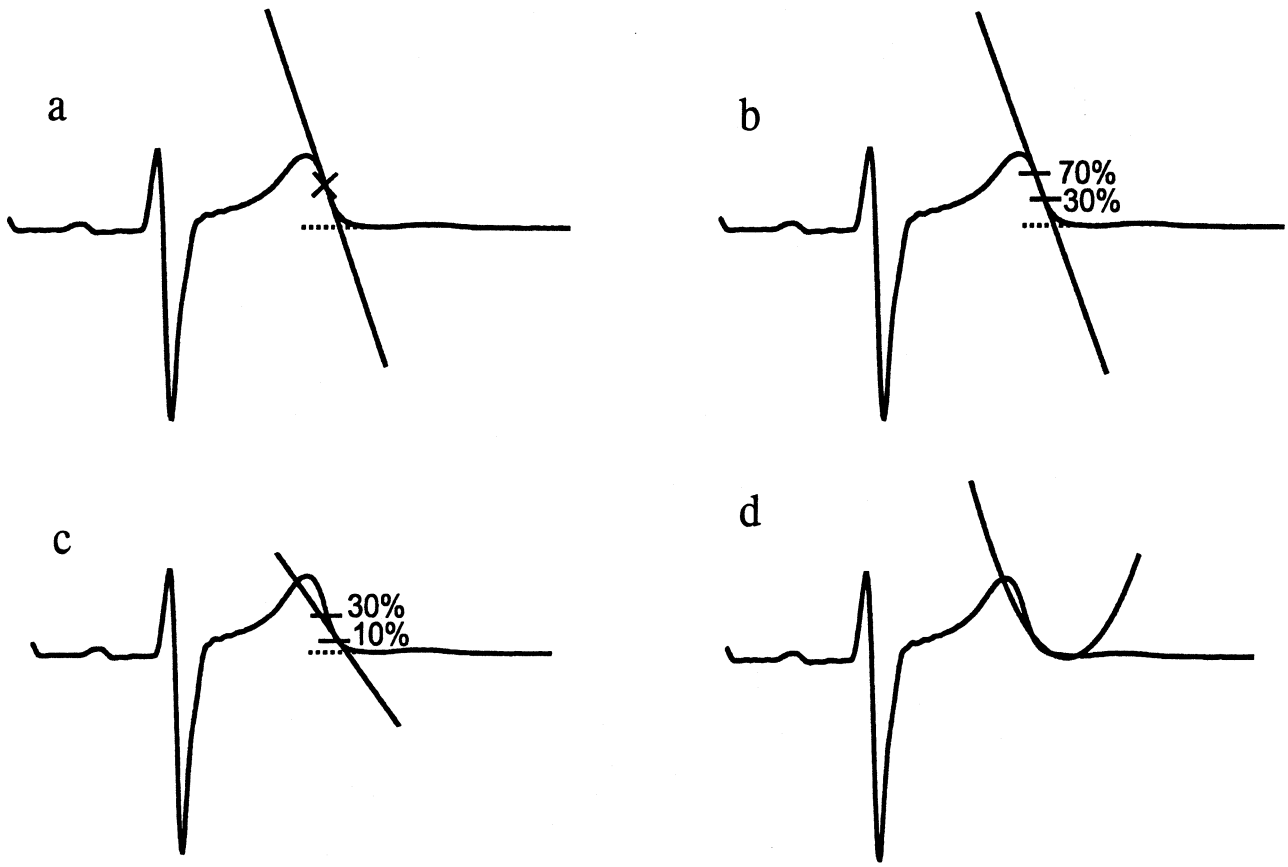

Figure 1. Illustration of techniques to automatically determine T wave end points. a) QTsi, b) QT30/70, c) QT10/30, d) QT2nd.

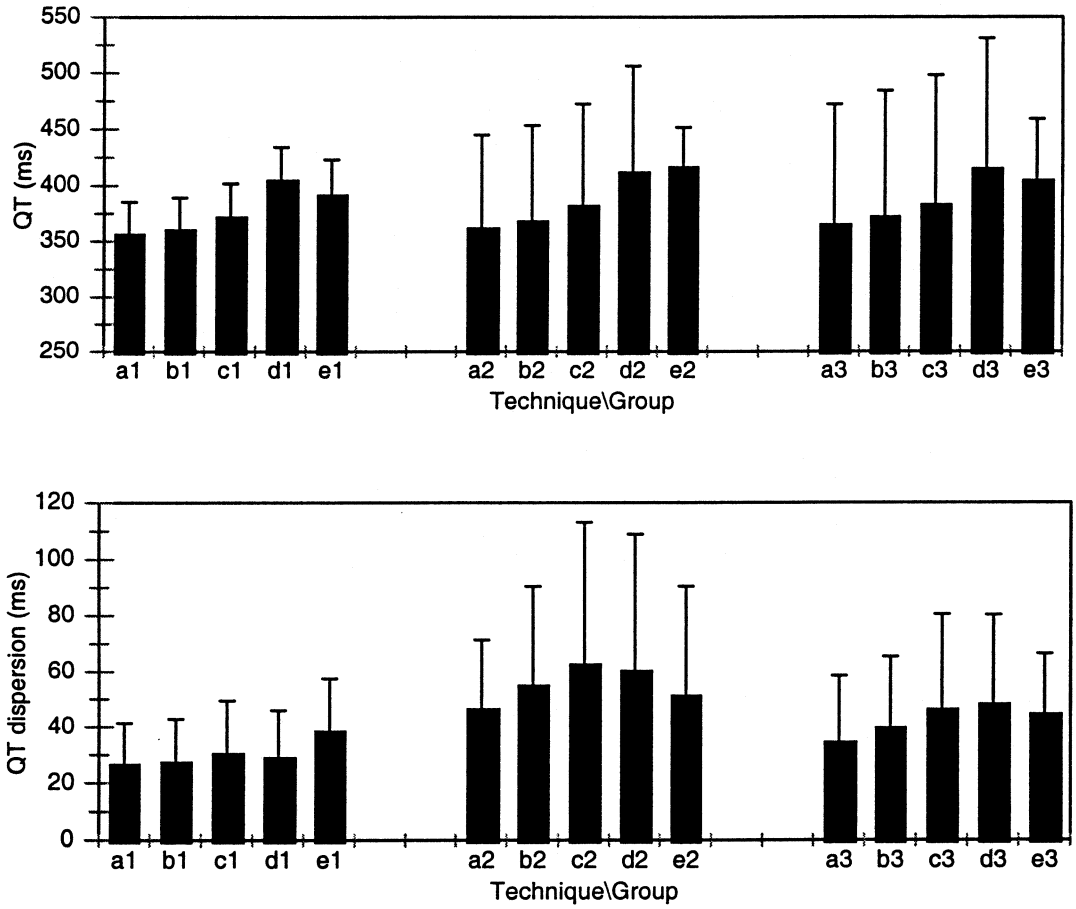

Figure 2. QT and QT dispersion for each of the techniques, a) QTsi, b) QT30/70, c) QT10/30, d) QT2nd and e) QTm for groups 1) normal, 2) infarct and 3) arrhythmia. Group mean and standard deviation are shown.

2.5. QT dispersion and statistical analysis

QT dispersion, maximum QT minus minimum QT, was calculated for each subject and for each technique. Group means and standard deviation were calculated and the Student t test was used to determine the statistical signifiance of differences between groups for each of the techniques. A significance level of 5% or greater was considered statistically significant.

3. Results

3.1. Exclusions

The number of subjects and average (range) number of leads remaining after exclusion was 25 subjects, 10 (9 - 11) leads in the normal group, and 19 subjects, 8 (4 - 11) leads in both the infarct and arrhythmia groups.

3.2. QT

QT for each group and technique is illustrated in Figure 2. With the exception of QT2nd, the automatic techniques tended to underestimate QT relative to manual measurement.

3.3. QT dispersion

Figure 2 also shows the dispersion measurements for each technique and group. There was general agreement between techniques that dispersion was greatest in the infarct group and least in the normal group.

Table 1 shows the significance of differences between normal and infarct and arrhythmia groups for each of the techniques. There were significant differences between normal and infarct groups for all automatic techniques.

Additionally, QT30/70 and QT2nd showed significant differences between the normal and arrhythmia groups. QT dispersion measured manually did not separate normal from either patient group.

Table 1. p values for differences in QT dispersion between normal and patient groups.

Normal vs	infarct	arrhythmia
QTsi	< 0.002	ns
QT30/70	< 0.002	< 0.05
QT10/30	< 0.002	ns
QT2nd	< 0.005	< 0.02
QTm	ns	ns

4. Discussion and conclusions

Previous work by our group indicated that automatic measurement of QT dispersion was more discriminant than manual measurement [6]. It is believed that this is because automatic techniques use features of T wave shape to determine T wave end. Manual measurement attempts to identify absolute T wave end, which is poorly defined. The work presented here confirms the previous results, as all the automatic techniques were able to discriminate between normal and infarct groups, whereas manual measurement could not. We have compared several automatic QT measurement algorithms which use different features of T wave shape to determine the T wave end. The slope intercept technique (QTsi) is potentially sensitive to noise because it uses a localised gradient value to determine T wave end. Less so are the techniques which use a section of T wave to model the T wave downslope. QT30/70 takes a global fit of the downslope centred around half peak amplitude. QT10/30 uses the slope towards the end of the T wave. QT2nd takes a global fit over a fixed time interval. All of the automatic techniques give dispersion values which are less than manual measurement for the normal group. The superior discriminating power of the automatic techniques would, in part, seem to result from this.

In conclusion, automatic techniques are more powerful at discriminating between cardiac and normal subject groups. T wave end detection based on models of terminal T wave shape provide additional discriminating power in our subject groups. This supports the hypothesis that important information relating to repolarisation is contained in the shape of the T wave.

Acknowledgements

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