Effect of Averaging for the Automatic Measurement of QT Dispersion Using Multichannel Magnetocardiography and Electrocardiography

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Abstract

Multichannel magnetocardiograms (MCGs) and 12-lead ECGs were recorded simultaneously using the PTB multichannel SQUID system from 8 normal volunteers. An automatic method for QT interval measurement was used to determine T wave end with measurements made over 10 consecutive beats in both the MCG and ECG. Channels/leads with small absolute T wave amplitudes and smallest and longest QT measurements were excluded from the analysis. QT dispersion, expressed as the QT interval range, was calculated for a single beat and the average QT interval for each channel/lead over 10 beats.

Mean QT dispersion measurement (standard deviation) for the single beat was 44 (26) ms for MCG and 37 (35) ms for ECG over all subjects. Averaging over 10 beats reduced mean QT dispersion to 36.1 (14.6) ms for MCG and 20.9 (13.2) ms for ECG. QT dispersion in the MCG was greater than in the ECG, by 7 ms for the single beat and by 15 ms ($p < 0.03$) for averaged data over all subjects.

Averaging influenced ventricular dispersion measurements in both MCG and ECG waveforms. There were differences in dispersion of ventricular repolarisation time between ECG and MCG, with MCG significantly greater than ECG for averaged data.

1. Introduction

Multichannel magnetocardiography is a non-invasive measure of the variation in cardiac magnetic field strength from many sites over the body surface and can be used to detect electrophysiological phenomena in the heart. MCGs have been shown to be more accurate than ECGs for a variety of different cardiac conditions and may provide useful regional information about dispersion of ventricular repolarisation time (QT dispersion) [1,2,3,4].
High QT dispersion is often considered an important clinical indicator of cardiac disease and arrhythmia susceptibility, however automatic QT dispersion can be influenced by T wave shape changes across measurement channels which may contribute to increased QT dispersion in some subjects due to measurement uncertainty and error [5,6].

The aim of this study was to determine the effect of averaging for the automatic determination of QT dispersion measurement in multichannel MCGs and 12-lead ECGs and investigate the agreement between MCG and ECG dispersion measurements.

2. Methods

2.1. Subjects

49-channel MCG and 12-lead ECG recordings, of 10 consecutive beats, from 8 normal subjects were used for the study.

2.2. Data collection

MCGs were detected using a multichannel SQUID magnetometer installed inside a magnetically shielded room at Benjamin Franklin University Hospital, Berlin [7]. The magnetometer consisted of 49 first order gradiometers for normal components of the magnetic field (Bz) arranged in a lattice on a plane covering an approximate circular area of diameter 20 cm. Figure 1 reflects the spatial arrangement of the 49 detector channels. The multichannel device was placed with its central SQUID sensor 12 cm below the manubrium sternal junction at a distance of approximately 4 cm above the chest. ECG data, referenced to the Wilson Central Terminal, were recorded simultaneously with MCG recordings. MCG and ECG recordings of 10-second length, sampled at 1,000 Hz, were used for the analysis. 10 consecutive beats were selected manually from a stable section of the recording, with the first beat in the series chosen as the single beat.

2.3. Automatic QT measurement

T-wave end was identified in both the MCG and ECG from the intersection of the line of best fit between 30% and 70% of peak T-wave amplitude with the TP baseline. An example of the technique is given elsewhere [8].

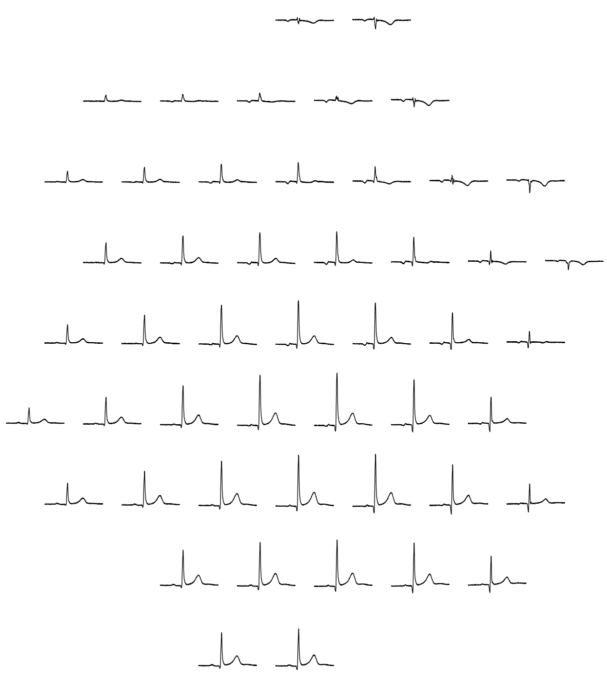

Figure 1. Example of the spatial arrangement of the 49 MCG signals for one heart beat.

2.4. Channel/lead exclusion criteria

In order to reduce measurement error two categories of channel/lead exclusion criteria were applied. Exclusion based on absolute T-wave amplitude (MCG channels with T-wave amplitudes less than 1 pT and ECG leads with amplitudes less than 0.1 mV were removed from the study) and exclusion based on QT measurement (channels/leads lying at both extremes of measured QT were excluded from the analysis) [9].

2.5. Analysis

QT dispersion, expressed as the QT interval range, was calculated for a single beat and from the mean QT interval for each channel/lead over 10 beats for all subjects. The Mann-Whitney non-parametric test, at 95% confidence was used to determine the significance of differences between MCG and ECG QT dispersion measurements.

3. Results

Automatic MCG and ECG QT dispersion measurements for the single beat for all subjects are listed in Table 1. The mean QT dispersion (standard deviation) was 44 (26) ms for MCG and 37 (25) ms for ECG over all subjects. These results are summarised in Figure 2.

Table 1. Automatic QT dispersion measurements for a single beat.

Subject	MCG QT dispersion (ms)	ECG QT dispersion (ms)
1	78	7
2	27	18
3	37	17
4	11	35
5	45	48
6	30	24
7	88	118
8	39	28
Mean	44	37
SD	26	35

Table 2. Automatic QT dispersion measurements over 10 beats averaged.

Subject	MCG QT dispersion (ms)	ECG QT dispersion (ms)
1	30.3	15.8
2	31.8	20.8
3	45.4	19.1
4	13.8	32.3
5	36.9	47.8
6	33.6	10.6
7	29.0	13.4
8	41.0	7.6
Mean	36.1	20.9
SD	14.6	13.2

QT dispersion measurements, calculated from the average QT interval for each channel/lead over 10 beats for all subjects are given in Table 2. Averaging reduced mean automatic QT dispersion, to 36.1 (14.6) ms for MCG and 20.9 (13.2) ms for ECG (Figure 2).

QT dispersion in the MCG was greater than in the ECG, by 7 ms for single beat data and by 15 ms ($p < 0.03$) for averaged data over all subjects. Bland and Altman plots for the single beat and averaged data are shown in Figure 3 and illustrate greater differences between MCG and ECG waveforms for the averaged data.

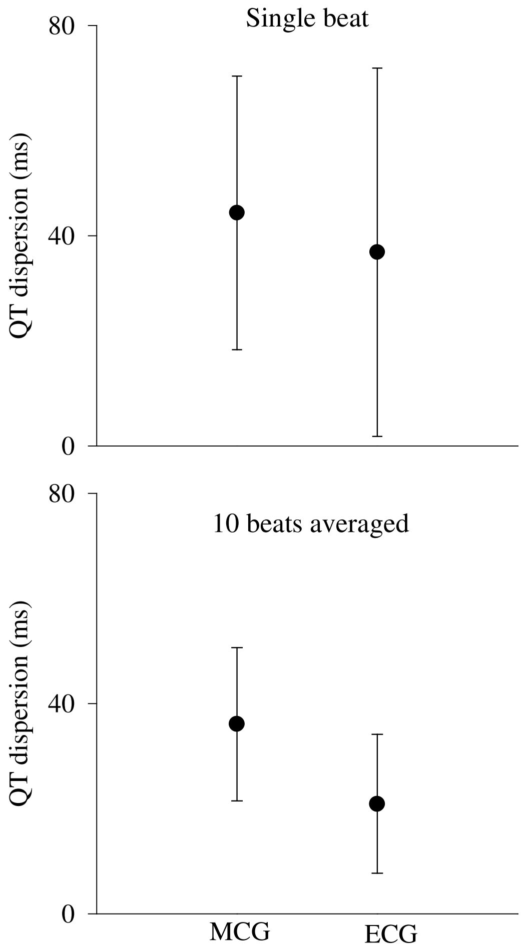

Figure 2. Mean QT dispersion measurements for MCG and ECG of a single beat and averaged beats.

4. Discussion and conclusions

Averaging, which is commonly used to reduce MCG noise, reduced automatic QT dispersion in both MCGs and ECGs, influencing agreement between MCG and ECG dispersion measurements and reducing inter-subject variability. For averaged data, MCG dispersion was significantly greater than ECG dispersion, by 15 ms, over all subjects.

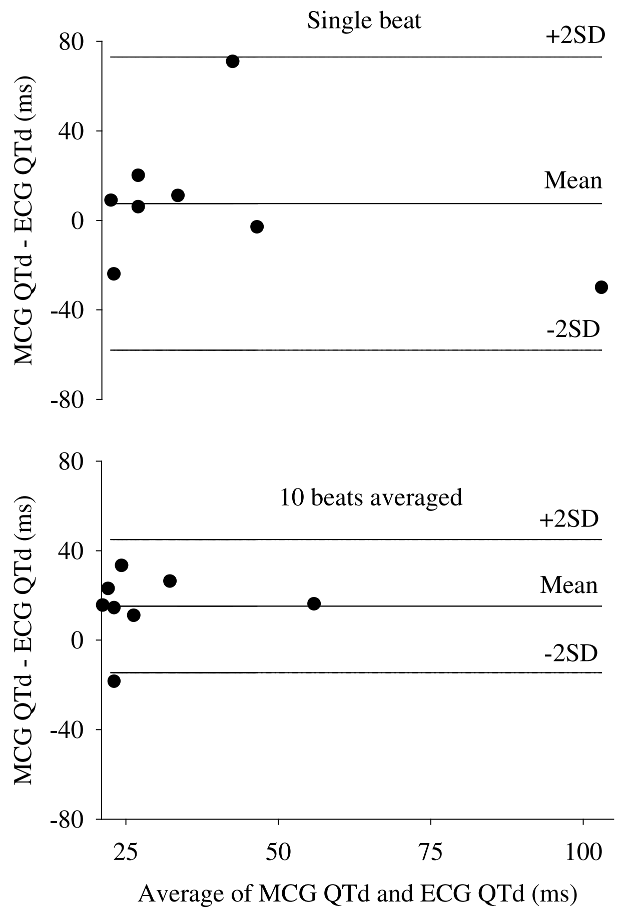

Figure 3. Bland and Altman plot for MCG and ECG data of a single beat and averaged beats.

These results might have important implications for the use of automatic QT dispersion measurements to distinguish between healthy and patient groups using averaged data.

Acknowledgements

The Engineering and Physical Sciences Research Council (GR/M97183/01) supported this work.

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