Effects of Filtering on Automatic Repolarisation Measurements using Magnetocardiography

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Abstract

Cardiac repolarisation can be detected by magnetocardiograms (MCGs) which non-invasively measure the variation in magnetic field strength at the body surface. The aim of this study was to assess quantitatively the influence of MCG filtering on repolarisation interval measurements. A technique for automatic analysis of ECG signals, which used modelling of the terminal T wave section to determine the end point, was extended and applied to multichannel MCG recordings of 8 normal subjects. Automatic repolarisation interval measurements were made following the addition of high and low pass filters. An experienced analyst also manually measured repolarisation intervals of the unfiltered data. The automatic technique underestimated repolarisation interval in the unfiltered data relative to manual measurement by 34.1 (8.9) ms (mean (standard deviation)). Low pass, 40Hz, filtering increased repolarisation intervals relative to unfiltered measurements by 5.1 (1.3) ms. High pass, 0.5 Hz, filtering decreased the values by 7.6 (5.0) ms.

1. Introduction

Repolarisation interval measurement is a clinically useful measure of ventricular repolarisation time [1]. In MCGs, as in ECGs, it is measured from the beginning of the QRS to the end of the T-wave. The spatial distribution of repolarisation interval in body surface ECGs has been shown to be an indicator of cardiac arrhythmia susceptibility and predictor of patients vulnerable to numerous cardiac conditions [2,3]. Compared to conventional ECGs, multichannel MCGs allow easy evaluation of the repolarisation interval at multiple sites on the torso, increasing information about cardiac repolarisation. However, the large number of recording channels makes manual analysis time consuming. The aim of this study was to assess the influence of MCG filtering on measurements from an automatic algorithm for repolarisation detection.

2. Method

2.1. Subjects

Unfiltered MCG recordings, of 10 s length, from 8 normal subjects (sampled at 1000 Hz) 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 [4]. The magnetometer consisted of 49 first order gradiometers for normal components of magnetic field (B_z) arranged in a lattice on a plane covering an approximate circular area of diameter 20 cm. Figure 1 reflects the approximate spatial arrangement of the 49 detector channels. The multichannel device was placed with its central SQUID sensor 120 mm below the manubrium sternal junction at a distance of approximately 40 mm from the skin.

2.3. Signal processing

Filtered versions of each MCG were generated using 2^{nd} order recursive Butterworth filters. 40 Hz low pass and 0.5 Hz high pass filters were used for the study.

2.4. Manual QT measurement

Each MCG channel in every subject's recording was displayed to computer screen using a program developed under MATLAB [5]. The beginning of the QRS complex and the end of the T-wave at its return to TP baseline were measured manually using a mouse driven cross hair on the display screen. In order to reduce variability between channels, the median QRS start value was obtained across all channels for each subject.

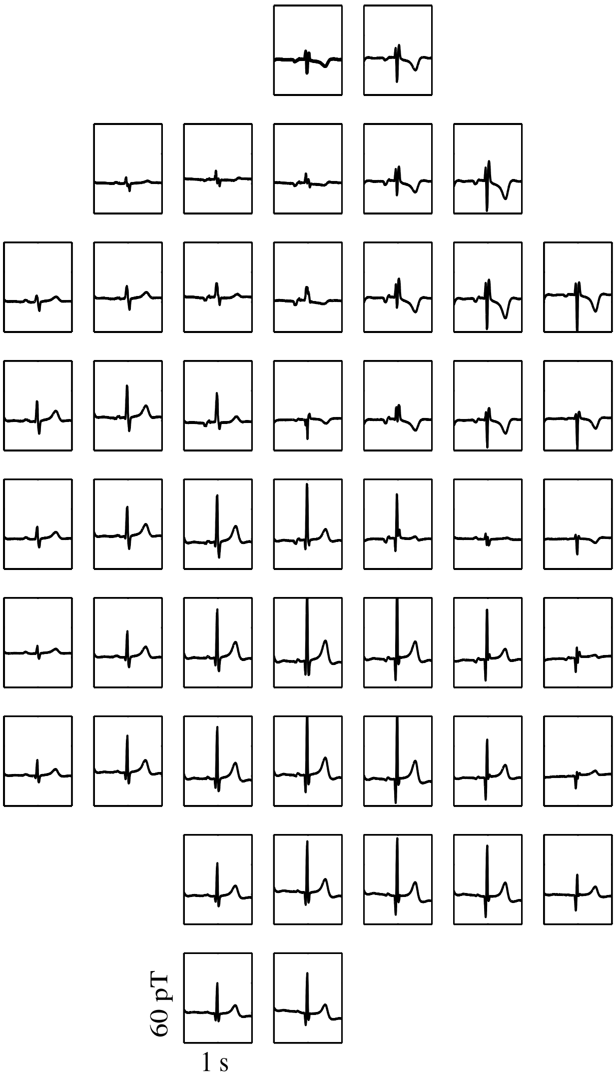

Figure 1. 49 MCG recording channels of single subject

Manual repolarisation intervals for each channel in every subject’s recording were then calculated as the difference between median QRS start and T-wave end.

2.5. Automatic QT measurement

Variability in QT interval between manual and automatic techniques was minimised by using the same median QRS start value as manual measurement for each subject.

T-wave end was identified from the intersection of the line of best fit between 30% and 70% of peak T-wave amplitude with the TP baseline (Figure 2).

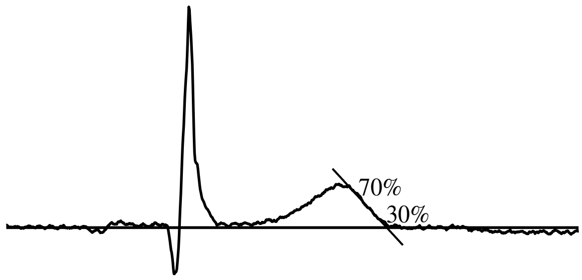

Figure 2. Automatic T-wave end detector.

Baseline was calculated as the averaged magnetic field from a stable section of the T to P interval.

2.6. T-wave peak detection

Automatic measurements of T-wave amplitude were obtained from the peak of the T-wave to the TP baseline. Peaks were detected by searching for a local maxima or minima in the MCG from an approximate position indicated manually.

2.7. Channel exclusion

In order to reduce measurement error, channels with T-wave amplitudes less than 0.8 pT were removed from the study. [6] T-wave peaks greater than this value, but for which manual measurement was not possible were also excluded, ensuring that the same channels were measured for both techniques.

2.8. Statistical analysis

The means of unfiltered automatic and manual repolarisation intervals were determined across all channels for each subject. Mean and standard deviation of automatic repolarisation interval differences between the filtered and unfiltered measurements were also determined across all channels for every subject.

3. Results

3.1. T-wave amplitude

MCG recording channels were characterized by a large variation of T-wave amplitudes and shapes. Figure 3 shows typical examples of measured and excluded T-waves.

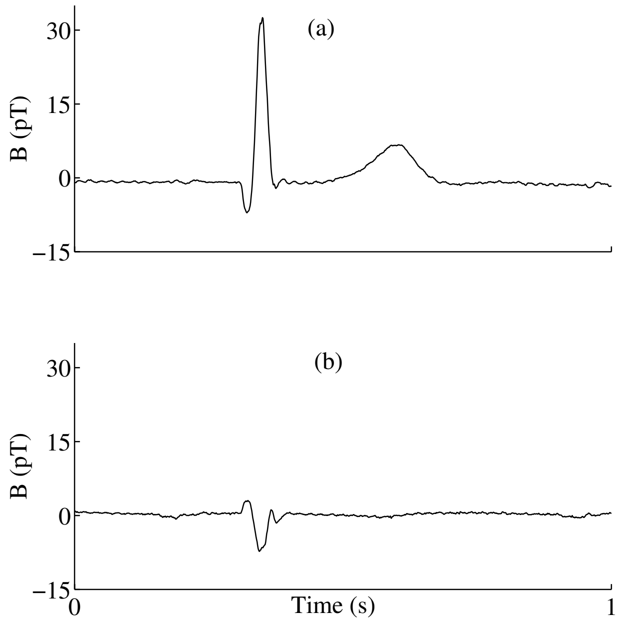

Figure 3. Example of measured (a) and excluded (b) T-waves.

3.2. Repolarisation interval

Mean unfiltered automatic and manual repolarisation interval measurements for the subject group are summarised in Table 1.

Table 1. Mean automatic and manual repolarisation interval measurements and standard deviations for unfiltered data.

Subject	Mean unfiltered automatic QT interval (ms)	Mean unfiltered manual QT interval (ms)
1	317.0	351.4
2	344.4	391.0
3	365.3	401.6
4	369.1	416.1
5	388.3	419.3
6	333.2	367.0
7	331.7	359.7
8	343.7	361.7
Mean	349.4	383.5
SD	21.9	25.2

The automatic technique underestimated mean repolarisation interval in the unfiltered MCG data relative to manual measurement by 34.1 (8.9) ms across the subject group. Manual and automatic techniques are compared in Figure 4 for each subject.

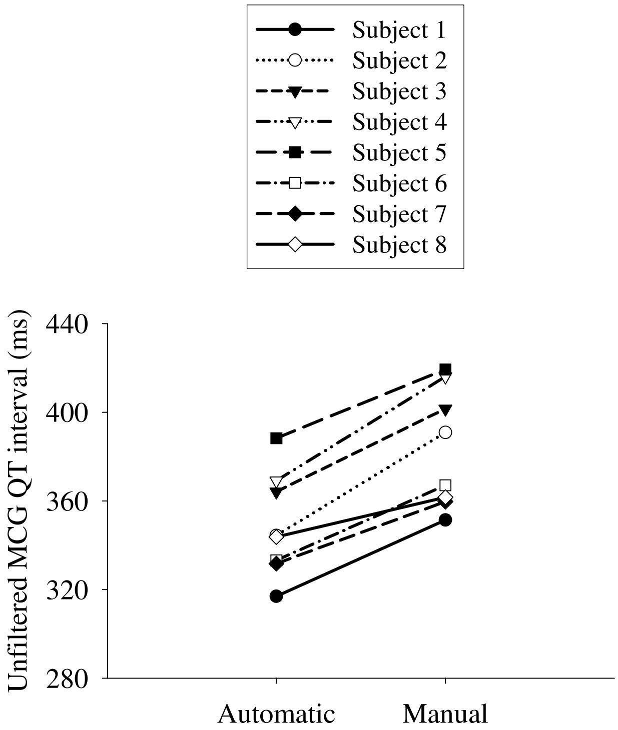

Figure 4. Comparison between unfiltered automatic and manual repolarisation measurements for all subjects.

Mean (standard deviation) of the differences between low pass filtered and unfiltered automatic repolarisation measurements across all channels for each subject are illustrated in Figure 5. Low pass filtering tended to increase repolarisation interval relative to unfiltered measurements, by 5.1 (1.3) ms across the subject group. Figure 6 shows the mean (SD) of the differences between high pass filtered and unfiltered interval measurements across all channels for each subject. High pass filtering decreased the difference by 7.6 (5.0) ms across the study population.

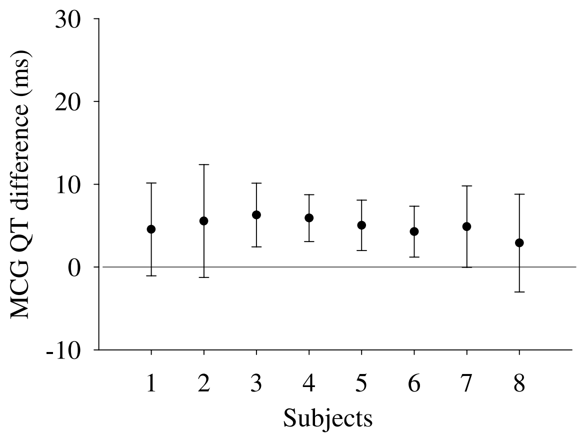

Figure 5. Mean MCG QT difference between low pass filtered (40 Hz) and unfiltered data for all subjects.

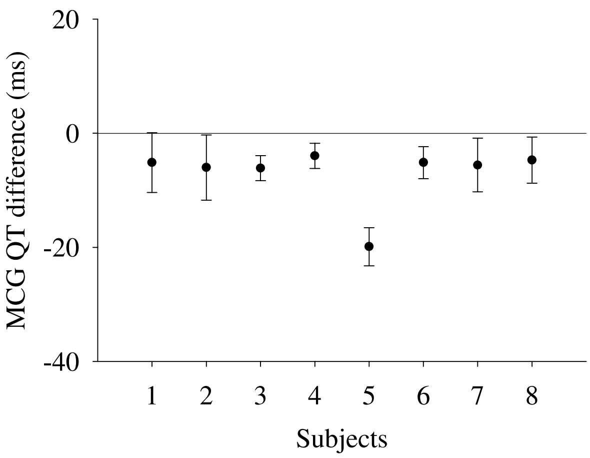

Figure 6. Mean (standard deviation) of the differences between high pass filtered (0.5 Hz) and unfiltered automatic repolarisation measurements for all subjects.

4. Discussion

This study has made a preliminary assessment of the influence of MCG filtering on the measurements of an automatic algorithm for repolarisation interval measurement.

In unfiltered data the automatic technique tended to underestimate T-wave end compared to manual measurement. This was because, as in ECGs, manual measurement of MCGs attempts to identify an ill-defined T-wave end, whereas the automatic method uses features of T-wave shape to determine the end point.

MCG filtering modifies the slope of the T-wave and this was reflected in the results. Low pass filtering tended to increase repolarisation interval relative to unfiltered measurements. High pass filtering decreased the mean interval value.

5. Conclusion

Automatic repolarisation intervals were shorter than manual measurements and were influenced by high and low pass filtering.

Acknowledgements

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References

[1] Mirvis DM. Spatial variation of QT intervals in normal patients with acute myocardial infarction. *JACC* 1985;5:625-31.

[2] Day CP, McComb JM, Campbell RWF. QT dispersion: an indication of arrhythmia risk in patients with long QTintervals. *Br Heart J* 1990; 63:342-4.

[3] Punske BB, Lux RL, MacLeod RS, Fuller MS, Ershler PR, Dustman TJ, *et al*. Mechanisms of the spatial distribution of QT intervals on the epicardial and body surfaces. *J Cardiovascular Electrophysiology* 1999;10:1605-18.

[4] Drung D. The PTB 83-SQUID system for biomagnetic applications in a clinic. *IEEE Trans Appl Supercond* 1995;5:2112-7.

[5] Smith FE, Langley P, Trahms L, Steinhoff U, Bourke JP, Murray A. Errors in cardiac repolarisation measurement using magnetocardiography. *PACE* 2002;25:1223-9

[6] Langley P, Di Bernado D, Murray A. Effect of lead exclusion for manual measurement of QT dispersion. *PACE* 2001;24:75-81.

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