Relation Between Spatial Properties of Repolarisation Interval and T-Wave Amplitude Using Magnetocardiography

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Abstract

Spatial distribution of repolarisation interval and T-wave amplitude were examined using multichannel magnetocardiograms (MCGs), which noninvasively measure variations in magnetic field strength at the body surface.

MCGs were obtained using the PTB multichannel SQUID system at 49 sites over the heart from 8 healthy volunteers. Each recording channel was displayed on a computer screen. Repolarisation intervals and T-wave amplitudes in each channel were measured manually and displayed graphically as contour maps. The Pearson correlation was used to determine the spatial relationship between the two variables.

Mean (SD) values of repolarisation interval and T-wave amplitude equalled 381(7) ms and 4(2) pT respectively. The standard deviation of the difference between repeat measurements for repolarisation interval and T-wave amplitude was 5.2 ms and 0.4 pT respectively. Repolarisation measurements tended to increase by approximately 8 ms for a doubling of T wave height. Contour maps showed two distinct regions of high repolarisation interval (>380 ms), corresponding spatially to concentrated areas of high absolute T-wave amplitude (>4 pT). A Pearson correlation coefficient of 0.7 (p< 0.0005) was obtained from this analysis.

Repolarisation intervals and T-wave heights in normal subjects recorded from magnetocardiography have distinctive but related spatial distributions.

1. Introduction

Electrophysiological phenomena in the heart can be detected not only by ECGs but also by MCGs, which noninvasively measure variations in magnetic field strength at the body surface. The repolarisation interval is a clinically important electrocardiographic measurement [1]. The spatial distribution of the repolarisation interval in body surface ECGs has been shown to be a predictor of cardiac arrhythmia susceptibility and identifier of patients vulnerable to a range of cardiac conditions [2,3]. Although T-wave amplitude is known to influence the measured repolarisation interval in the ECG [4], the multichannel MCG allows the spatial relationship between these variables to be determined. The aim of this study was to examine the spatial distribution of repolarisation interval and T-wave amplitude on the torso of healthy subjects obtaining interval and amplitude by magnetocardiography.

2. Methods

2.1. Subjects

Magnetocardiographic recordings were obtained from eight healthy volunteers, lying supine. A 10 second MCG recording from each subject (sampled at 1000 Hz) was used for the study.

2.2. Data acquisition

Figure 1 illustrates the data acquisition and analysis procedure. MCGs were recorded using a multichannel SQUID magnetometer installed inside a magnetically shielded room at the Benjamin Franklin University Hospital, Berlin [5]. 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 2 reflects the approximate spatial arrangement of the 49 magnetic (B_z) 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. Computer display

Each channel in every subject's recording was displayed as 156 mm/s and 5.2 mm/pT on a computer screen using a program developed with Matlab [6].

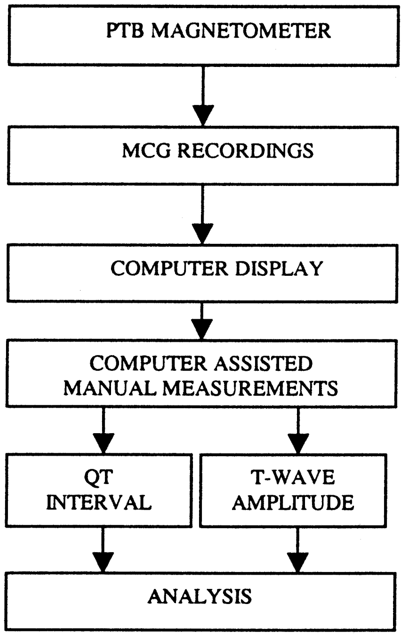

Figure 1. Schematic of MCG data acquisition and processing.

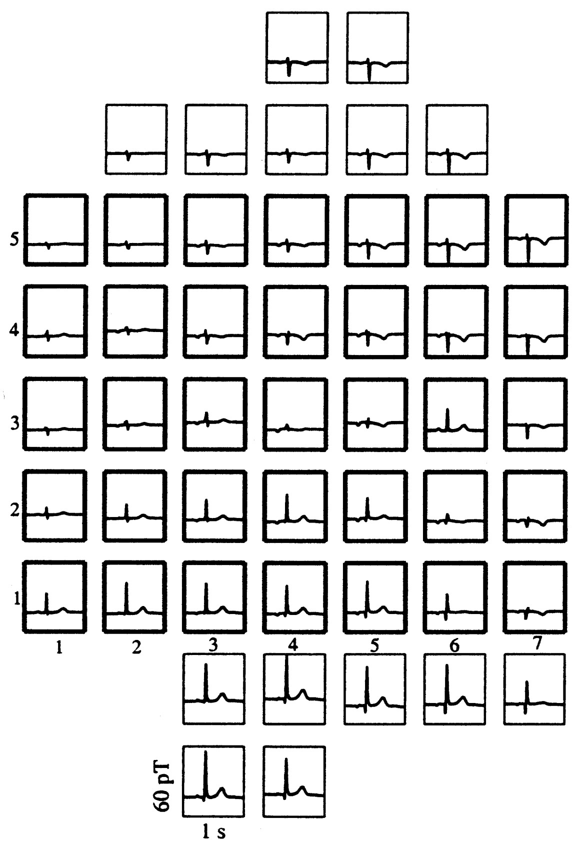

Figure 2. Example of the 49 MCG recording channels.

2.4. MCG measurements

Repolarisation intervals and T-wave amplitudes in each channel were determined by computer assisted manual measurement. Repolarisation intervals were measured from the beginning of the QRS complex to the end of the T-wave at its return to the TP baseline using a mouse driven cross hair on the display screen. When a U wave was present, the nadir between the T and U wave was taken as the end of the T-wave. T-wave amplitudes were determined from the peak of the T-wave to the TP baseline. In total, 98 repolarisation intervals and T-wave amplitudes (49 channels × 2 repeats) were measured for each subject.

2.5. Data analysis

The subject measurements were averaged across all channel positions and the standard deviation of the difference between repeat measurements determined for each MCG recording. Mean measured repolarisation intervals and T-wave amplitudes for MCG channels highlighted in Figure 2 were displayed as contour maps and the Pearson correlation was used to determine the spatial relationship between the two variables

3. Results

3.1. T-wave amplitude

The MCG recording channels were characterized by a large variation of T-wave amplitudes. Figure 3 shows illustrative examples of some of the different T-wave shapes.

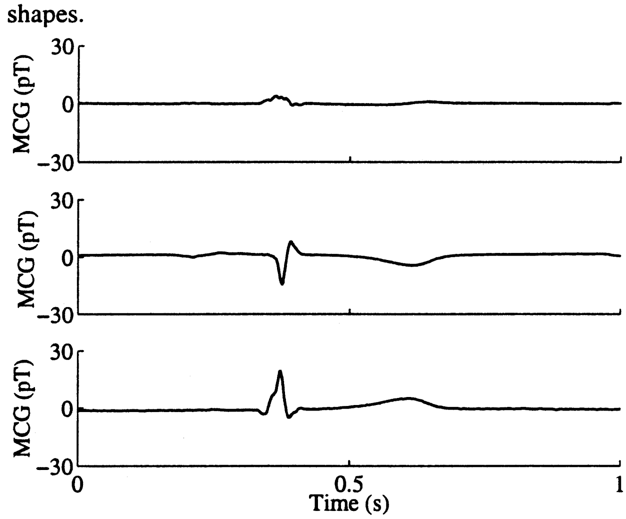

Figure 3. Three MCG channels for one subject showing examples of T-wave amplitude variation

T-wave amplitudes averaged across all channel positions for each subject are summarised in Table 1.

Mean (SD) T-wave amplitude for the subject group equalled 4 (2) pT.

Table 1. Mean repolarisation interval and T-wave measurements for each subject.

Subject	Mean repolarisation interval (SD) / ms	Mean T-wave amplitude (SD) / pT
1	391.1 (7.9)	2.4 (1.5)
2	381.5 (16.3)	3.9 (2.4)
3	393.3 (12.3)	4.9 (3.0)
4	407.7 (12.1)	5.2 (3.0)
5	409.4 (13.0)	2.0 (1.1)
6	360.2 (13.4)	4.8 (2.2)
7	350.0 (12.2)	3.3 (1.8)
8	358.0 (13.7)	3.9 (2.0)
Average	381.4 (6.7)	3.8 (1.8)

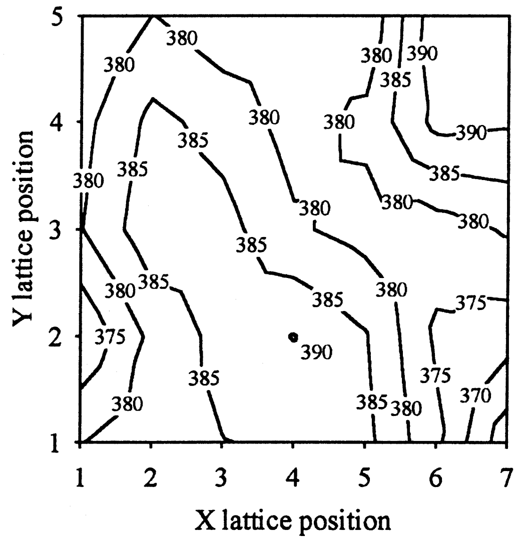

Figure 4. Contour map of repolarisation interval (ms). Y lattice positions and X lattice positions correspond to the measurement grid positions highlighted in Figure 2.

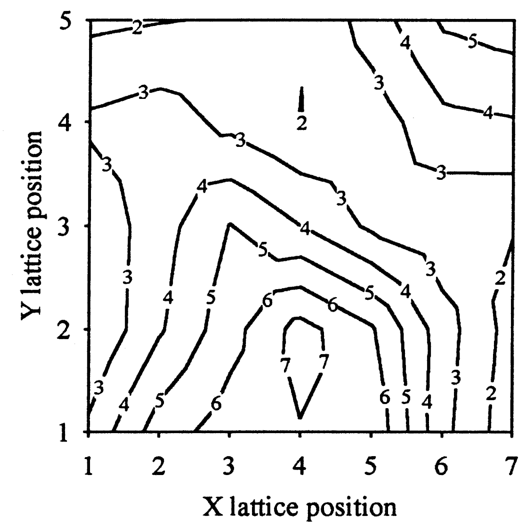

Figure 5. Contour map of T-wave amplitude (pT).

3.2. Repolarisation interval

Mean repolarisation interval measurements for each subject are given in Table 1. Mean (SD) repolarisation interval for the group was 381(7) ms. Repolarisation measurements tended to increase by approximately 8 ms for a doubling of T wave height

3.3. Repeatability

The standard deviation of the difference between repeat measurements for repolarisation interval and T-wave amplitude was 5.2 ms and 0.4 pT respectively.

3.4. Contour maps

Contour maps showed two distinct regions of high repolarisation interval (>380 ms) (Figure 4). corresponding spatially to concentrated areas of high absolute T-wave amplitude (>4 pT) (Figure 5).

A Pearson correlation coefficient of 0.7 ($p < 0.0005$) was obtained from this analysis. Figure 6 shows the linear relationship between mean measured repolarisation interval and T-wave amplitude for all subjects.

4. Discussion

Compared to the recording of ECGs from conventional leads, multichannel magnetocardiography allows easy evaluation of repolarisation interval at many positions on the body surface, increasing information about cardiac repolarisation. This study has analysed the spatial distribution of manually measured repolarisation interval and T-wave amplitude on the torso of healthy subjects. The results have shown that regions of high T-wave amplitude correspond spatially to areas of lengthened repolarisation interval. These observations are not unexpected and may be partially explained by the variation of T-wave end gradients in the MCG, which can influence manual repolarisation measurement [7]. Spatially distributed manual repolarisation intervals in MCGs also show distinctive features that are not artifacts of T-wave morphology. In order to investigate these results further the size of the study group must be increased and automated repolarisation measurement techniques, shown to produce consistent quantification of repolarisation interval in ECGs, should be applied [8].

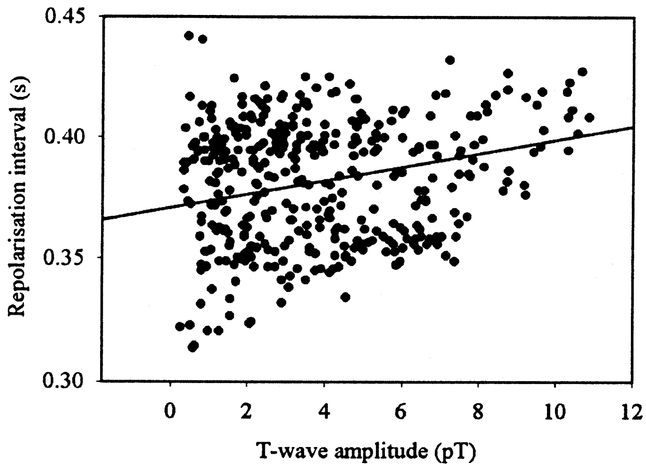

Figure 6. Measured repolarisation interval and T-wave amplitude for all subjects

5. Conclusion

Magnetogardiography permits the examination of spatial as well as sequential aspects of cardiac repolarisation. The observations of measured repolarisation intervals and T-wave amplitudes in normal subjects from this study have shown that these variables have characteristic but correlated spatial distributions.

Acknowledgements

FES is supported by an EPSRC research grant.
PL is supported by a British Heart Foundation research grant.

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