Assessment of vulnerability to ventricular arrhythmias using magnetocardiographic QRST integral mapping

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1 Introduction

It has been shown that regional disparities of ventricular primary repolarization properties can be reflected in body surface distributions of electrocardiographic QRST deflection areas (integrals) [1-4]. To quantitatively assess complexity of spatial features of QRST-integral distributions, several authors (see, e.g., [2,4] and references therein) used orthogonal-expansion methods. In their seminal work, Hubley-Kozey et al. [4] provided evidence that extraction of spatial features of QRST integral maps is suitable for identifying patients at risk of ventricular arrhythmias. Recently, Stroink et al. [5] reported different fragmentation of electric and magnetic ST-T trajectory plots between patients who are at risk of recurrent arrhythmias and those that are not, but found no differences between groups of patients in features of QRST integral maps.

In our earlier study [6], we indicated that magnetocardiographic (MCG) QRST integral maps also offer information about the regional electrophysiological properties of the ventricles. We corroborated findings obtained with electrocardiographic QRST integral maps [4] by showing that patients who are at risk of lethal arrhythmias have a markedly higher index of nondipolar content than do healthy subjects. However, nondipolar QRST integral maps can also be found in patients with myocardial infarction (MI) but no clinical arrhythmias [4,7]. The major clinical problem is thus differentiating patients with a history of sustained ventricular tachycardia (VT) and/or ventricular fibrillation (VF) and postinfarction patients who have no history of VT [4]. In this study, we addressed this problem by applying orthogonal-expansion techniques to magnetocardiographic QRST integral maps.

2 Methods

2.1 Patient population and recording techniques

Magnetic field maps were recorded during sinus rhythm from 49 high-resolution magnetic leads [8] above the anterior chest in 28 patients (mean age: 61 years) with VT/VF and in 45 patients (mean age: 61) with MI but no VT/VF (MI/non-VT). All MCG recordings were performed in the magnetically shielded room located in the Universitatsklinikum Benjamin Franklin, Berlin. All 49 leads were recorded simultaneously at a sampling rate of 1000 Hz (with 15-bit amplitude resolution) using superconducting quantum inteference device (dcSQUID) first order gradiometers (baseline 7 cm). Analog high pass (RC type) and low pass (Bessel type) filtering was applied to magnetocardiograms at 0.16 and 250 Hz. The UP segment was taken as the zero reference line for all measurements. The MCG signals were processed off-line and averaged over about 80 cardiac cycles.

2.2 Eigenvector analysis

In each subject QRST integral maps were calculated and then examined using spatial Karhunen-Loeve (KL) transformation. We calculated the percentage nondipolar content (relative contribution of all KL expansion coefficients beyond the third) as has been described in detail elsewhere [4,6]. Statistical analysis was performed using the Wilcoxon rank sum test since a normal distribution of the values could not be assumed.

3 Results

Figures 1 and 2 show QRST integral maps for patients with VT/VF and patients with MI but no VT. We represented the entire pattern space of these QRST integral maps with eigenvectors. The first three eigenvectors had a relatively smooth dipolar distribution, while the higher order (>3) eigenvectors were multipolar with an increasing number of extrema. Mean values of KL transform weighting coefficients corresponding to the first 6 eigenvectors in the two patient groups are contained in Table 1. Significant differences between patients with VT/VF and those with MI but no VT were found for the weighting coefficients corresponding to the third and the fourth eigenvector ($p < 0.05$). Discrimination between the VT/VF and MI/non-VT patient groups was 65% accurate with a sensitivity

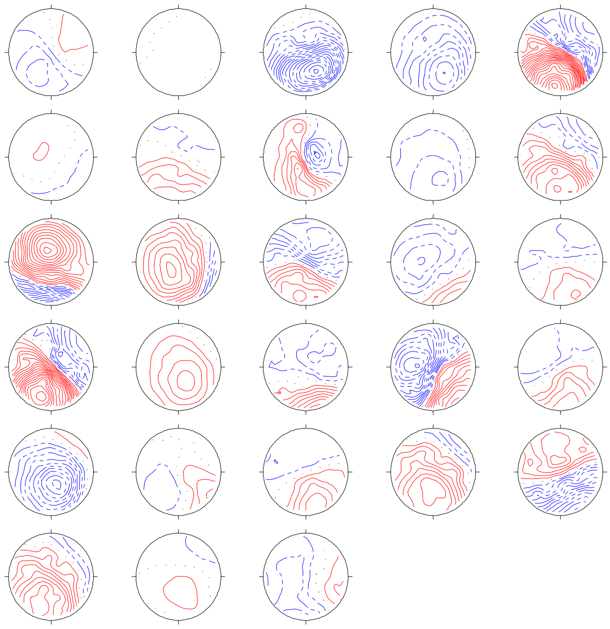

Figure 1**:** *Magnetocardiographic QRST integral maps of 28 patients with ventricular tachycardias (VTs) and ventricular fubrillation (VF). The isofield contour lines are plotted for equal intervals (250 pTms); solid lines represent the positive integral values of the magnetic field (magnetic field lines directed toward the body) and dashed-dot-dot lines represent the negative integral values; the zero line is shown with the dotted line.*

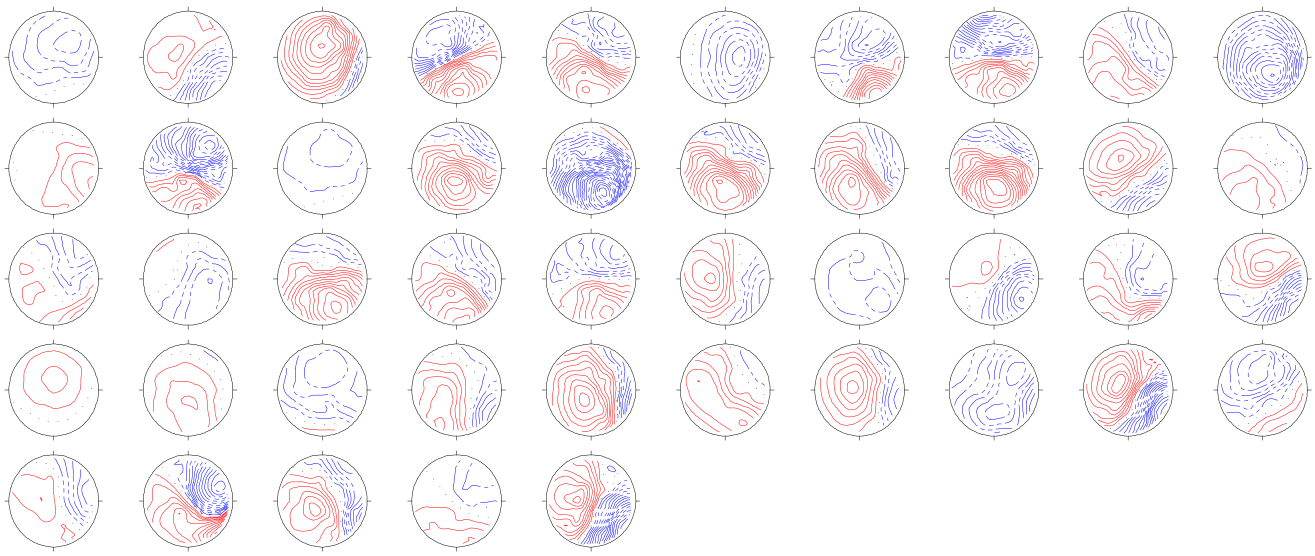

Figure 2**:** *Magnetocardiographic QRST integral maps of 45 patients with myocardial infarction but no clinical arrhythmias. See the legend of Figure 2 for details of the layout.*

of 71% and a specificity of 60%. On the other hand, nondipolar content of QRST integral maps showed no significant differences between VT/VF (9.8±10.1%) and MI/non-VT (9.6±9.5%, p=0.95) patients.

Table 1: *Mean (±SD) Karhunen-Loeve weighting coefficients of the first 6 eigenvectors in the VT/VF and MI/non-VT patient groups; p is a probability value.*

Eigenvector	VT/VF	p	MI/non-VT
1	564±2299	0.35	827±2170
2	-263±1587	0.72	-198±1708
3	**-728±1030**	**0.04**	**-215±1152**
4	**-11±408**	**0.04**	**-211±511**
5	-24±317	0.47	-101±502
6	-57±306	0.69	39±285

4 Discussion

Our study represents an attempt to further investigate the utility of spatial features derived from the magnetocardiographic QRST integral maps for predicting VT/VF vulnerability. While our earlier study [6] suggested that differences in index of nondipolarity could quantitatively distinguish between control subjects and patients with VT/VF, such a distinction could not be made between patients with VT/VF and those with MI but no VT. (This finding also supports the results of Stroink et al. [5], but on a larger cohort of patients.) However, we found significant differences between patient groups in specific features of QRST integral maps corresponding to the third and fourth eigenvectors. It appears that by examining such specific features, discriminating abilities of QRST integral maps may be enhanced. As already noted by Hubley-Kozey et al. [4], one of the drawbacks of nondipolarity index as a single measure of complexity of the QRST map is that it lumps all nondipolar features together, thereby potentially sacrificing some diagnostic information.

Overall, the results of this study suggest that KL analysis is a useful tool for analyzing magnetocardiographic QRST integral maps and providing noninvasive assessment of arrhythmic risk for patients with coronary artery disease.

Acknowledgements

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