

Study of ventricular repolarization in patients with myocardial ischemia, using unshielded multichannel magnetocardiography

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Abstract

Previous work, carried out in magnetically shielded rooms, has demonstrated that multichannel magnetocardiography (MMCG) is useful to detect ventricular repolarization abnormalities in patients (pts) with exercise induced myocardial ischemia. This study was aimed to evaluate the reliability of MMCG for the study of ventricular repolarization abnormalities due to myocardial ischemia, in an unshielded hospital environment, fully equipped for intensive care, as the first step for future investigation of critical pts with acute ischemia or infarction. Quantitative analysis of rest MCG ripolarization parameters was performed according to Hänninen et al. At rest magnetic field orientation of the integral of the second quarter from the J- point (ST angle α) was abnormal in 70% of the investigated patients. With present technology, MMCG can be performed also in an unshielded hospital room for intensive care, with quality good enough for non-contact monitoring and imaging of time evolution of acute myocardial ischemia.

1 Introduction

Myocardial ischemia and acute myocardial infarction (MI) determine changes in the electrophysiological properties of cardiac muscle cells and in electrocardiogram (ECG), as deviations of ST-segment and/or alterations of T-wave. Injury currents are detectable as consequent effect of altered membrane-potential of myocytes.

Early and accurate detection and localization of ischemia is important for therapeutic approach. The non invasive diagnosis of myocardial ischemia is usually performed with ECG, echocardiography, or myocardial scintigraphy at rest and under stress. More recently, Positron emission tomography (PET) and Magnetic Resonance Imaging (MRI) have more advanced functional imaging.

Multichannel Magnetocardiography (MMCG) has been used for the study of the ischemic heart disease in patients with different degree of coronary heart disease and the detection of ischemia has been attempted at rest and under physical stress.

As demonstrated in several recent studies, MMCG provides additional diagnostic information to evaluate coronary artery disease [1], to detect viable myocardium after infarction [2-4] and for risk-stratification of patients with previous MI [5-8]. Moreover MMCG can detect and three-dimensionally localize abnormal current flowing associated with ischemia [9]. So far the majority of MMCG system had been installed in magnetically shielded rooms, where critical and acute patients cannot be investigated.

We have recently introduced a novel MMCG in an unshielded hospital laboratory, fully equipped for intensive and interventional care of cardiac critical pts. Aim of the present study was to evaluate whether or not our MMCG set-up could be sensitive enough to detect ventricular repolarization abnormalities due to myocardial ischemia, using the same parameter described by Hänninen et al [10], as the first step for future investigation of pts with acute ischemia or MI.

2 Methods

2.1 The MCG mapping system

The MMCG system of Catholic University of Rome (*CARDIOMAG IMAGING INC, USA*) features: 9 DC-SQUID sensors, coupled to second-order axial gradiometers with 55 mm baseline. The cylindrical cryostat of limited dimension is not affecting the operational capability of the cardiologist during invasive interventions. Intrinsic sensitivity of measuring channels is about $20 \text{ fT/Hz}^{1/2}$ in the frequency range of interest for clinical MCG (*1 to 100 Hz*). Signals are recorded with a Windows NT-based acquisition system (*24 bits A/D conversion, 1-2 kHz sampling frequency. Automatic electronic noise rejection*). MMCG is recorded from a 36-point (6 x 6) grid, uniformly covering the area of 20 cm x 20 cm, with 4 sequential data acquisitions.

By shifting the patient couch from the MCG mapping system to a mobile fluoroscopy and viceversa, it is possible to combine, in a multi-modal way, images

obtained with body surface electric and magnetic mapping, intracardiac mapping and bidimensional digital radiology. The time required to record a 36 position MCG map is 4-6 minutes. Postprocessing is done with Windows NT-based PC software (*CMI, USA*) and UNIX-based X-MCG software (*NEUROMAG, FINLAND*). MCG were filtered, baseline corrected and averaged.

2.2 Signal analysis

After construction of the magnetic field maps (MFMs), two time intervals were chosen for the analysis, according to Hanninen et al [10]: 1) an integral of the second quarter from the J-point to the T-wave apex, representing ST-segment, and 2) the T-wave apex. For the determination of the magnetic field orientation, the surface gradient method, based on the arrow maps, was applied. The location and direction of the largest spatial gradient of the signal distribution in the measurement plane was computed. The MFM **angle α** was then calculated as the angle between the direction of the largest gradient and the patient's right-left line, for both intervals (ST-segment and T-wave apex).

2.3 Patients

10 patients (pts) with ischemic heart disease, all but 2 pts with abnormal stress ECG, were studied. All pts had abnormal coronary angiography demonstrating: single vessel CAD (4 pts); two vessel CAD (4 pts) and with three vessel CAD (2 pts) (**Table 1**). Their MCG data were compared with those of 10 healthy subjects.

	Vessel	Site	% stenosis	Coron	Ex Test	MCG
1	1	CX	100	pos	neg	pos
2	3	LAD,CX,RCA	90,90,95	pos	pos	pos
3	1	RCA	70	pos	pos	pos
4	2	LAD,CX	90,75	pos	pos	pos
5	2	LAD,RCA	95,80	pos	pos	pos
6	3	LAD,CX,RCA	70,70,50	pos	pos	pos
7	1	LAD	100	pos	pos	pos
8	2	DA,CX	50,70	pos	pos	pos
9	2	DA,CX	80,80	pos	pos	pos
10	1	DA	95	pos	neg	pos

Table 1 Patients data.

3 Results

All parameters are summarized in **Table 2**. At rest magnetic field orientation of the integral of the second quarter from the J point (**ST angle α**) was abnormal in 7/10 (70%) pts. The **T-wave apex angle α** was normal in all but one patients.

case #	PATIENTS				CONTROLS			
	ST alfa	T alfa	J time	T time	ST alfa	T alfa	J time	T time
1	<i>290.7</i>	32.0	420	630	70.6	74.0	370	554
2	<i>350.0</i>	48.0	380	610	45.6	40.0	395	611
3	<i>216.1</i>	0.4	393	632	71.0	62.0	385	580
4	<i>285.4</i>	62.4	370	630	72.0	66.9	395	603
5	<i>233.9</i>	46.4	380	610	67.3	56.1	386	588
6	<i>315.2</i>	<i>333.0</i>	395	615	85.0	42.9	390	570
7	22.3	48.7	385	620	29.1	45.0	400	650
8	<i>296.8</i>	78.5	395	660	84.3	79.0	380	595
9	64.6	41.3	390	665	64.8	55.0	410	650
10	98.4	87.9	398	565	73.4	58.6	390	550
Mean	<i>217.3</i>	80.4	391	624	66.3	58.0	390	595
SD	<i>115.1</i>	100.5	14	28	17.0	13.0	11	35

Table 2 Abnormal values in *italic*.

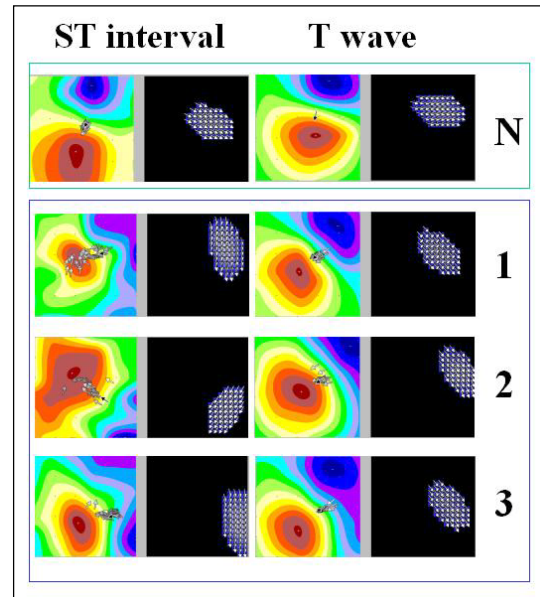


Fig. 1 MFM and Current Density Reconstruction (black squares) in one normal (N) and 3 pts, with single- (1), two- (2) and three- (3) vessel CAD.

4 Discussion

Myocardial ischemia and acute myocardial infarction determine changes in the electrophysiological properties of cardiac muscle cells. As consequent effect of altered membrane-potential of myocytes, injury currents flow from electropositive (ischemic) to electronegative (normal) areas. Such currents are not directly detectable with the ECG, which can only record the extracellular potential difference carried by volume currents at the body surface. On the contrary MCG is in theory an optimal method to detect, localize and image abnormal current flowing associated with ischemia [9].

Previous studies have already demonstrated that both rest and stress MMCG of patients with different de-

gree of coronary heart disease may show repolarization abnormalities, in patients with multiple ischemic lesions and myocardial infarction, with a higher sensitivity than resting 12-lead ECG, also in the absence of ventricular asynergy [11]. MCG T wave abnormalities may persist, when T waves in the standard ECG has already returned to normality. MCG appears more feasible during exercise and more sensitive than ECG in detecting early ST segment shifts [12-13].

Using the same analysis applied in our study, Takala et al reported that exercise-induced ischemia determines abnormalities in the ST-segment orientation of magnetic field, after cessation of stress, and that T-wave MFM orientation abnormalities appear later. However the rotational change of T-wave magnetic field, after exercise, was useful to differentiate patients with right coronary artery disease from those with left descending anterior, and circumflex coronary arteries. Moreover MMCG seems to be more sensitive to detect inferior wall ischemia [14].

All above mentioned studies were carried out in magnetically shielded rooms. Our study provides the new demonstration that, with presently available technology, the quality of MMCG recordings is good enough, in an unshielded room fully equipped for intensive cardiac care, to use the method for the study and magnetic monitoring of patients with acute myocardial ischemia or infarction.

Furthermore, although the number of patients is limited, we have found that MMCG evidences abnormalities of MFM orientation of the ST-segment at rest in 70% of patients with chronic CAD, independently of the presence of T-wave abnormality. This confirms previous findings [11] and foster wider use of MMCG for the screening of patients for early detection of silent ischemia.

5 Literature

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