Detection of coronary artery disease in patients with normal or unspecifically changed ECG on the basis of magnetocardiography

I. Chaikovsky[1], J. Kohler[2], Th. Hecker[2], B. Hailer[2], S. Auth- Eisernitz[2], V. Sosnytsky[3], L. Feinzilberg[1], N. Budnik[3], and F. Steinberg[1]

[1]Institute for BioScience, University Witten/Herdecke; [2]Philippusstift Kath. Krankenhaus; [3]SQUID AG, Essen, Germany

1 Introduction

The noninvasive diagnosis of coronary artery disease remains a clinical challenge. Electrocardiogram (ECG) at rest is frequently normal in these patients and the predictive value of stress methods and nuclear imaging is often limited and may be associated with risk. Magneto-cardiography (MCG) is known as a fully noninvasive method to measure cardiac activity. Various studies have confirmed that MCG may give additional information compared to 12 lead ECG [1].

However, the acceptance of the method in clinical practice is limited with regard to the expensive installation of the system inside a shielded location.

The aim of our study is the investigation of the potential og MCG on the basis of inverse problem solution in patients with CAD and normal or unspecific changes in resting ECG using a system in unshielded location.

2 Methods

2.1 Patient group

MCG measurments were performed in 51 patients with CAD and symptoms of stable angina but without previous myocardial infarction (MI) (18 patients of them had a triple-vessel disease, 17 - double-vessel disease, 16 patients - one-vessel disease). Left heart catheterization was performed using the Judkins technique. Selective coronary angiograms were obtained in multiple projections (Siemens Cathcor, Erlangen, Germany). CAD was diagnosed in case of stenosis >50% in ≥ 1 vessel . All patients were in sinus rhythm. Patients with hypertension, bundle branch block, atrial fibrillation and impaired left ventricular function were not included in this study.

The control group consisted of 49 healthy subjects with no history of cardiovascular disease, normal ECG at rest and stress as well as a normal echocardiography at rest. MCG was performed using a single-channel SQUID-magnetometer in unshielded location. Single MCG recordings were taken from in total 36 positions on the basis of a 6x6 rectangle grid with a 4 cm pitch over the precordial area. The sensor was positionted as close to the thorax as possible, directly over the heart. Data were recorded at each registration point for 30 seconds with simultaneous registration of lead II of the surface ECG and stored on hard disk.

2.2 Data acquisition

In each raw data set all beats were averaged at each position. Equiinductional maps of magnetic field distribution were plotted in course of ST-T interval with 10 ms apart using two dimensional interpolation algorhims. For inverse problem solution the method of magnetic moments (MMM) was applied [2]. Briefly this method based on assumption that the sources of measured magnetic field are distributed on a plane located inside the human thorax. This model could be described as a double layer of so called magnetic charges and is equivalent to the layer of elementary magnetic moments. The inverse problem solution is formulated by an integral equation that describes the relation between the unknown “magnetic charges” distribution and the measured magnetic field. In result, the distribution of the current density - which is equivalent to the “magnetic charges” density- is obtained.

This distribution is visualised in form of current line maps and current density vector maps. The spatial density of current lines is proporsional to current density at each point. The current density vectors are directed tangentially to current lines, Their length is proportional to the value of current density at each point.

Current vector and current line maps were first analyzed visually. For quantification a so called complex ventricular excitation index (CVEI) was calculated.

This index based based on certain criteria:

a) Direction of the largest vectors (≥ 80 % from maximal vector value) in course of the ventricular repolarisation. Each map was

classified to one of 9 classes in accordance to a ratio between vectors directed to sector from 0° to 90° and to different direction. Averaged values of those classes were calculated.

b) Stability of current maps in the course of the ventricular repolarisation. The cross correlation of maps was calculated.

c) Analysis of a current density values. A ratio of the current density values at selected time moments in course of the ventricular excitation was calculated.

As mentioned above the criteria were determined by original threshold decision rules. Optimal values of thresholds were obtained based on statistical treatment of learning population. Values of the CVEI were calculated as a distance from defined thresholds in the criteria space and presented in scale from –100 to 0 (zone of abnormal values) and from 1 to 100 units (zone of normal values).

3 Results

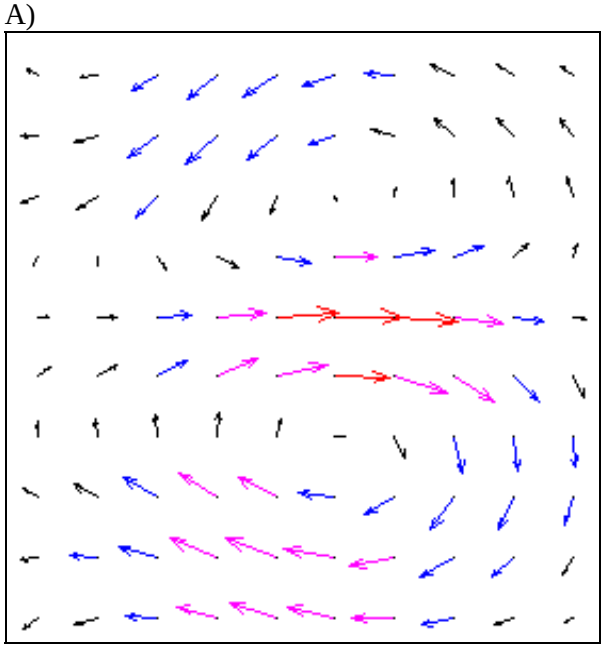
Current density vectors maps and current lines maps in control group and CAD patients with normal resting ECG are shown on Fig. 1 and 2. Resting ECG of CAD patient presented on Fig. 3.

Maps of healthy volunteers showed a homogeneous distribution of currents. There is only one main current area in each map. Main current density vectors were located on the lower left-hand part of maps and directed left-to-down. These maps remain stable over the whole ST-T interval. In contrast, map of CAD patients showed 1-3 additional areas of current vectors with deviated direction. These additional current areas existed no less than in 1/3 of maps.

We supposed that additional current areas on central and upper part of maps reflect perfusion insufficiency in the region of left anterior descendend (LAD), on the left part of maps in the region of ramus circumflex (RCX), on the right part of maps in the region of right coronary artery (RCA). In 81 % there was a correct correlation between location of additional currents area and stenosed vessel documented coronaroangiographically.

CVEI was calculated for the CAD group, for subgroup of patients with one vessel disease and for control group. Results are presented in Table 1. Sensitivity of CVEI was 91%, specificity was 84%.

A)



B)

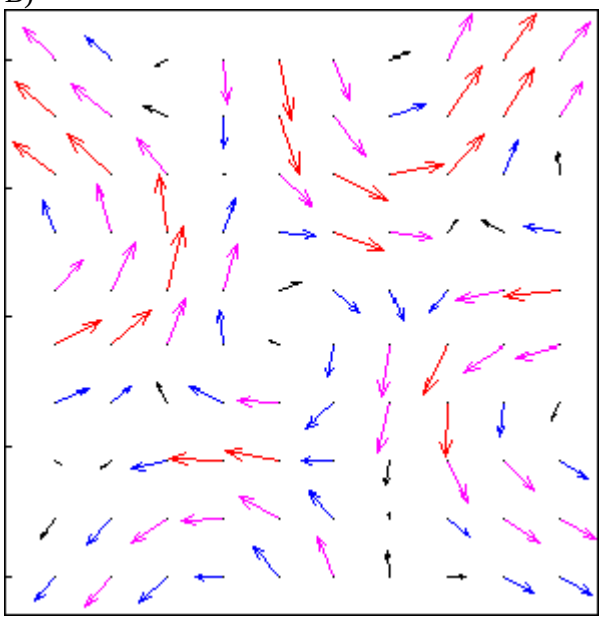
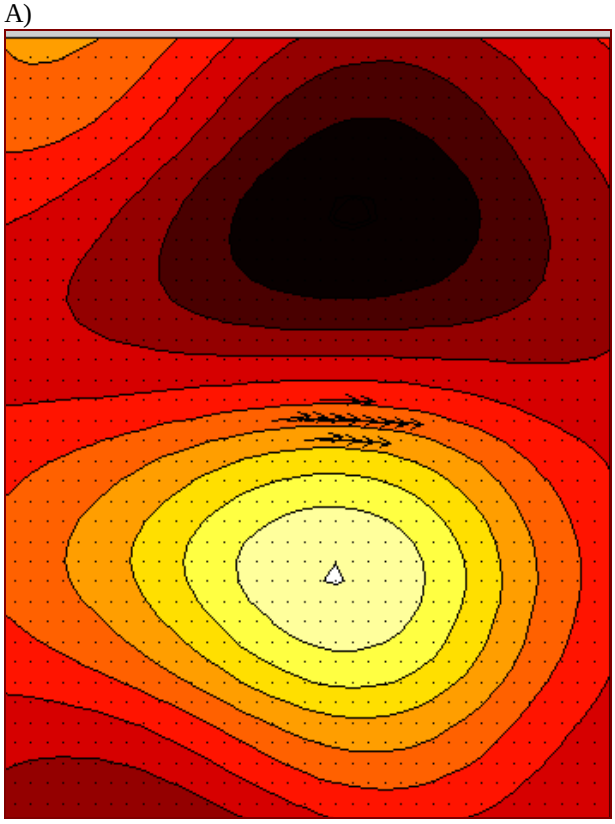


Figure 1: *Current density vectors maps of healthy volunteer (A) and CAD patient with 3-vessel disease (B) at the 80 ms after J-point.*

A)



B)

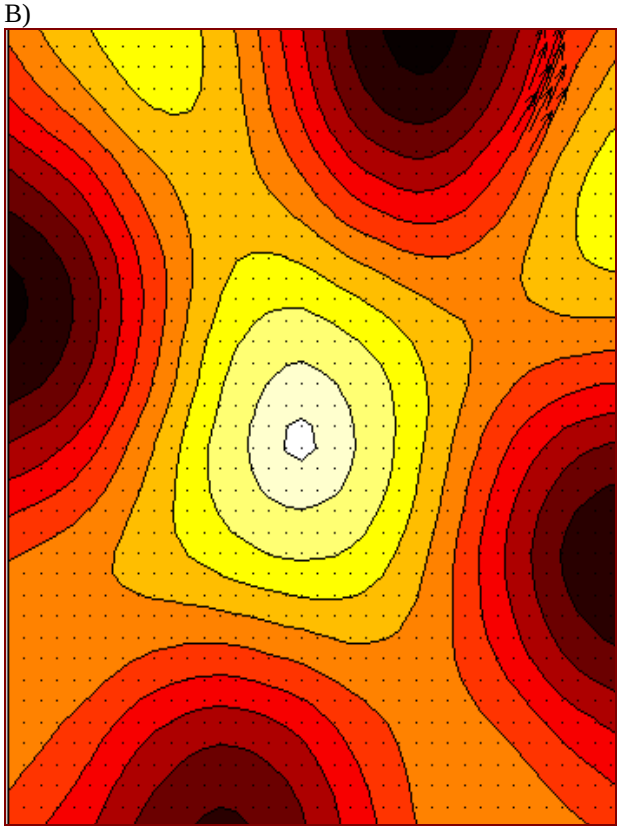


Figure 2: *Current lines maps of healthy volunteer (A) and CAD patient with 3-vessel disease (B) at the 80 ms after J-point.*

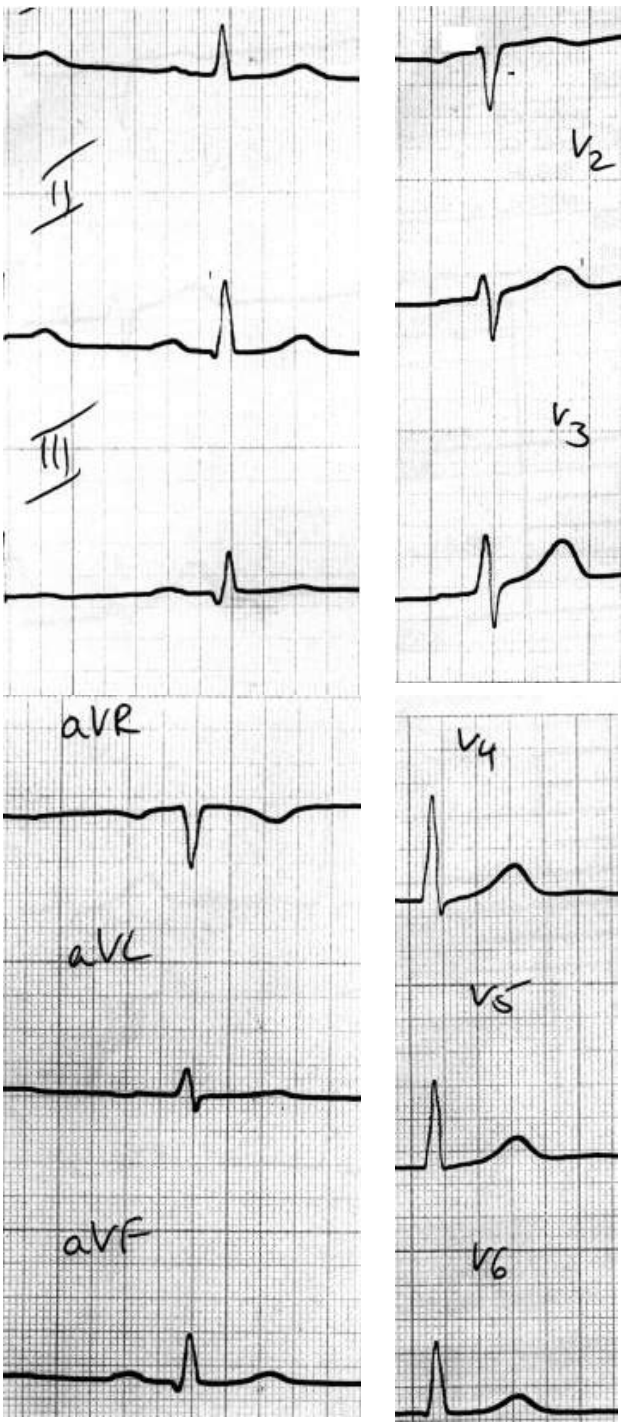


Figure 3: *ECG at rest of CAD patien t, see Figs. 1-2.*

Table 1: *CVEI values in groups examined.*

Groups examined	CVEI (mean value ± se)
CAD patients total, n=51	- 42.9 ± 6.8*
CAD patients, 1-vessel diseases, n=16	- 39.5 ± 13.6*
Control group, n=49	54.1 ± 9.1

** p<0.001 in comparison with control group*

4 Discussion

MCG seems to be able to detect and to localize ischaemia in patients at rest with normal ECG at that time . Newertheless , myocardial ischemia could be present , although 12 lead surface ECG is normal and the patient has no symptoms of angina. As an example, anomalies of glucose methabolism in patients with CAD at rest based on positron emission tomography (PET) results were shown in former studies. These facts enable to suppose existence of a silent myocardial ischemia in CAD patients at rest.

One could suggest that the changes seen in CAD patients could be caused by pathological inhomogeneity of a repolarisation in various regions of the myocardium compared to healthy subjects. Accordingly, transmembrane action potential duration is longer in regions with decreased myocardial perfusion compared to zones with unchanged perfusion[3]. Hence, local currents appear on borderzones of of ischemic and normal myocardium.

High sensitivity to tangentially propagated local currents is the characteristic feature of MCG . We suppose, that these local currents are displayed as additional current areas on current distribution maps during ventricular repolarization.

It is interesting to note, that in some cases there was a difference between the severity of pathological changes in MCG maps and the coronaro-angiographical status, i.e. changes on MCG maps were lower than it could be expected based on coronaroangiography results and vice versa. This indicates that characteristic of CAD severity based only on the number of stenosed vessels only is not complete. We concider , that it is very promising to compare MCG results with different methods, like PET or SPECT in CAD patients.

MCG analysis on the base of inverse problem solution takes the most important aspects of excitation into consideration: directions of excitation fronts propagation , stability and intensity of electrical processes in the myocardium and exhibits high ability to detect myocardial ischeamia sensitivity, even in patients with one-vessel disease. This is confirmed the results of former MCG studies earlier in patients with chronic CAD and normal or unspecifically changed resting ECG [4-7].

In conclusion , MCG-mapping, especially with aid of a relatively simple unshielded system, could be a very useful tool for non-invasive CAD diagnosis in routine cardiological practice.

Of course, multicentral investigations are needed to confirme these results.

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