International Congress Series 1300 (2007) 468–471

www.ics-elsevier.com

Sensitivity and specificity of magnetocardiography, using computerized classification of current density vectors maps, in ischemic patients with normal ECG and echocardiogram

L. Fainzilberg [a], I. Chaikovsky [a,b,*], S. Auth-Eisernitz [c], B. Awolin [b], D. Ivaschenko [a], B. Hailer [c]

[a] *International Research and Training Center for Information Technologies and Systems, Kiev, Ukraine*
[b] *Essen University, Essen, Germany*
[c] *Department of Medicine, Phillipusstift, Essen, Germany*

Abstract. The present study aimed to develop a computerized classification of magnetocardiograms (MCG) on the basis of current density vectors (CDV) map analysis for the diagnosis of coronary artery disease (CAD). The study included 123 patients with angina and angiographically documented CAD but with normal ECG at rest and normal left ventricular function. The control group consisted of 124 normals. 4-channel SQUID-magnetometer systems located in an unshielded hospital environment was used. MCG recordings were taken at 36 pre-thoracic sites over the pericardial area and reconstruction of CDV maps within the ST–T interval was applied. Each CDV map was classified automatically with a scale from 0 (normal) to 4 (grossly abnormal). The classification number depends on the number of large vectors directed left–downward and the presence of additional clusters. The mean class was calculated for each subject in order to discriminate between groups. Using a mean class value of 1.75 as threshold for the discrimination between healthy persons and CAD patients, 76% sensitivity and 81% specificity were achieved. The computerized classification of CDV maps seems to be a useful tool for the diagnosis of CAD.

Keywords: Magnetocardiogram; Coronary artery disease; ECG; EchoCG; Mapping

* Corresponding author. Glushkova ave 40, 03680, Kyiv, Ukraine. Tel.: +380 44 5261267; fax: +380 44 5263348.
E-mail address: illya_6@hotmail.com (I. Chaikovsky).

0531-5131/
doi:10.1016/j.ics.2007.01.042

1. Introduction

The purpose of MCG investigations in the human is the evaluation of electrical activity of the heart, in particular its current density rather than the surface potential, with the aim to obtain reliable information on its physiological state.

A variety of methods and indicators for analysis are already available in the current stage of MCG development allowing a discussion of each merit and pitfalls.

Analysis of the distributed sources as CDV maps is most attractive for physicians because this method contains information in terms of a current distribution, that is the main and final focus of any clinical electrophysiological investigation. The acquired CDV have to be evaluated i.e. classified in terms of normal or pathological.

Several approaches exist for these map classification based on visual analysis that could be provided by trained physicians [1,2]. The basic ideas of the visual approach are based on mutual location of low and high current density zones as well as on the direction of the largest CDV at certain time instant. That is a useful clinical tool but depends to some degree on the experience of the observers with the need for a training procedure. An automatic classification has several advantages for clinical routine, especially in terms of reproducibility of the results and a fast diagnostic procedure.

In clinical praxis MCG recordings are of special importance in patients with suspected CAD but no definite diagnosis as a result of routine noninvasive diagnostic tools. In order to avoid serious side effects coronary angiography – as a gold standard for the diagnosis of CAD – should be restricted to patients in whom the diagnosis is confirmed prior to the procedure and in whom interventional therapy appears to be indicated. MCG seems to be promising as a new complete noninvasive method for the diagnosis of CAD, especially in patients with normal ECG at rest [3].

The aim of this study is the development of an objective computerized classification of the CDV maps based on clear and transparent principles and the evaluation of this classification system in patients with proven CAD but normal ECG and EchoCG at rest.

2. Subjects and methods

MCG recordings were taken using a stationary system, installed in a division of cardiology (Department of Medicine II, Phillipusstift, Essen, Germany).

The patient group included 123 patients with stable or unstable angina and angiographically documented CAD with stenosis of $\geq 50\%$ of at least one coronary vessel but with normal or unspecifically changed ECG at rest (absence of ST-segment depression or elevation, negative T-waves in no more than 2 leads), normal left ventricular function without wall motion disturbances. The control group consisted of 124 healthy subjects. The patients were selected consecutively from all patients admitted to hospital with the indication for coronary angiography due to chest pain. The control group consisted of healthy subjects with no history of any cardiovascular disease, normal ECG at rest and stress as well as a normal EchoCG at rest. 15 volunteers with no history of any cardiovascular disease were used for run-to-run and day-to-day reproducibility assessment. In all patients MCG were performed in close time relationship (24–48 h) prior to coronary angiography. All volunteers had MCG recordings in the morning time. In 15 volunteers served for reproducibility assessment 2nd recording was

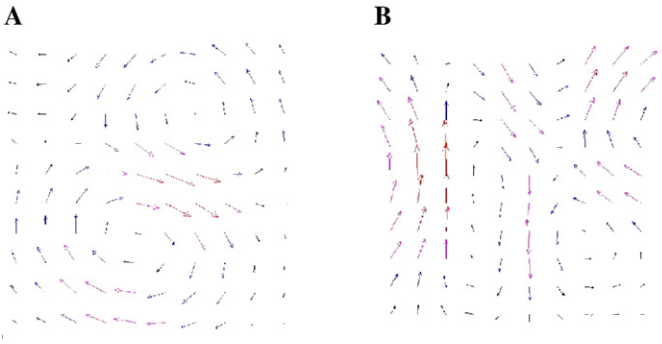

Fig. 1. CDV maps of Class 0 (A) and Class 4 (B).

done in a separate session later that day, which included repositioning and MCG recording. The third recording was done next day, in about 24–30 h after baseline MCG recording.

3. Data acquisition and analysis

12 lead ECG, EchoCG and MCG were performed in all subjects. MCG examinations and coronary angiography were done as described earlier [2,3,6]. Data acquisition, analysis, and CDV maps classification were performed by the software system MagWin [5].

From the coronary angiograms two experienced observers assessed the degree of stenosis visually in major branches. Only patients with narrowing of the coronary arteries $\geq 50\%$ were included in the study. From the MCG data at 36 registration sites at each latency, the cardiac de- and repolarization process was projected onto a plane containing 100 patients. At each point, the lead fields were shown as vector magnitudes indicating the strength and direction of the field.

In both groups CDV maps were generated every 10 ms within the ST–T interval starting with the J-point. Each CDV map was classified automatically by means of a classification system with a scale from 0 (normal) to 4 (grossly abnormal).The classification is mainly based on the dipolar or non-dipolar structure of the map and the direction of the main current density vectors. The presence of additional clusters served for further specification. In other words , this classification is intended to evaluate the homogeneity of electrical properties of myocardium. In case of homogeneous properties the volume currents constitute two vortices, which are symmetrical and equal in strength, there is no additional vector clusters. The largest vectors directed left–downwards. The resulting map has an "ideal" dipolar structure—class 0 in accordance with an classification score. When the dipole structure is absent, maps are graded from 1 to 4 depending on the extent of abnormalities (see Fig. 1). This principles of maps classification are described in more details elsewhere [4,6].

Table 1
Average map class C_0 for CAD patients and healthy volunteers ($P<0.001$)

Groups examined	C_0, $M \pm m$
Patients with CAD, $n=123$	2.4 ± 1.11
Healthy volunteers, $n=124$	1.16 ± 0.71

4. Results

In group served for reproducibility assessment 21.9±1.5 maps per person were generated in average. The majority of maps were classified as category 0, 1 or 2. The differences of averaged map class C_0 also was statistically insignificant both between the 1st and 2nd measurements and between the 1st and 3rd ones. Over all subjects 22.5±1.8 maps per person with CAD in comparison with normals were generated in average.

In control group a majority of maps was classified as term 0, 1 or 2 compared to patients with CAD in whom the terms 3 and 4 were found most frequently. The differences of averaged map class C_0 between two groups were highly statistically significant (see Table 1).

To define the diagnostic usefulness of the averaged map class the threshold $C_0=1.75$ was set based on ROC curve. Subjects with the averaged map class greater than 1.75 were classified as CAD patients, subjects with a map class less than 1.75 were classified as normal. Sensitivity 76%, specificity 81%, PPV 80%, NPV 73% were achieved.

Further, analysis of C_0 in accordance to numbers of vessels occluded was done. There is a tendency for increasing of C_0 in patients with the higher number of vessels occluded but differences were statistically insignificant. There were no statistically significant difference between patients with occlusion of LAD, LCX and RCA.

5. Discussion

The present study evaluates a computerized classification system for the analysis of MCG on the basis of CDV maps for the diagnosis of CAD in patients with normal ECG and Echo at rest. The fact that CAD patients, presumably with ischemia but a normal ECG and Echo at rest, might be identified on the basis of a completely noninvasive method is of great clinical interest.

A fast, reproducible and practical concept of data analysis is an obligatory requirement for the wide clinical acceptance of the method. The proposed computer system for CDV maps classification is based on well-understandable parameters of current distribution in the course of ventricular repolarization: homogeneity of the process and direction of the vectors.

The prospective multi-center studies are needed in order to evaluate the predictive value of this test for the diagnosis of CAD in patients suffering from chest pain.

References

[1] K. Pesola, H. Hanninen, K. Laurema, Current density estimation of the left ventricular epicardium: a potential method for ischemia localization, Biomed. Tech. (1999) 143–146.
[2] B. Hailer, et al., The value of magnetocardiography in patients with and without relevant stenoses of the coronary arteries using an unshielded system, PACE 28 (2005) 8–15.
[3] I. Chaikovsky, et al., Detection of CAD in patients with normal or unspecifically changed ECG on the basis of magnetocardiography, in: J. Nenonen, R. Ilmoniemi, T. Katila (Eds.), Proc of the 12th Int. Conf. on Biomagnetism, HUT, Espoo, 2001, pp. 565–568.
[4] I. Chaikovsky, D. Katz, M. Katz, Principles of magnetocardiographic maps classification and CAD detection, Int. J. Bioelectromagn. 5 (2003) 100–101.
[5] L. Fainzilberg, Dissertation of Doctor of Science, International Research and Training Center, Kyiv, (2004), 409 pp.
[6] I. Chaikovsky, Magnetocardiography in unshielded location in coronary artery disease detection using computerized classification of current density vectors maps, Dissertation of Doctor of Medicine, University Duisburg-Essen, (2005), 76 pp.