An Investigation on Signals in Magnetocardiography

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Abstract – **The main purpose of this paper is to discuss the lead systems currently being applied in detecting the equivalent magnetic dipole of the heart, and to discuss briefly on the relationship between signals in the cases of ECG-MCG**

***Keywords*– Magnetocardiography, elektrokardiography**

I. INTRODUCTION

It's well known that in electrocardiography, the mapping of the distribution of the electric potential on the surface of the thorax has been-applied since the first detection of the human electrocardiogram. It's simirarly in magnetocardiography. Though the magnetic field is a vector quantity and has therefore three components at each location in space, the mapping method has usually been applied for registering only one component (the x-component) of the magnetic field around the thorax. The mapping has usually been done on a certain grid. In lead field theory, it may be shown that lead systems used in mapping often introduce a distortion of the signal that necessarily originates from the in homogeneities of the volume conductor. (The situation is the same as in mapping the electric potential field.) Some of these magnetic measurements may also be realized with a similar sensitivity distribution by use of electric measurements with a higher signal-to-noise ratio and with easier application (Fig.1).

II. METHODS OF MAGNETOCARDIOGRAPHY

In addition to the analysis of the parameters of the MCG signals, recorded either by determining the equivalent magnetic dipole or by the mapping method, several other techniques have also been applied. Of these the localization of cardiac sources is briefly discussed here. The localization of cardiac electric sources is a highly desired objective since it may enable the localization of cardiac abnormalities including those of abnormal conduction pathways. These may cause dangerous arrhythmias or contribute to a reduction in cardiac performance. Abnormal conduction pathways, for example, conduct electric activity from the atrial muscle directly to the ventricular muscle, bypassing the AV junction. This is called Wolff-Parkinson-White or(WPW) syndrome.If a retrograde conduction pathway also exists from the ventricular mass back to the atrial mass, this reentry path may result in tachycardia. If the symptoms due to this abnormal conduction do not respond to drugs, then the tissue forming the abnormal pathway must be removed surgically, hence requiring prior localization. In clinical practice the conduction pathways are at present localized invasively with a catheter in an electrophysiological study, which may last several hours. This time may be shortened by first making an initial noninvasive localization of the equivalent source of the conduction pathway from the electric potentials on the surface of the thorax.

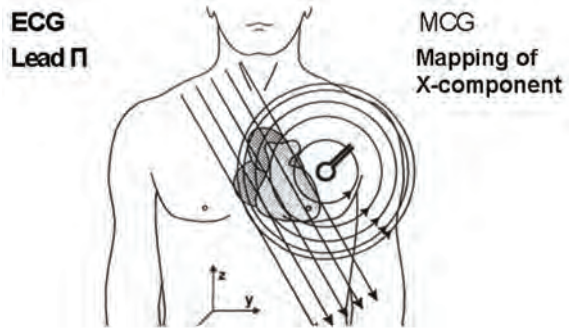

Fig.1 The similarity between the lead fields of certain electric and magnetic leads are illustrated. If the magnetic field is measured in such an orientation (in the x direction in this example) and location, that the symmetry axis is located far from the region of the heart, the magnetic lead field in the heart's region is similar to the electric lead field of a lead, which is oriented normal to the symmetry axis of the magnetic lead. This similarity may also be verified from the similarity of the corresponding detected signals.

In magnetocardiographic localization the goal is to introduce an alternative to the electric localization using the magnetic methods. Utilization of this complementary technique may improve the overall localization accuracy. The magnetocardiographic localization is usually made by mapping the x component of the cardiac magnetic field at 30-40 locations on the anterior surface of the thorax with consecutive measurements using a single-channel magnetometer or simultaneously using a multichannel magnetometer. The dipole model is the most obvious to use as a source model for the localization methods. The accuracy of the magnetocardiographic localization depends to a great extent on the accuracy of the volume conductor model applied The accuracy of the magnetocardiographic localization of the origin of an abnormal conduction pathway is of the order of 2-3

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cm. Because magnetocardiographic localization hasbeen shown to have greater complexity and costs as compared to the electric method, the magnetic method does not, at present, compete with the electric method in clinical practice

III. METODS FOR DETECTING OF MAGNETIC HEART VECTOR

It's possible to assume that the heart is a spherical conducting region between the insulating lungs. For the XYZ and ABC lead systems it would be enough to assume cylindrical symmetry for each component, which leads to a spherically symmetric volume conductor for the three orthogonal measurements.The *y* and *z* components of the unipositional lead system require, however, an assumption of a conducting spherical heart region inside the insulating lungs. This assumption forces the lead fields to flow tangentially within the heart region. This is called a *self-centering* effect. The magnetic dipole moment of a volume current distribution $\vec{J}$ in an infinite, homogeneous volume conductor with respect to an arbitrary origin can be defined as:

$$\vec{m} = \frac{1}{2}\int \vec{r} x \vec{J} dv \qquad (1)$$

where:

$\vec{m}$ is the magnetic dipole moment;

$\vec{J}$ is the density of volume current distribution

$\vec{r}$ is the radius of an arbitrary current contuor

v is the volum of calculation

The lead system that detects this magnetic dipole moment has three orthogonal components. Each component produces, when energized with the reciprocal current, a linear, homogeneous, reciprocal magnetic field $\vec{B}_{ML}$ over the source region. These reciprocal magnetic fields induce lead fields $\vec{J}_{LM}$ in which the lead current is directed tangentially, and its density is proportional to the distance from the symmetry axis(Fig.2).

Fig.2A One component of the reciprocal magnetic field $\vec{B}_{ML}$

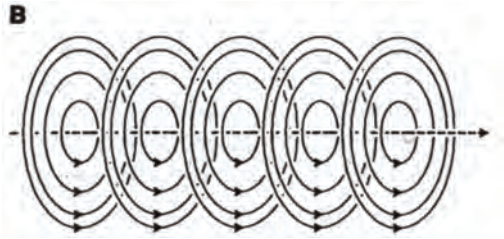

Fig.2(B) One component of the lead field $\vec{J}_{LM}$ of an ideal lead system detecting the magnetic dipole moment of a volume source. Three such orthogonal components form the complete lead system.

A natural method to realize such a lead system is to make either unipolar or bipolar measurements on the coordinate axes (Fig.3).

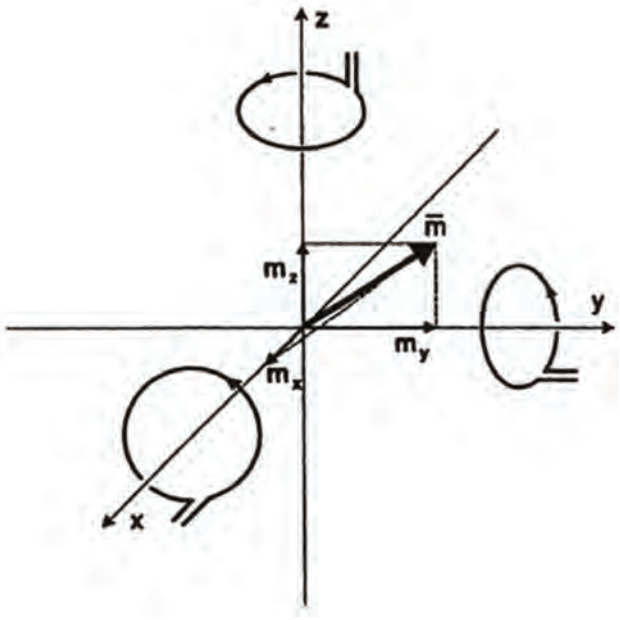

Fig.3. A natural method to measure the magnetic dipole moment of a source locating in the origin is to measure (x, y, z) componets of the magnetic fielt on corresponding coordinate axes.

IV. COMPARISON BETWEEN MCG AND ECG

It can be noted that the bioelectric activity in the heart is responsible for the generation of a source current density, namely $\vec{J}(x, y, z, t)$. As stated before, both the electric and magnetic fields are generated by this same source which, in turn, responds to the electrophysiological phenomenon of depolarization and repolarization of cardiac muscle cells. A logical question arises as to whether any new information might be provided by the magnetic field measurement that is not available from the electric potential field measurement. While it appears, on certain theoretical grounds, that the electric and magnetic fields are not fully independent, other reasons exist for the use of magnetocardiography. These may be divided into *theoretical* and *technical* features. The former ones are based on the universal properties of biomagnetic fields and the latter ones to the technical features of the instrumentation. There are some differences between the plots of potential's curves VMCG and VECG in the cases of MCG and ECG (Fig.4)

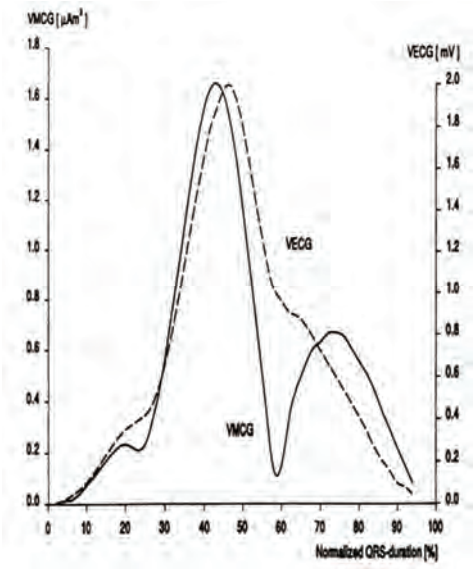

Fig.4 Simultaneous plots of the experimental potential's curves during the QRS complex in the cases of MCG (solid curve) and ECG (dashed curve).

A.Theoretical Advantages of MCG

First, the nature of lead fields of electric and magnetic leads is quite different. Specifically, the ideal magnetic lead is sensitive only to tangential components of activation sources and therefore should be particularly responsive to abnormalities in activation (since normal activation sources are primarily radial). Furthermore, the tangential components are attenuated in the ECG because of the Brody effect. Another factor is that the signal-to-noise ratio for the electrical and magnetic recordings are affected by different factors, so there could be a practical advantage in using one over the other despite their similarities in content

Second, the magnetic permeability of the tissue is that of free space. Therefore the sensitivity of the MCG is not affected by the high electric resistivity of lung tissue. This makes it possible to record with MCG from the posterior side of the thorax the electric activity of the posterior side of the heart. That is difficult to do with surface ECG electrodes, but is possible to do with an esophageal electrode which is, however, inconvenient for the patient Another important application of this feature is the recording of the fetal MCG. During a certain phase of pregnancy the fetal ECG is very difficult to record because of the insulating fat layer in the fetus.

B.Technical Advantages of MCG

First, a possibly important distinction is that the magnetic detector is not in contact with the subject. For mass screening, there is an advantage in not requiring skin preparation and attachment of electrodes. (In the case of patients with skin burns this is a crucial advantage.)

Second, the SQUID (Superconducting QUantum Interference Device) magnetometer is readily capable of measuring DC signals. These are associated with the S-T segment shift in myocardial infarction. Such signals can be obtained electrically only with great difficulty. Although the clinical value has yet to be demonstrated, it should be noted that because of the difficulty in performing electrical measurements, there have been few investigations of DC potentials.

V. CONCLUSION

1.It's clear that application of the MCG-signals in medical diagnostic has many advantages:

a/ The ECG measures the electric potential field, which is a *scalar* field. Therefore, one measurement at each measurement location is enough. The MCG measures the magnetic field, which is a *vector* field. Therefore, MCG measurements should provide a vector description - that is, three orthogonal measurements at each measurement location- to get all available information .

b/In MCG we are interested in the electric activation of the whole cardiac muscle, not only on its anterior surface. Therefore, to compensate the proximity effect, MCG measurements should be done symmetrically both on the anterior and on the posterior side of the thorax. Actually, the posterior measurement of the MCG increases the information especially on the posterior side of the heart, where the sensitivity of all ECG leads is low due to the insulating effect of the lungs. (As noted earlier, in the measurement of the MEG, we are mainly interested in the electric activation of the surface of the brain, the cortex. Therefore a unipolar measurement is more relevant in measuring the MEG.)

c/On the basis of the existing literature on the MCG, non symmetric unipositional measurement seems to give the same diagnostic performance as the mapping of the *x* component of the magnetic field on the anterior side of the thorax.

2. A *combination* of electric and magnetic measurements (i.e., ECG and MCG) gives a better diagnostic performance than either method alone with the same number of diagnostic parameters, because the number of independent measurements doubles.

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