Magnetocardiograms as Tools over Electrocardiograms

Magnetocardiograms (MCGs) are body surface mappings that detect the cardiac magnetic fields and especially weak electrophysiological phenomena that could be missed by ECGs. In 1820, Hans Oersted found that every time an electrical current is switched on, a compass needle near the wire carrying the currents moves. The needle is moved by magnetic fields accompanying the electrical currents. This principle also applies to the currents associated with the electrophysiological phenomena in the human body. Action potentials originating in myocardial cells create both electrical currents and magnetic fields. At the body surface, the cardiac electrical currents are measured by ECGs, while the cardiac magnetic fields are measured by MCGs. In other words, ECGs and MCGs both provide information about the same myocardial activity. The cardiac magnetic field was detected much later and was first described by Baule and McFee in 1963. Over the years advances have been made in this field of MCGs and it has been developed as a useful diagnostic tool with multichannel recordings.

The cardiac electrical currents are strong enough to be recorded at the body surface despite the presence of urban noise, while the cardiac magnetic field is a million times weaker than the earth’s magnetic field and a thousand times weaker than the magnetic fields associated with urban noise. Picking up these weak physiological signals in a noisy environment is therefore one of the biggest issues in clinical MCG studies. Current systems use superconducting quantum interference devices (SQUIDs), a gradiometer (first-order or up to a third-order), a magnetically shielded room, filtering, and signal averaging.

MCGs have some advantages over ECGs. First, they are recorded by a completely noninvasive system measuring the spontaneous magnetic fields that accompany the heartbeat. There is no need for electrodes, radiation, or stimulation procedures. A second advantage is that MCGs are less affected by body tissues than ECGs are. A third advantage is that skin electrode interference does not exist in MCGs. These three advantages make MCGs unique values in fetal diagnosis. Fetal MCGs are unaffected by vernix caseosa and by amniotic fluid and are reliable throughout the second and third trimester of pregnancy, whereas fetal ECCs measured on the maternal abdomen are reliable only before the 27th week of gestation.

Atrial activation, ventricular depolarization, and ventricular repolarization, which respectively correspond to the P wave, QRS complex, and T wave in ECCs, can be observed in the MCG of a fetus after about 15–20 weeks of gestation. Normal development of the heart, congenital long QT syndrome, fetal supraventricular tachycardia, congenital complete atrioventricular block, and fetal cardiac hypertrophy have all been diagnosed using MCGs. Fetal MCGs are useful for detecting high-risk pregnancies and congenital arrhythmias. Moreover, direct-current components are not filtered in MCGs and this advantage makes them valuable for analyzing baseline shift in cardiac ischemia. The data are applied to not only an electrophysiological phenomena which can be approximated by a single-dipole model, such as a premature complex, an accessory pathway, a His potential and tachyarrhythmias.

MCGs, body surface mapping of the cardiac magnetic fields measured using SQUID sensors, are used in clinical diagnosis when ECGs are not practical or not diagnostic. The most important advantage of MCGs over ECGs is that they are more sensitive to small signals. Although they are not necessary in the diagnosis and treatment of individuals who show obviously abnormal ECGs, MCGs can provide unique and additional information when ECGs are not practical or not sensitive enough. Establishing their utility will require further studies in both basic and clinical approaches.

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