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Study and Mechanism of Magnetocardiography (MCG) Device and its Comparison to Electrocardiography (ECG) in Heart Diseases

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ABSTRACT

Background: Magnetocardiography device is the best tool for diagnosing heart diseases in a more accurate way. This device is related to the superconductors and squid. In Afghanistan there has been no research conducted about it. Therefore, the aim of this study is to explore the structure, activity and information related to the application of magnetocardiography theoretically.

Materials and Methods: The research design for this study is reflective in nature, utilizing a review research approach. This involves examining existing literature, reports, and empirical studies published in peer review journals about the structure and mechanism of the magnetocardiography device and its comparison with electrocardiography. The obtained information was summarized, compared the previous and current articles, and the results obtained are placed here.

Findings: Today, in the medical field, magnetocardiography is an advanced device, which diagnoses diseases in shortage of time accurately and quickly. In addition, the magnetocardiography device used to diagnose heart diseases has very few negative effects on human body against other devices.

Conclusion: Calculation of this magnetic field from the superconducting quantum interference device (SQUID) is the only powerful magnetic sensor to measure human biological magnetic activity so far. A comparison of conventional sensor arrangements (MCG/ECG) and optimized sensor arrangements were made by determining the slope of individual values, and its application for heart diseases very effectively. MCG is used in the imaging of patients for whom the time required is much less than the time of ECG measurement.

Keyword: Electrocardiography, Magnetocardiography, Superconductivity, Squid.

INTRODUCTION

The human body is made up of 70% water and the molecules of water are in a bipolar form(Clark & Brangiski, 2004). An adult human has an average of 70 trillion cells and next to these cells there are different parts of bacteria that perform metabolic activities in the human body. According to the research, changes in metabolic activity in the human body are caused by the magnetic field as shown in Figure 1. Electromagnetic biological activity is important for the health of the body, decreasing the magnetic field in the human body causes metabolic disease (Wacker et al., 2022).

In the human body, electrical activity occurs in membrane cells and produces the appropriate voltage. Healthy cells produce 80 to 100 millivolt potential and cancer cells produce 20 to 25 millivolt potential. In 1920, a German physicist named (Kuhn's) discovered the phenomenon of superconductivity (Fish& Geddes, 2009).

He brought mercury down to 2.4 K (-269C^0) degrees and noticed the reduction and disappearance of resistance. If we take a magnet near a conductive material, the rotating current is induced in it, but bringing the magnet closer to the superconducting material will cause the superconductor to be suspended and the current will be maintained in it forever. The magnetometer and its protected housing introduced to measure the magnetic field as a function of time (Fish & Geddes, 2009).

Fig 1: Electric and magnetic field of human body.

Squid has used Josephson's effect to measure very small changes in magnetic flux. In 1962, Josephson proposed the possibility of electron tunneling between two superconducting regions separated by a resistive barrier (weak coupling) (Gubser et al., 2009). The amount of current that is characteristic of a weak connection and smaller than a critical value can penetrate the body by creating a pressure drop in the resistance barrier. The sensitive element in the squid is a superconducting ring, cut by Josephson coils. In the Figure 2, This sensor works at a temperature lower than the transient temperature (Tc), usually 5°K, and is able to detect constant magnetic fields and alternating fields as small as 10^{-14} (Clarke & Braginski, 2004).

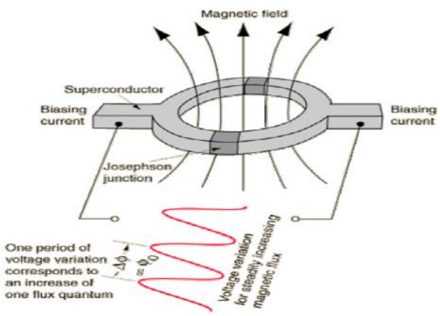

Fig 2: Superconductors in the Josephson ring and magnetic field generation.

In order to avoid disturbance caused by external fields, measurements are usually performed in rooms protected from the magnetic field. These rooms are made of multiple layers of aluminum and mu-mental (Chakeres & de Vocht, 2005). A type of superconductor that works at low temperature is made of niobium or a lead alloy with 10% gold or indium that works at low temperature and uses liquid helium to keep it cool, and another type of YBCO that works at temperature It works high and is cooled with liquid nitrogen and has less sensitivity (Douine et al., 2021). They usually work in two modes, dc and Rf. In dc mode, the pressure changes are revealed by the voltage drop in the links, and the squid ring consists of two Joseph Son links. In Rf mode, the pressure changes are detected by the resonant tank circuit and inductively coupled with the squid loop (Rath, A et al., 2021).

Superconductivity

Nowadays, the applications of superconductivity are heard even in our own country. This technology, with its speed of development, promises to approach a world without electrical resistance, which even the initial idea reveals the infinite diversity of its usage fields. On the other hand, nanotechnology is at the forefront of global research. The new collaborations of these two sciences can be very useful and profitable and attract the attention of researchers (Scanlan et al., 2004). On April 28, 1911, the news of the Leiden laboratory was published, which shook the world of physics. Hick Kimberling Ones, who later became known as Mr. Absolute Zero, observed that the electrical resistance suddenly dropped and disappeared when investigating the resistance of mercury at a temperature close to zero Kelvin, and this was the beginning of the discovery of superconductivity (Gubser et al., 2009).

Superconductivity means superconductivity is a phenomenon that occurs at very low temperatures for some zero DC materials. In the state of superconductivity (Chakeres & de Vocht, 2005), the electrical resistance of the material flows during passage, and the material becomes completely diamagnetic, that is, it rejects the magnetic field from within. Rejection of the magnetic field is the only main difference between a superconductor and a perfect conductor, because in a perfect conductor the magnetic field is expected to remain constant, while in a superconductor the magnetic field is always zero. In other words, conductivity is a property of materials that causes the transfer of electric energy in them. This property is not the same in different materials. Gold and silver are very good conductors, while glass or plastic are not conductors at all. Small thermodynamic and electromagnetic changes affect it. Superconductivity is a name that refers to an extraordinary combination of electrical and magnetic properties that appear in certain materials at very low temperatures (Jensen et al., 2021).

Magnetocardiography (MCG)

The human body produces very small magnetic fields, the measurement of which is very important in the diagnosis of diseases and bio magnetic applications of Magnetocardiography, Magnetoencephalography, Magneton urography and Magnetopneumography. The flux flow that passes through the heart produces a field of about 50 PT, this amount is within the range of tracking low and high temperature squids. The basis of MCG is based on an array of SQUID sensors that covers the entire chest area and sometimes the back and face. The number of sensors is between 7 and 64 (Arai et al., 2022). This method should also be performed in a magnetically protected environment. The output of the local magnetic detector is recorded outside the protected room.

MCG is used for cardiac arrhythmia mapping, myocardial ischemia and fetal heart rate analysis in high-risk pregnant women. MCG is also used for non-invasive methods that do not require electrodes (Mori et al., 1988). Magnetocardiography technique is a non-invasive measurement of changes in the strength of the magnetic field above the chest and can be used to detect electromagnetic phenomena in the heart. The magnetic field sensors used to record magneto cardiograms (MCGs) are superconducting quantum interference devices (SQUIDs) that require liquid helium cooling and other materials Also, this simple non-invasive method to examine the electrophysiological signal of the fetus, which It is difficult to obtain from surface ECG and may be useful in prenatal evaluation, identification and classification of clinically relevant arrhythmias (Hänninen et al., 2001).

The detectors are very sensitive and can measure the weak magnetic fields produced by the heart's electrical activity. Because of their cost and the need for magnetic shielding, the diagnostic utility of MCG systems must be carefully evaluated. Many studies have shown the potential advantages of magnetocardiography over electrocardiography for some applications Based on studies and research, MCG has the advantage over ECG Over ECG allows to collect electrophysiological waveform without any physical contact between the device and the patient, thus avoiding skin-electrode contact problems in ECG. Modern MCG multichannel measuring devices typically have more than 50 SQUID detectors and can detect precordia magnetic fields originating from many locations on the heart with good signal-to-noise ratio and spatial and temporal signal resolution. The SQUID sensors are fixed within the system, so that their relative positions are exactly repeatable in each patient measurement. Patient preparation is reduced to removing jewelry or magnetic items from clothing, so that a typical multichannel MCG measurement takes only 5–10 minutes (Wacker et al., 2022).

Figure 3 shows the MCG system; MCG is used in the imaging of patients for which the required time is much less than the time of ECG measurement. It is also used for mapping cardiac arrhythmias. In this case, with the MCG method, the location of the arrhythmia is determined first, and then a map of the location of the catheter is prepared to determine the cut area more precisely. In this case, MCG is much more accurate than ECG. This method is also used to predict myocardial ischemia (Van Leeuwen et al., 2004).

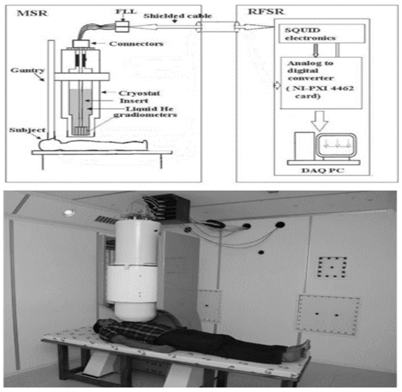

Fig 3: Treatment of heart diseases by Magnetocardiography.

Comparison and improvement of MCG and ECG devices

Today, in medicine, the MCG device is superior and better than all other devices for diagnosing heart diseases. In MCG, the magnetic field exists in quantum (small) packages, the size of each quantum is given by the following mathematical formula:

$$\Phi_o = \frac{h}{2e} = 2,07.10^{-15} weber$$

The electrocardiogram has a major potential advantage over the ECG, allowing it to collect MCG waveforms without contact. In addition, the MCG has a different information potential, since the waveforms are not affected in the same way as the ECG by the complex conduction paths outside the border of the heart (Wacker et al., 2022). Cardiac magnetic field has been found to be more accurate than ECG for detecting right atrial hypertrophy and right ventricular hypertrophy and has been used to noninvasively locate conduction pathways in the heart, making MCG potentially useful for localizing arrhythmia sources can be useful. Catheter ablation Magnetocardiography can also detect circular eddy currents that do not give an ECG signal. Consequently, the MCG may show ischemia-induced deviations from the normal direction of depolarization and repolarization better than or in a different manner than the ECG (Hänninen et al., 2001).

Based on the research of one of the articles, the initial assessment of MCG was obtained by manual measurement. Preliminary analysis of multichannel MCGs from normal subjects showed that MCG T waveforms differed from ECG T waveforms and that manual measurement of repolarization was significantly affected by T wave amplitude. The results showed that MCG errors are similar to ECG with 30 ms difference between cardiologists; this is compared to 40 ms for normal repolarization dispersion (Arai et al., 2022). The results and superiority of the MCG device are written the Table1.

Table 1. Comparison between MCG method and other devices method. MCG is ideal first-line diagnosis for the patient (Arai et al., 2022).

Devices	Diagnostic accuracy	Special resolution	Time Resolution	Investigation speed
MCG	+ + +	+ +	+ + +	+ + +
ECG	+	+	+ + +	+ +
Echo	+ +	+ +	+ +	+ +
SPECT	+ +	+	-	-
CT	+ +	+ + +	+	+ +
MRI	+ + +	+ +	+	-
PET	+ + +	+ +	-	-

The best way to reveal these weak signals is to use a SQUID, which converts the magnetic field flow measured in the quantum limit into measurable signals (Van Leeuwen et al., 2004). This process is shown in Figure 4.

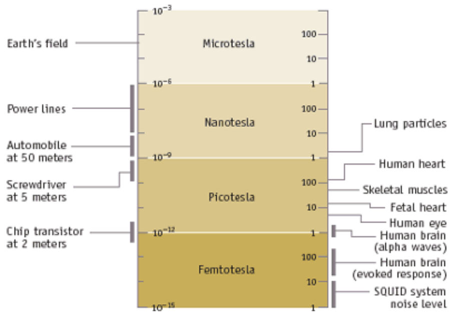

Fig 4: Objects with different magnetic field size can be seen in the figure.

In this way, SQUIDs are the only measuring devices that are capable of measuring the magnetic field in the quantum limit of the femtotesla order. Therefore, SQUIDs are one of the most sensitive magnetic field measuring devices.

SUGGESTIONS

- ✓ According to the result of this research that showed Magnetocardiography is the most advanced and accurate device for heart patients. It is useful for diagnosis, accuracy, high speed and short time, it is suggested to take appropriate steps toward educating medical staff for the better human treatment.
- ✓ In Afghanistan we have many heart affected diseases patients, It is suggested that governmental and non-governmental medical organizations to use magnetocardiography.

- ✓ It is suggested that governmental and non-governmental medical organizations the use magnetocardiography device heart affected diseases which does not cause any harm to the patients, as compare to other technologies.

DISCUSSION

The first application of magnetocardiography was tested on the human body in 1974, and then it was used for geomagnetic studies, mining and other medical biology studies. So far, various sensors have been identified to measure the magnetic field, but the squid sensor is the only device (Fioranelli, M et al, 2022). It is a sensor that is able to record the magnetic field at the quantum limit of the order of femtotesla. Since biological cells signals have a very weak magnetic field, only the squid sensor is placed in the range of these fields and is able to measure with high sensitivity and resolution.

The human body produces very small magnetic fields, the measurement of which is very important in the diagnosis of diseases and bio magnetic applications. Using this tool, small quantum magnetic fields of femtotesla can be measured at low temperature and converted into electrical signals (Parimita Swain et al., 2020). It should be noted that in this article, the definition of information content is based on the slope of singular values. This meta-analysis does not account for differences in sensitivity to spatial resolution or localization errors due to errors in the trunk model or cardiac motion (Hänninen et al., 2001). It confirms the power of this device to identify coronary artery stenosis (more than 70%) in a population with a pre-test risk of disease ranging from 27.7% to 43.4%. The subjects included in the trial were outpatients who visited their doctors for evaluation. Physicians used commonly available tools, including available stress ECG methods, to decide whether to refer a patient for coronary angiography, without knowing whether the patient was a candidate for or included in the MCG study (Bhat et al., 2023).

The study of MCG was not intended as a screening device, but the main focus was on its potential as a diagnostic method for relevant coronary artery stenosis. Analysis of a resting ECG, including a 12-lead ECG, is usually less sensitive in detecting ischemia or coronary occlusive disease in low-risk preclinical patients.

CONCLUSION

Today, the magnetocardiography device is very accurate to the electrocardiography device for heart patients, and the use of this device does not cause any harm to the patients, as compare to other technologies which has mention above in the table .1, it has been obtained that MCG is a modern and advanced device technology. Magnetocardiography is the most advanced and accurate device for heart patients. It is useful for diagnosis, accuracy, high speed and short time. A comparison of conventional sensor arrangements (MCG/ECG) and optimized sensor arrangements was made by determining the slope of individual values. It is shown that optimized sensor combinations allow the reconstruction of more source patterns by minimizing the slope of the individual values.

CONFLICT OF INTERST

The authors declare no conflict of interest.

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