Recent advancements have been made in the methods for medical examinations of the heart involving electrophysiological activity. Magnetocardiography will soon replace the electrocardiogram as the primary means for diagnosing defects and other phenomena surrounding the heart. Magnetocardiography (MCG) allows for the testing of patients without the requirement of leads, contrast agents, or injected tracers. Unlike an electrocardiogram (EKG), however, magnetocardiography cannot record data while a patient is actively exercising. In an electrocardiogram or stress test, it is important that the heart is actively engaged. Exercise induces a measurable stress on the heart which helps to diagnose the heart's condition. The objective of this project has been to design an exercise mechanism that allows patients to be actively engaged throughout the magnetocardiographic procedure. The design process began with research of magnetocardiography and the heart, and moved towards designing a system that could function around the characteristics associated with magnetocardiography. Below is an image of an actual test conducted with MCG. The image on the right is that of a standard EKG test.

**Introduction**

For over 100 years, the first diagnostic test performed in the evaluation of a patient has been the electrocardiogram (EKG). An inexpensive, non-invasive, and relatively portable procedure, the electrocardiogram has shown to be a functional method in determining stress in its relation to the heart. However, even as ubiquitous and as useful as the electrocardiogram has been, it fails to provide complete information about the electrophysiological activity of the heart especially in its detection of coronary artery disease. Electrical current in the heart is the driving force by which the heart operates, and the EKG is nothing more than a limited recording of the heart’s activity. The waves that appear on an EKG primarily reflect the electrical activity of the myocardial cells, of which there are many. Perturbations in the normal electrical patterns as seen in an EKG allow one to diagnose many different cardiac disorders without being able to pinpoint an exact disorder or defect.

More recently, developments have been made that allow for procedures that were once used in measuring currents of the heart muscle that are generated by local magnetic fields though never coming in contact with the body. The same currents create electric potential differences on the body surface of a patient and can be measured by conventional electrodography. By measuring the Z-component of local magnetic fields simultaneously at 36 positions in a plane over the heart, MCG can provide 3D source localization as well as quantitative estimates of electrophysiological parameters with accuracy good enough for clinical use.

**Characteristics**

MCG can make measurements with astounding accuracy. However, it has been confirmed that radio frequency can be a major cause of problems. The proximity of metallic objects, or other pieces of electronic equipment can interfere with the ability of MCG to gather a “clean” signal. Furthermore, movement of rotating parts creates magnetic artifacts that are visible as baseline periodical displacement that can impede MCG recording efforts. Although digital filtering of noise has been shown to still allow for data to be collected in real time, the direct presence of a concurrent magnetic field by secondary objects can cause a failure in the acquisition of data. A secondary effect occurring MCG is movements of the chest and heart due to respiration and pumping action. It appears to be essential for the localization accuracy to perform all measurements with the patient on the bed under the same conditions with little movement. The third characteristic is exercise. In any exercise, extending through the full range of motion is necessary to induce the greatest amount of stress on the heart and body.

**Critical Requirements**

As a result of the aforementioned characteristics, the mechanism has been designed with the following parameters in mind:

- All parts should be non-metallic or the design should contain the least amount of metallic components as possible
- Rotation of parts is prohibited due to the creation of disrupting magnetic fields
- Full body activity should be kept to a minimum
- Full range of motion is desirable in order to maximize stress on the heart
- Resistance in exercise action is critical to inducing stress

**The Design**

The principle behind this design is similar to that of a bellows. The function entails nothing more than forcing air into and out of a designated volume of space. Air is displaced from the bellows by applying a compressive force. The compressive force in this instant will be the extension of a patient’s leg against the bellows. This necessary force is lifted work, and will be generated by the patient.

**Principle of Operation:**

Air is forced towards a hollow space cut into the base-plate where it exits through two of the four holes known as outlets. Upon complete compression of the bellows, air will re-enter the space through the two inlet holes. One-way valves in each of the holes ensure that air does not escape or re-enter at inappropriate moments. A linear compression spring is perched inside of the bellows as a means of returning the bellows to its original position. Resistance is created by controlling the diameter or each of the four holes. Nozzles are threaded into each of the exit/entry points. By varying the exit/inlet diameter or each nozzle, the volume flow rate of the air also varies, thus creating different levels of resistance that can be imparted on the patient.

**Materials:**

- The base-plate, valves, and nozzles can all be manufactured from hardened plastics of other composite materials. The bellows are produced from a soft thermoplastic with deformation and elastic properties. The springs will be produced from brass due to its low metallic signature.

**Methodology of Magnetocardiography**

By using a Superconducting Quantum Interference Device, magnetocardiography can measure ionic currents of the heart muscle that are generated by local magnetic fields through never coming in contact with the body. The same currents create electric potential differences on the body surface of a patient and can be measured by conventional electrodography. By measuring the Z-component of local magnetic fields simultaneously at 36 positions in a plane over the heart, MCG can provide 3D source localization as well as quantitative estimates of electrophysiological parameters such as arrhythmias or abnormalities of ventricular repolarization. The following image presents the positioning of the sensors.

**Results**

The final design adheres to the characteristics and requirements as previously described. There are no moving or rotating components in which friction between parts could lead to the creation of magnetic fields. Material selection has also limited the possibility of interference with data acquisition. As shown by the accompanying SOLIDWORKS model, the design is relatively simple. The number of parts is low and construction is of relative ease. Scaled models of the design show it to be an effective means of exercise. Success can be measured once the system has been implemented into the magnetocardiographic environment.

**Conclusions**

In conclusion, there is still more work to be done. The final phase of the design cannot be established until all of the design requirements have been satisfied. Those further requirements include incorporating adjustability to the design so as to accompany for all patients. Furthermore, the design does not include a plan for how it will be integrated into the current test bed. No final design can be produced until these conditions have been sated. The original goal of this project was to create a design that satisfied all of the conditions and could be put into production form. However time constraints have limited the scope to the design of only the exercise segment. It is hoped that the work already accomplished will lead to the creation of a final design in the near future.

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