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Single Arm ECG System Acquisition Sites for Monitoring Applications

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Abstract*: *Electrocardiography (ECG) is the procedure by which the heart's electrical activity is recorded. The resulting electrocardiogram provides an insight into the various physiological activities of the heart, including the heart rate and the status of the heart. This work analyses single arm ECG system which uses two dry electrode material, namely copper and nickel of dimension 3 cm x 3 cm x 0.5 mm for the acquisition of ECG signal. The criteria for the selection of dry electrodes in this study are availability, cost, toxicity, impedance and conductivity. For this study, five ECG acquisition sites from the left arm are tested and the heart rate is calculated using National Instruments Biomedical workbench software. For this study, a total of 5 subject's reading are taken. The position of the positive and negative electrode is fixed on the left arm referencing the base paper. Only the position of the reference electrode is changed which are, (i) straight line configuration (between the two leads), (ii) triangle configuration (7 cm diagonally below the two leads), (iii) wrist configuration, (iv) palm configuration (at the centre of the dorsal side or back of the hand), (v) elbow configuration. Using these sites, the best position for obtaining ECG is found to be: (i) wrist configuration, (ii) triangle configuration, and (iii) straight configuration. It is concluded that the best material for the acquisition of the ECG signal is Copper and stable output obtained from the wrist, triangle and straight configuration compared to the other two.

Index Terms*: *ECG, Acquisition Sites, Dry Electrodes, Single Arm.

I. INTRODUCTION

Electrocardiograph, being the instrument is used for acquiring the signal shown in Fig. 1. It is done by placing electrodes on different parts of the body. Conventionally, 12 lead system is used to extract and process the signal. All the 10 electrodes are placed over different parts of the body to obtain the 12-lead information.

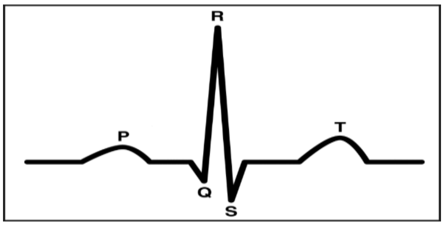

Fig. 1 A basic ECG waveform

In one of the paper discusses the different way of acquiring the ECG signal from the human body [1].

A lot of research work has been done in the field of ECG. An existing work clearly explains the effects of different positions of electrodes [2]. Even extensive work has been done in acquiring the single arm ECG. This system is cost-effective, portable and hassle-free [3]. A study regarding the locations apt for the acquisition of ECG from the left arm and right arm is presented [4]. Also, the most suitable dry electrode material of a specified dimension has been studied and concluded [4]. Another work clearly explains the negative impacts of wet electrodes, as it leads to skin irritation, scars [5]. The importance of two electrode system regarding the patient safety which involves the needs of the double ended amplifier with high CMRR and the comparatively low input impedance is present [6]. Some of the other papers also use two electrode technique to acquire the ECG signal [7], [8]. There are various studies showed the acquisition of ECG from the subject's arm using flexible print circuit and using Electric Potential Integrated Circuit (EPIC) sensors [9], [10]. Recently a low-power wearable device based on single-arm ECG is developed for sport monitoring application [11].

The main aim of this study is to find the various ECG acquisition sites on Left Arm. Five configurations have been taken for this study. The requirement of such configuration will enable easy access of the electrode site, mobile point care of technology, and portable system.

II. METHODOLOGY AND MATERIALS

A. Block Diagram

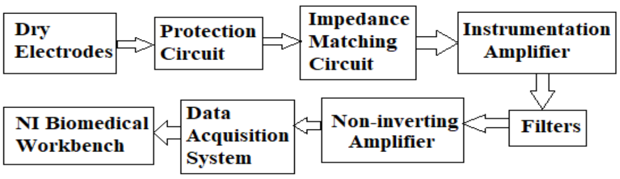

Fig. 2 Block diagram of the system

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Fig. 2 shows the block diagram of the ECG acquisition system. Dry electrodes are used to pick the ECG from the left arm [4]. In Fig. 2, a protection circuit prevents dangerous or excess amounts of temperature, current or a short circuit in a conductor. It safeguards the hardware circuit, the user and the operator as well. A voltage follower (known as a buffer amplifier) effectively removes the impedance mismatch at the input.

IC OP07 has been used with a gain of 1. To increase the signal strength, a preamplifier (instrumentation amplifier) is used which helps to obtain the bio-signal without any common mode noises and gain set as required by the user. Here AD620 has been used as a preamplifier with a gain of 500. After the instrumentation amplifier, various filters are used to remove the noises from the signal. The filters used are High pass filter, low pass filter and notch filter. A second order Butterworth high pass filter is used with a cut-off frequency of 2 Hz. An eighth order Butterworth low pass filter is used with a cut-off frequency of 40 Hz. The notch filter is used to remove the power line 50 Hz noise. After all the filters, a non-inverting amplifier is used which have a variable gain setting as gain can be changed from subject to subject for obtaining readings. It performs the function of amplifying the incoming signal depending upon the gain value set. For data acquisition system, NI ELVIS (National Instruments Engineering Laboratory Virtual Instrumentation Suite) is used which is interfaced with the biomedical workbench for recording the signal and also to find the heart rate of the recorded ECG as shown in Fig. 3. In Fig. 3, part 1 depicts data logger which is used to record the ECG, part 2 depicts the ECG feature extractor and is used to obtain the heart rate and finally, part 3 is the Heart Rate Variability, which is used to obtain the mean heart rate.

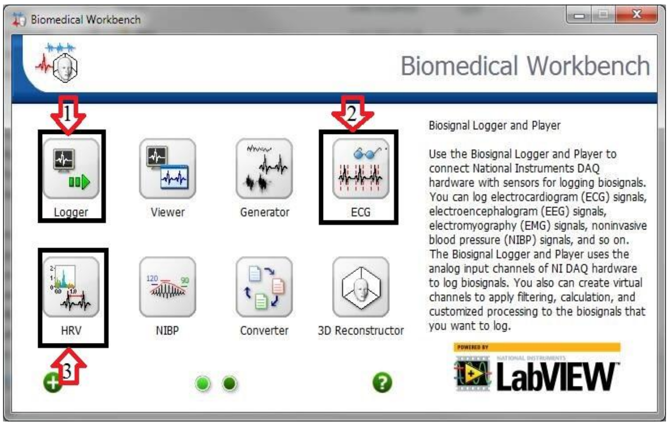

Fig. 3 Biomedical Workbench Interface

B. Materials

Generally, two types of electrodes are in use nowadays: wet electrodes and dry electrodes. Bio-potentials from patients are usually measured using wet disposable electrodes. Though they provide the excellent signal quality, they are irritating for long term use. To overcome these difficulties, the usage of dry electrodes to acquire the heart rate is the focus of this project. Dry electrodes are more favorable because they can be used without gel, no more skin irritations, are reusable and long lasting. Dry electrodes used in this work are copper and nickel. In Fig. 4, A depicts nickel electrode and B depicts copper electrode. The dimension of electrode materials used in this study is 3 cm x 3 cm with a 0.5 mm of thickness as Fig. 4.

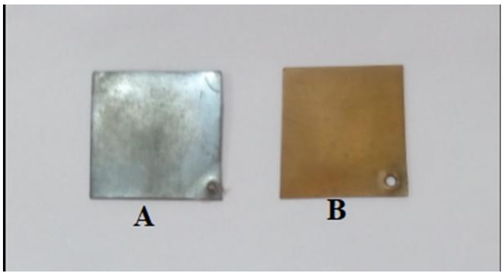

Fig. 4 Dry Electrode Material

C. Positioning of Electrodes

The study involves the acquisition of ECG signal from five positional configurations of the left arm. For the placement of electrodes, the left leg electrode corresponds to the positive electrode, the right arm electrode corresponds to the negative electrode and the reference electrode which is the right leg electrode, corresponds to the ground.

The first configuration involves placing the electrodes in a triangle fashion. The positive (LL) and negative (RA) electrodes are placed at 2 cms distance from either side of the armpit and the reference electrode (REF) placed approximately 7 cms diagonally below the other two electrodes as shown in Fig. 5.

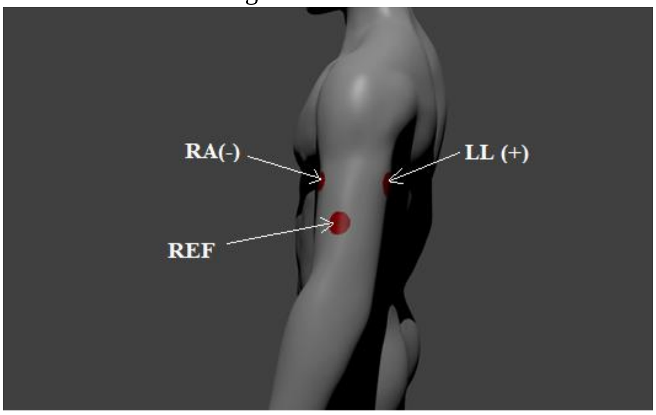

Fig. 5 Triangle Configuration

The second one is the straight-line configuration in which all the three electrodes, i.e. positive (LL), negative (RA) and reference (REF) are placed in a straight line as shown in Fig. 6.

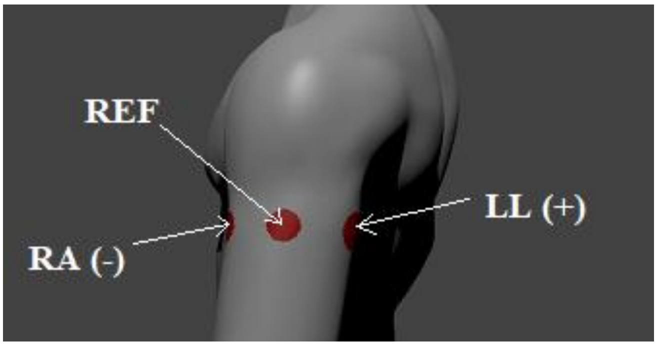

Fig. 6 Straight- Line Configuration

The elbow configuration involves the reference electrode (REF) to be placed on the elbow (inner folding side) as shown in Fig. 7. The other two (RA and LL) are placed near the armpits of the left arm as same as in Fig.

5 and Fig. 6.

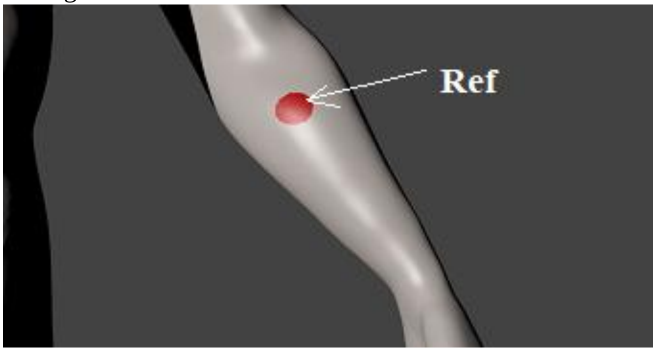

Fig. 7 Elbow configuration

The wrist configuration involves placing the reference electrode (REF) on the wrist as shown in Fig. 8, the other two on the same fixed location, i.e., near the armpit.

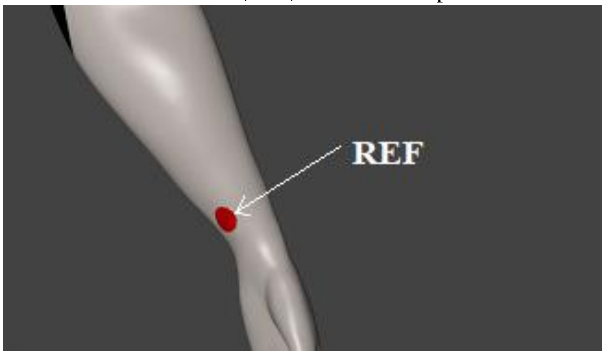

Fig. 8 Wrist configuration

Lastly, the palm configuration involves placing the reference electrode (REF) at the centre of the dorsal side or back of the hand as shown in Fig. 9.

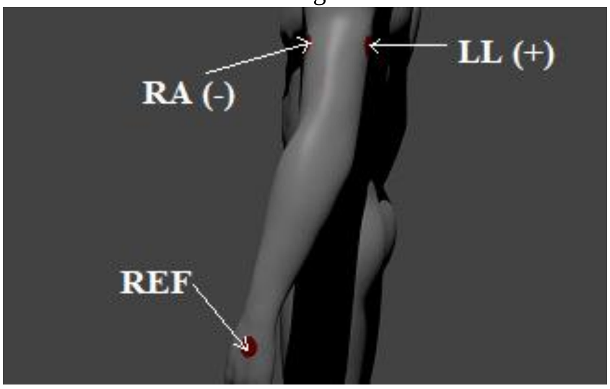

Fig. 9 Palm configuration

III. RESULT

Table 1 indicates the notations used for the five-reference electrode positions used in this study.

Table 1 Notation used for five-reference electrode position

Notation	Position
1	Elbow
2	Wrist
3	Palm
4	Triangle
5	Straight

A. Copper

The following ECG waveforms were obtained for the five different reference electrode positions using copper. Refer Table 1 for identifying the notations used. ECG feature extractor is used to calculate the mean heart rate.

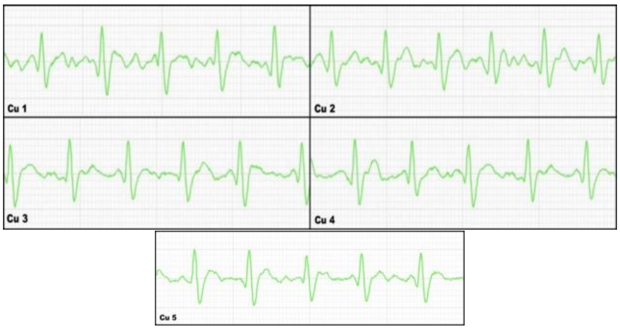

Fig. 10 Output ECG obtained for five reference electrode positions for subject 1 (Copper)

Fig. 10 shows the output ECG obtained using copper electrode.

B. Nickel

The following ECG waveforms were obtained for the five different reference electrode positions using Nickel in Fig. 11.

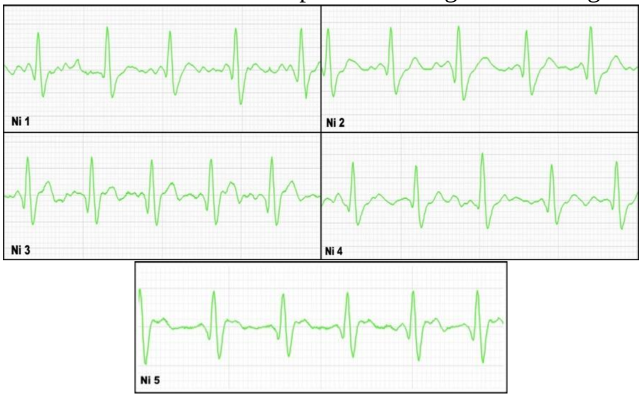

Fig. 11 Output ECG obtained for five reference electrode positions for subject 1 (Nickel)

Fig. 12 and Fig. 13 shows the mean heart rate comparison for all subjects using copper and nickel electrode.

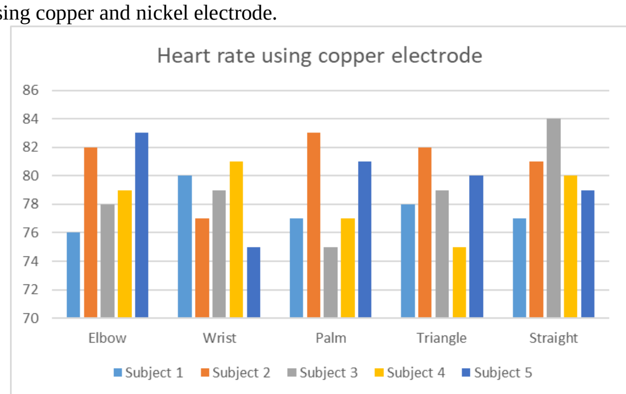

Fig. 12 Heart rate bar graph (copper electrode)

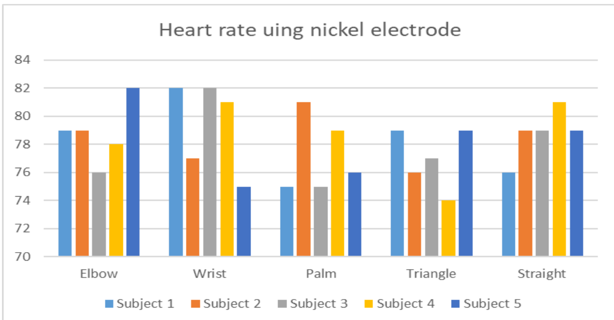

Fig. 13 Heart rate bar graph (nickel electrode)

IV. DISCUSSION

For all the five positions for both copper and nickel electrode, a non-inverting gain of 11 is used. Using copper, reasonable signal strength is obtained as shown in Fig. 10 and acquisition time is less. The signals are logged using biomedical workbench tool. Nickel takes more acquisition time. However, when it starts acquiring the signal, the signal strength and quality are better than that of copper. The heart rate obtained from subjects (shown in Fig. 12 and Fig. 13) all fall on the normal range that is from 72 to 90 beats per minute. It is found that copper output is more stable than the nickel output and moreover reliable output obtained from the wrist, triangle and straight configuration compared to the other two.

V. CONCLUSION AND FUTURE SCOPE

The main objective of this study is to acquire ECG from different positions of left arm for monitoring purposes using dry electrode materials. Two different dry electrode materials i.e., Nickel and Copper of dimension 3 cm x 3 cm of thickness 0.5 mm has been tested on five healthy subjects in a relaxed state. By analyzing the results, it has been found that copper is a better material for acquiring ECG from all the five positions of the left arm. However, nickel gives good signal amplitude when acquired but is very unstable and thus, acquiring signals from nickel is a challenge. The position which provides a distinguishable R-R interval in the ECG signals obtained among the five includes wrist configuration, triangle configuration and straight configuration.

In the future, Cupronickel metal can be used which consists of copper and nickel in varying proportions to acquire ECG. It is expected that cupronickel will give clear, distinguishable ECG signal of a good amplitude. And lastly, making the device wireless.

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Oinam Robita Chanu is currently working as Assistant Professor in the Department of Biomedical Engineering, SRM Institute of Science and Technology. She received the Master degree from the Manipal Institute of Technology, Manipal in 2012. She joined Assistant Professor at the Bharath University, Department of Biomedical Engineering in 2013 till May and moved to SRM Institute of Science and Technology, Chennai in June 2013. Her work at this institute is teaching, academic administration and research focus on investigation and development on medical devices, biomechanics, medical imaging techniques on segmentation and bio-implant.