Influence of Electrode Quantity on Bioimpedance Based Cardiac Diagnosis

[1]Sheeba Santhosh, [2]G Hari Krishnan, [3]T. Sudhakar, [4]G Umashankar, [5]G Mohandass

[1]Department of Electronics and Communication Engineering, Panimalar Engineering College, Chennai, India

[2]Department of Electrical and Electronics Engineering, Sree Vidyanikethan Engineering College, Mohan Babu University, Tirupati, Andhra Pradesh, India.

[3]Department of Biomedical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.

[4]Department of Biomedical Engineering, GRT Institute of Engineering and Technology, Tiruttani, Tiruvallur District, Tamil Nadu, India.

[5]Department of Biomedical Engineering, Agni Institute of Technology, Chennai, India.

Corresponding Author: haris_eee@yahoo.com

ABSTRACT:

In making a diagnosis, the placement of the electrodes is crucial. ECG, EEG, and other electrical signals produced by the human body serve as crucial diagnostic indicators. By carefully choosing an electrode and placing it on the surface of the human body, bio-impedance signals can be acquired without noise. The electrodes placement location and type of electrode used are crucial factors in electrical bioimpedance diagnostics, which are used to identify a variety of disorders. In impedance measurements, minimum two electrodes are required to acquire the biomedical signals obtained from body tissue through skin surface placement for voltage measurement across the two electrodes. Various electrode methods for bioimpedance cardiac observation are examined in this research depending on the electrodes that are used, where they are located on the human body, and where they are placed.

INTRODUCTION:

Using bio-impedance analysis, numerous functional body vital signals have been identified. Essentially, it measures the resistance to electricity passing through tissues [1] and [2]. There were numerous methods proposed to determine the impedance variation [3, 4, and 5]. Electrode placement on the body surface is the only factor that influences impedance measurement. Impedance diagnosis fundamentally passes the electrical current through the tissue region with the help of surface electrodes in a non-invasive approach, which further alters the impedance and is measured in terms of voltage drop across the two electrodes. [6] [7]. The electrode system can be categorised in a number of ways depending on the electrodes needed to measure cardiac impedance [8, 9].

Two Electrode Systems

The relatively simple way to determine impedance uses two electrodes and is also referred to as the bipolar method. It uses both electrodes to inject current into the surface of the skin, and the two electrodes also detect voltage changes on the body surface [10] [11]. During impedance measurement the skin surface contact impedance should be greater than the electrode impedance for efficient measurements. The summation of the electrode impedance the body surface skin contact impedance results in impedance transition [12] [13] [14]. The electrode-electrolyte impedance rises above the body surface as electrolyte is applied on the skin surface for impedance measurement, leading to wrong measurement with low frequency signals [14] [15]. The issue of internal consistency and high reliability arises, and at higher frequencies, parasitic capacitance has a negative impact on the diagnosis [16] [17]. As a result, the evaluation of soft tissues with a two-electrode system has mainly been used in skin and dental application domains [18].

Tri-Electrode systems:
In order to increase the surface area of the electrode and also to diminish the bio-impedance interference, the four electrode workplace conditions can be changed to a Tri-electrode mode.

Penta-electrode systems:
The disadvantage of frameworks is that they have a higher voltage and a lower CMRR at lower frequencies. The electrode impedance must be reduced as a result, and the input impedance must be precisely matched to the impedance of the instruments being used. Common mode can be made less noticeable by utilizing a five-electrode measuring system that significantly lessens the impact of common voltage.

Tetra-electrode Systems:
Tetra polar method is another name for systems with four working electrodes. It uses four electrodes, as the name would imply, to measure bio-impedance. Two electrodes are used to give input signal, allowing current to be injected through non-invasive surface electrode to read the tissue region, and a different pair serves as an output electrode, allowing the measurement of the voltage sensed by the body surface. Therefore, the electrode-electrolyte impedance effect has no bearing on the measurement in this method. However, its impact might be quite significant at lower frequencies. The parasitic capacitance across the two electrodes diminishes the conduction on the surface for larger frequency values. The input capacitance of the instrumentation itself and the stray capacitance across the impedance measuring electrodes are responsible for parasitic capacitances. Despite its drawbacks, the tetra-electrode mode is the most popular way to obtain the bio-impedance signal because it is a practical technique.

The impedance measurement with tetra electrode system is given in equation (1) with error impedance and voltage drop.

$$Z_T = \frac{(V \times CMRR_E) + (I \times Z_E)}{CMRR_E \times I} \quad --- (1)$$

ZT can also be written as given in equation (2) with respect to voltage, current, Impedance and common mode rejection ratio CMRR.

$$Z_T = \frac{V}{I} + \frac{Z_E}{CMRR_E} \quad --- (2)$$

The fact that the five-electrode system generates more noise is one of its main disadvantages. As a result, it is not used to measure living tissues and is primarily used to measure low conductance of homogeneous material [41].

The environment, the measuring system and incredibly weak bio-potential sources during signal acquisition cause issues when attempting to extract the internal generated human electrical potential. Invasive microelectrodes, wire electrodes, or noninvasive skin surface electrodes are the three categories of electrodes used for biopotential measurement. The most common types of metal surface electrodes used as biopotential electrodes are surface electrodes for applying signal and measuring in limbs, metal disc electrodes, disposable foam-pad electrodes (like those in figure 1), and metallic suction electrodes (like those in figure 2).

(a) (b)

Figure .1 Surface electrodes (a) Disposable and (b) Suction-cup

These kinds of widely used electrode systems use 8 electrodes, as shown in the figure. To provide source signal through the neck area near and the lower limb, four electrodes are used. Figure 3 illustrates the positioning of the electrode in traditional approach.

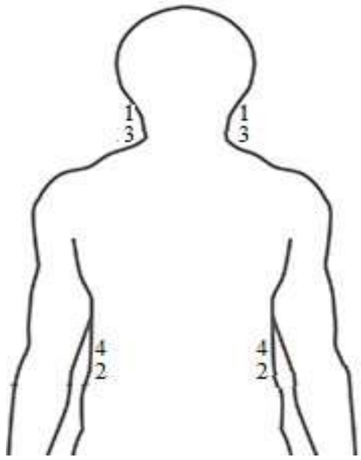

Figure .2 Electrode placements for impedance diagnosis using 8 electrodes

The Classical Impedance Cardiography approach which uses eight metal surface electrodes located at neck and lower part of chest with operating frequency of 100Hz as shown in figure 2. A one volt, 100 Hz source signal is applied across electrodes 1 and 2. The use of electrodes 3 and 4 to gather tissue response to electrical current application.In Bio-impedance based plethysmography approach disposable electrodes are used at hand wrist region using four electrodes at an operating frequency of 50 to 100Hz. Clip type electrodes are used on hand palm and foot region for quantifying body composition with operating frequency between 50kHz to 200kHz.

Table .1 Voltage equivalents to Bio-impedance for different electrode modes

Method	Number of Electrodes	Min value in volts	Max value in volts
Di-electrode mode	2	0.760	0.854
Tri-electrode mode	3	0.924	1.032
Tetra-electrode mode	4	1.056	1.245
Penta Electrode mode	5	1.386	1.659

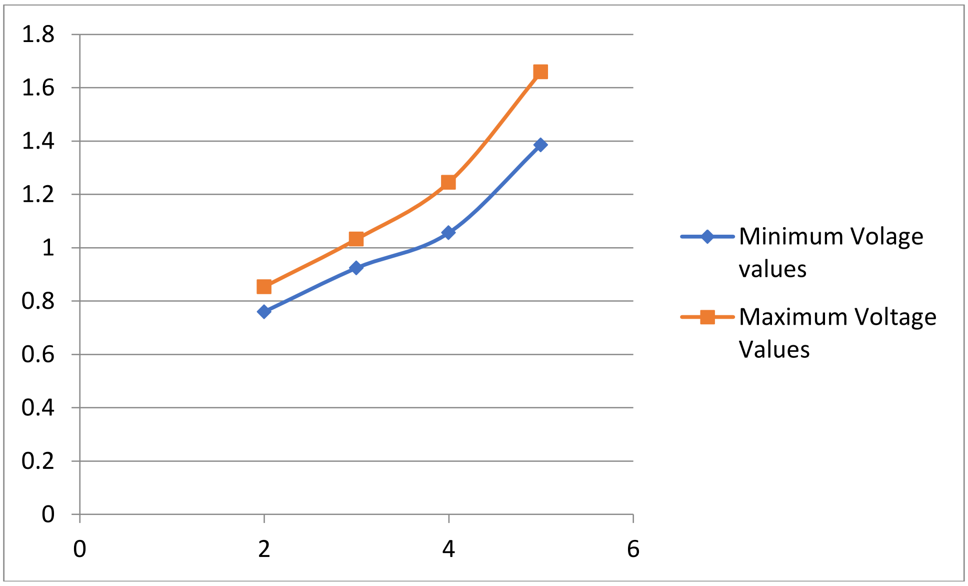

Figure .3 Voltage drop variation with respect to type of electrode mode

Basic experiment was conducted with 50 bio-impedance measurement in terms of voltage drop were taken from 50 individuals including male and female with different age groups between 18 to 45 years. The experimental data were categorized in to four groups based on the quantity of electrodes used. The voltage values with respect to the impedance were tabulated as shown in table 1. The graph was plotted between type of the electrode system and the impedance equivalent voltage drop values as shown in figure 3. It has been observed that higher the number of electrodes used for the measurement of bio-impedance higher the accuracy of the measurement.

CONCLUSION:

Comparative analysis was conducted on the bio-impedance electrode systememployed for bioimpedance cardiac diagnosis todifferentiate the variations in impedance signal caused by electrode placement. When specific cardiac diseases are diagnosed using the right electrode system, the patient's condition can be diagnosed with high accuracy. Comparing impedance cardio graphs to traditional electrocardiography measuring systems, highly accurate diagnoses can be made because impedance cardio graphs depend on volume. It has been observed that higher the number of electrodes used for the measurement of bio-impedance higher the accuracy of the measurement.

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