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Impact of Electrodes Separation Distance on Bio-impedance Diagnosis

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Bio-impedance diagnosis depends mainly on two factors first being the location of electrode placement and second being the distance between electrodes. To minimize the errors caused during bio impedance measurement at variable frequencies, it is required to study the electrodes used for the measurement and its exact location where the electrodes are placed. This paper analyses various electrode separations used for bioimpedance measurement for cardiac signal. The electrode system is used based on the type of tissue under consideration for measurement. It is found that the errors are dependent on the frequencies at which the measurement is carried out and it also depends on the intensity of current applied. Thus, selection of current and frequency is very important for measurements. In this paper, the impact of size, distance and location of the electrodes that can be used for bio-impedance cardiograph.

Keywords: Bio-impedance, electrode configuration, Bio potential measurement, Electrodes distance, Magnitude and Impedance Analyzer.

Techniques used in bioimpedance methods completely depend on the application of low intense high frequency current on the surface of a tissue[1,2]. These electric current produces a voltage drop which is basically caused due to variation in impedance of the tissue under test. Tissues or the medium acts as a conductor which can produce different impedance values based on the composition of the underlying tissues or cells[3,4]. These impedance values can be utilized for studying various physiological and pathological changes of the tissues that can provide information about the conditions of the tissues[5].

One of the most popular application of bioimpedance technique used is the analysis of bioimpedance of cardiac signal for the detection of cardiovascular diseases[6]. All types of measurement are conducted by the use of an effective electrode system. An electrode is basically an electro-chemical interface which acts as abridge to connect the tissue or cells to measuring instruments[7].

Figure 1 shows the generalized model of the electrodes. 'E' represents the potential between the electrode and the electrolyte, 'R' represents the resistance associated with the conduction current and 'C' represents the displacement current and 'Rskin' is associated with the conduction losses from the electrolyte. Electrodes are available in different sizes. Most commonly used electrodes used for bioimpedance measurement are available in mm diameter for the ease of comfort for the subject[8,9].

Bioimpedance diagnosis depends on proper selection of electrodes type, region of electrodes placement and distance of separation between electrodes. Researchers in Bio-impedance focus mostly on location of the electrode placement depending on the part of human body to be diagnosed and type of electrodes used (Benjamin Sanchez et al., 2016 & Eiko Priidel et al 2020). Nonuniformly spaced electrodes were studied with intra class correlation between electrode placement and qualitative estimation. EIM reproducible depended minimum muscle length based electrode position (Benjamin Sanchez et al., 2016). For accurate diagnosis electrode separation distance plays a vital role in addition to selection of region for placement of electrodes based on the disease type. Proposed work focus on the analysis of electrodes separation distance impact on measured bio-impedance data. Work flow starts with electrodes type and electrode placement location for measurement of bio-impedance later experimental data analysis based on electrode separation distance.

Electrodes are made of variety of materials. Most prominent materials used are copper, titanium, silver, platinum, etc. Silver-Silver Chloride electrodes are popularly used in much bioimpedance measurement system. Electrodes can be further classified as gel electrodes, capacitive electrodes, and active electrodes. Bioimpedance measurements depend on the number of electrodes selected for the measurement of bio potential signal. Based on this, the electrode system can be classified as:

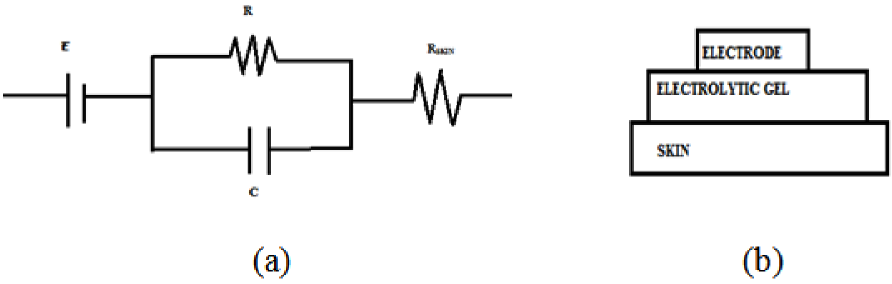


Fig. 1. (a) General Model of Electrode (b) Electrode Skin Interface

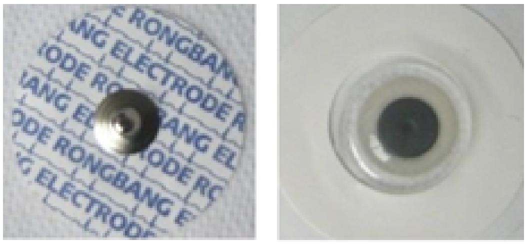


Fig. 2. Disposable ECG surface electrodes

Bipolar Method

It is the cheapest and most common configuration used for the measurement purpose.

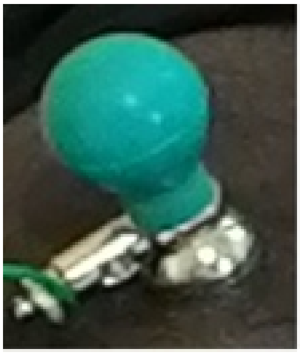


Fig. 3. Suction cup metal surface electrodes

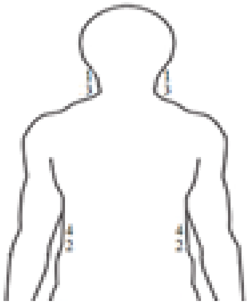
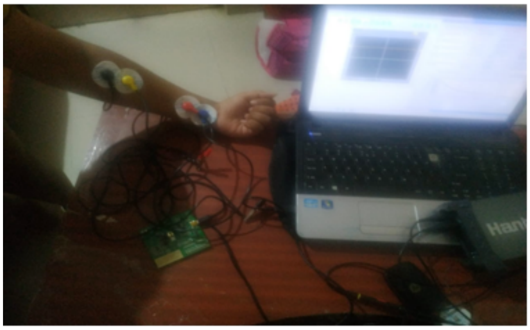


Fig. 4. Conventional Electrode Configuration for Cardiac Impedance Measurement

It utilizes two electrodes; both can be used as injecting electrodes and measuring electrodes. Since, both electrodes acts as input and output electrodes, measurement of bioimpedance leads to interference [10,11]. It gives better result only under the condition that the impedance of electrode should be lesser than the impedance of the biological medium. The problem with this configuration is that reading has to repeated and taken many times to set the accuracy of the values obtained[12,13]. At higher frequencies parasitic capacitance effect worsens the measurement. Therefore, this method is restricted to low frequency application and not used for analysis of soft tissues[14,15].

(a)



(b)

Fig. 5. (a) Electrode configuration and (b) Experimental setup for Bio-impedance diagnosis with electrodes placement

Tetrapolar Method

It makes use of two pair of electrodes, one pair of electrodes are considered as input electrodes and another pair of electrodes are considered as output electrodes. Input electrodes are used to apply a low intense high frequency current generated from a current source into the biological medium. These current disturbs the ionic movements underlying the tissue and thereby produces variation in the impedance of the tissue. Output electrodes sense the variation of the impedance in the form of voltage change [16]. It works well at high frequencies reducing the effect of electrode-electrolyte impedance change. Most popularly used in the analysis of soft tissues. Another most important aspect of bioimpedance measurement is the position where electrodes are placed [17]. For cardiac signal measurement, electrodes can be positioned at various locations [18]. In general surface electrodes are used and are further classified as shown in figure 1 and figure2

For bioimpedance measurement 8 electrodes are used, four electrodes are used to inject input current and four near the lower limb region. The electrode system configuration for conventional Cardiac Impedance measurement is shown in figure 4.

Impedance Plethysmography method utilizes disposable electrodes for measurement. This It uses 4 electrodes which are placed on the wrist to measure bioimpedance signal. This measurement is carried at high frequency analysis. A current signal of 5mA with frequency

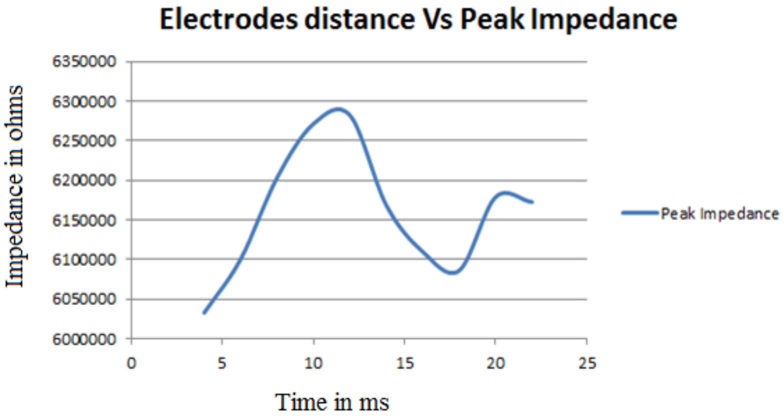


Fig. 6. Peak impedance variation with respect to electrodes distance

sweep of ranging between 500 Hz -5.5kHz with increment of 500Hz is used as input excitation signal. Two electrodes acts as input electrodes and two electrodes act as output electrodes. This method measures the impedance change due the blood volume changes along a segment. The change in blood volume is related to the electrical conductivity.

EXPERIMENTAL METHODS AND RESULTS

Experiment were conducted using AD5933EBZ evaluation board by Analaog Electronics. Initial configuration were done with start frequency set at 500Hz, Delta Frequency 50Hz with number of increments was set at 100. During frequency sweep each frequency value will stay for 14seconds. Input exciation signal was set to sine wave of 2V peak to peak. Proper calibration was carried out by setting the value of feedback resistance between Vin and Vout voltage nodes for getting un distorted impedance wave.

Once the initial configuration was done program device register was loaded with the set values and made the setup to calculate the value of gain factor. Frequency sweep option was selected to excited the part upder study with differenct set frequencies. After taking the readings for a electrodes placements at a particular distance (22 cm initially) the electrodes are removed and distance between electrodes were changed to 20 cm and same procedure to get frequency sweep was done and readings were tabulated as given in table 1

Table 1. Experimental data with different electrodes placement distances

S. No	Electrodes distance in cm	Peak Impedance	Phase	Magnitude
1	22	6172563	9.641915	6732.603
2	20	6178830	11.04035	6530.755
3	18	6086207	11.48377	6489.356
4	16	6109916	6.818947	6344.05
5	14	6168390	12.3733	6314.951
6	12	6282094	13.05496	6028.763
7	10	6271306	13.18936	6020.925
8	8	6203427	7.741548	6000.469
9	6	6100504	7.577627	5858.264
10	4	6032968	7.324137	5955.906

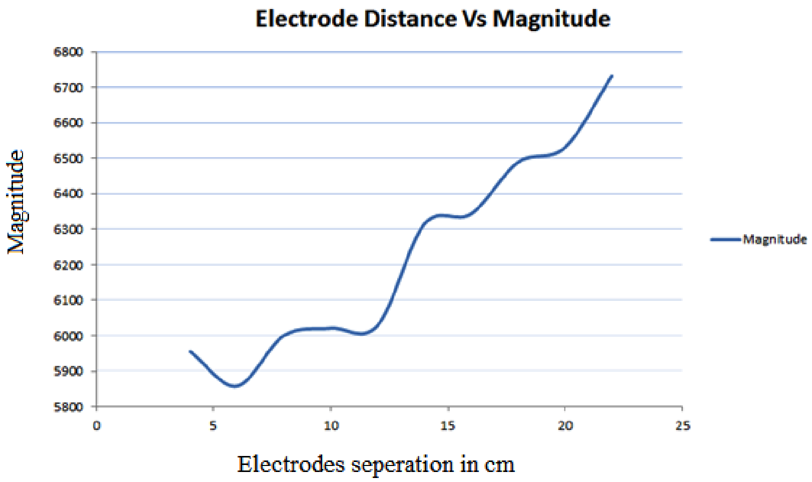


Fig. 7. Magnitude variation with respect to electrodes seperation

Graphs were plotted between electrodes distance in x-axis and its corresponding variation in magnitude and peak impedance value were plotted in y-axis as shown in figure 6 and figure 7. From graph it has been observed that magnitude varies linearly with respect to the variation in distance between electrodes as distance increases peak magnitude increaes. It has been observed that resonance frequency where peak magnitude was obtained varies between 1700Hz to 1800Hz for various electrode distances.

CONCLUSION

Analysis on electrodes placement with respect to distance was performed. The deviation in impedance signal with respect to magnitude due to location of the placement of electrode are differentiated. Magnitude and impedance variation due to the change in distance between electrodes under bio-impedance diagnosis were analyzed. Proper placement of electrode system to diagnosis particular diseases leads to the high efficient diagnosis of the patient condition.

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Conflict of interest

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