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Electrode System Analysis for Bioimpedance Cardiac Diagnosis

Sheeba Santhosh, A Vimala Juliet, G Hari Krishnan

Abstract: ***Electrodes and their placement play a vital role in medical diagnosis. Electrical signal in human body such as ECG, EEG and EMG etc., are the critical diagnosis parameter. Measurements of such signals are obtained by proper selection of electrode and their placement on human body surface. Electrical bioimpedance diagnoses used to detect various disorders are critically depends on type of the electrodes used and their position. In impedance measurements two electrodes are used to send electrical signal and minimum two electrodes to pick the electrical signal response on tissues in terms of voltage across two terminals. In this paper different electrode systems used for bioimpedance cardiac monitoring are analyzed based on the type of electrodes used, location of electrodes in human body and positioning of electrodes in specific location.***

Keywords : Bio-impedance cardiograph, electrode system, Ag-AgCl electrode, Signal generator and Low frequency.

I. INTRODUCTION

Bioimpedance analysis has been frequently used for determining various functional body parameters.It basically measures the impedance in opposition to a current flowing through tissues. There was variety of approaches suggested to determine the impedance variation. The measurement of impedance purely depends on the placement of electrodes on the body surface. The main aim of impedance measurement is to inject a small amount of current to a tissue which in turn changes the impedance and the corresponding voltage change can be measured using electrodes. Based on the electrodes required for measurement of cardiac impedance, the electrode system can be classified into various ways.

Two Electrode Systems

Two electrode methods is also known as bipolar method and is simplest way of measuring impedance. It makes use of both the electrodes for injecting current into the surface of bode as well as the voltage change is picked up by the two electrodes. This works well if the impedance of the electrodes is less than the impedance of the contact region. The resultant impedance change will be due to the sum of impedance of the electrodes and the contact region. As we apply electrolyte to the surface of the body for measurement of impedance, the electrode –electrolyte impedance becomes higher than the body surface, which results in poor measurement with low frequency signals. It arise the problem of repeatability and reproducibility whereas, at higher frequencies the effect of parasitic capacitance badly affects the measurement. Thus, the use of two electrode system has been restricted to skin and dental applications and is rarely used in the analysis of so soft tissues.

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* Correspondence Author
Sheeba Santhosh, Professor, Department of Computer Science and Engineering, Vignan's Nirula Institute of Technology Science and Women, AP, India
A Vimala Juliet, Asst.professor, Department of Computer Science and Engineering, Vignan's Nirula Institute of Technology Science and Women, AP, India
G Hari Krishnan, Asst.professor, Department of Computer Science and Engineering, Vignan's Nirula Institute of Technology Science and Women, AP, India

Four electrode Systems:

Four electrode systems are also known as tetra polar method. As the name implies it uses four electrodes for bioimpedance measurement. One pair of electrodes act as an input electrode which is used to inject current into the tissue and another pair of electrodes act as output electrode to measure the voltage picked up by the body surface. Thus, in this method the effect of electrode –electrolyte impedance does not affect the measurement. However, at lower frequencies, its affect may be considerably large.

At higher frequencies, the effect of parasitic capacitance reduces the current flowing through the surface. These parasitic capacitances are mainly caused due to the stray capacitance between the electrodes and the input capacitance of instrumentation itself. In spite of the disadvantages, the four electrode method is most widely used to measure bioimpedance as it is a convenient method of measurement.

Three Electrode systems:

The four electrode system set up can be modified by increasing the area of one of the electrodes to reduce the impedance interference, thus reducing the structure to three electrode system.

Five electrode systems:

The problem with four electrode systems is that it has increased common voltage and reduced CMRR at lower frequencies. Thus, it is necessary to reduce the electrode impedance and exactly matching the input impedance with the impedance of the instruments used. The effect of common mode can be reduced by the use of a fifth electrode which greatly minimizes the effect of common voltage.

When a four electrode system is used, the common mode voltage produced by the error impedance Z_E will be considered as an error producing error impedance given as

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

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

Where, $CMRR_E$ is the effective common mode rejection ratio.

One of the major drawbacks of five electrode system is that it adds up more noise. Thus, it is mostly used in the measurement of low conductance of homogeneous material, but it is not used in the measurement of living tissues.

Bioimpedance measurement can be further classified based on the frequency used.

1. Single frequency Analysis:
2. Multiple frequency

While extracting the biopotential signal from the human body problems arises due to extremely weak characteristics of the biopotential signals, environment and the apparatus that are being used during signal acquisition. Electrodes for biopotential measurement are classified either as noninvasive skin surface electrodes or invasive microelectrodes or wire electrodes. Metal surface electrodes are most widely used as biopotential electrodes and they are classified as 1.Metal plate electrodes of limbs, 2.Metal disc electrode, 3.Disposable foam-pad electrodes as shown in figure 1and 4.Metallic suction electrode as shown in figure 2.

Figure 1: Disposable foam-pad metal surface electrode

Figure 2: Suction cup metal surface electrodes.

As shown in figure these type of widely used electrode system uses 8 electrodes. Four electrodes are used to give input current signal across neck and the region near lower limb. The electrode system positioning for Bio-Impedance Cardiograph conventional electrode are as shown in figure 3.

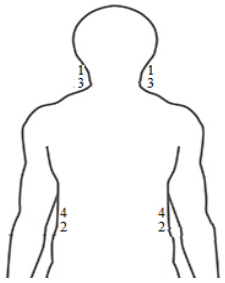

Figure 3: Bio-Impedance Cardiograph conventional electrode placements

Table 1: Different electrode system with their specifications

Electrode System	Type	Location	No. of electrodes	Frequency
Classical Bioimpedance Cardiograph method	Metal surface electrodes	Neck and region below chest	8	100Hz
Impedance Plethysmography method	Disposable Electrodes	Hand wrist	4	50-100kHz
Body composition Assesment	Clip type	Hand palm and foot	4	50kHz and 200kHz

Input signal applied through 1 and 2 electrodes are one volt and 100Hz frequency. Electrodes 3 and 4 are used to pick response from the tissues due to applied electrical current. The electrode system Bio-Impedance Plethysmography based cardiac diagnosis system electrode placement is as shown in figure 4.

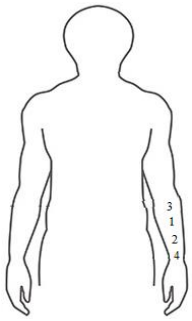

Figure 4: Bio-Impedance Plethysmography based cardiac diagnosis system electrode placement

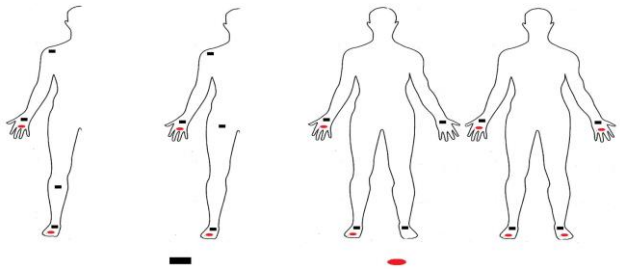

Figure 5. Segmental bioimpedance analysis techniques, (a) right side dual current and quad voltage electrodes, (b) right side dual current and quad voltage electrodes, (c) double sides dual current and quad voltage electrodes and (d) double sides quad current and quad voltage electrodes.

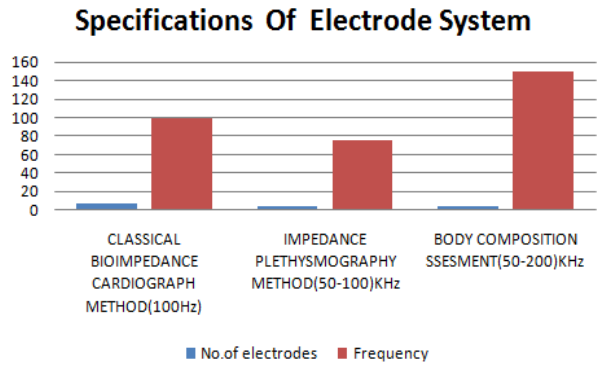

Figure 6: simulation results of Frequency Vs.No.of electrodes

II. CONCLUSION

Analysis on electrode system for electrical Bioimpedance cardiac diagnosis was done based on the type of electrode and materials used. The deviation in impedance signal due location of the placement of electrode are differentiated. Proper selection of electrode system to diagnosis particular cardiac diseases may leads to the high efficient diagnosis of the patient condition. Since impedance cardio graph depends on volume high accurate diagnosis can be obtained comparing to conventional electrocardiography measuring systems.

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REFERENCES

1. Gong WeiYan, LV JingHua, Wang Yan, Sha Hong, Zhao Shu, Ren ChaoShi, The impedance property of Electrode used in Electrical Bio-impedance Measurement, 3rd International Conference on Bioinformatics and Biomedical Engineering, Beijing, China, IEEE Xplore2009;11-13.
2. G. Hari Krishnan, R. Ananda Natarajan & Anima Nanda. Microcontroller based non invasive diagnosis of knee joint diseases, IEEE conference on Information Communication and Embedded Systems (ICICES-2014), IEEE Xplore2014; pp:1-3.
3. Jia-Jung Wang, Wei-Chih Hu, Tsiar Kao, Chun-Peng Liu and Shih-Kai Lin, Development of forearm impedance plethysmography for minimally invasive monitoring of cardiac pumping function, Journal of Biomedical Science and Engineering 2011; Vol.4, pp:122-129.
4. TusharKantiBera, Bioelectrical Impedance Method for Noninvasive Health Monitoring: A Review, Journal of Medical Engineering2014; pp:1-28,.
5. G. Hari Krishnan, R. Ananda Natarajan & Anima Nanda. Impact of Upper Limb Joint Fluid Variation on Inflammatory Diseases Diagnosis, Journal of Electrical Engineering & Technology (JEET)2014; Vol.9, No. 6, pp:2114-2017.
6. G. Hari Krishnan, R. Ananda Natarajan & Anima Nanda. Synovial Fluid Density Measurement for Diagnosis of Arthritis, Biomedical & Pharmacology2014; Vol.7, No.1, pp:221-224.
7. Wang Lei, The effect of medical electrodes on ECG & EEG verification instrument measurement, Practical medical technology journal 2007; vol.4(20), pp: 2625-2626.
8. RenChaoShi, Wang Yan, Deng Juan, The application study of Electrical Impedance Tomography, Chinese Journal of Medical Instrumentation 2007; vol. 31 (4), pp:235-238.
9. G. Hari Krishnan, R. Ananda Natarajan & Anima Nanda. Comparative Study of Rheumatoid Arthritis Diagnosis Using two Different Methods 2014; BPJ, Vol.7, No.1, pp: 379-382.
10. Suxian Cai, Shanshan Yang, Fang Zheng, Meng Lu, YunfengWu, & Sridhar Krishnan,Knee Joint Vibration Signal Analysis with Matching Pursuit Decomposition and Dynamic Weighted Classifier Fusion, Computational and Mathematical Methods in Medicine2013; pp.1-11.
11. Tanaka, N.I, Miyatani, M, Masuo, Y, Fukunaga, T, Kanehisa, H, Applicability of a segmental bioelectrical impedance analysis for predicting the whole body skeletal muscle volume, J. Appl. Physiol., 2007; vol.103, pp.1688–1695.