

DIFFERENT TYPES OF ELECTRICAL SIGNALS PRODUCED BY HUMAN BODY

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ABSTRACT

This article will allow readers to understand electrical processes going inside the human body. It will also provide idea of bio-potential produced in human body. These bio-potential produce a physiological phenomenon known as bio signals. Bio signals have been very helpful in examining activities of brain, eye, heart, muscles etc. As a result there have been technologies like EEG, ECG, EOG, ERG, MMG, MEG.

Keywords: *Types Of Bio-Potential, Classification of Bio-Signals, Sources of Bio-Potential.*

I INTRODUCTION

A human body is combination of multiple cells. These cells are made up of different chemical substances like sodium, potassium, calcium, chloride etc. These cells are categorized as excitable cells and non-excitable cells. Excitable cells are cells that create a tiny current when stimulated, for example, muscle fibers, neurons etc. Non excitable cells do not carry electricity but are responsible in protecting, nourishing, and supporting excitable cells, for example, glia, satellite cells, Schwann cells. Cell membrane is used to separate cells from their environment i.e. intracellular and extracellular. A lipid bilayer cell membrane acts as barrier between the two environments. The intracellular environment is rich in potassium ions while extracellular environment has abundance of sodium and chloride ions. Hence, both environments are at different potential, therefore, a flow of ions results between the two environments creating a potential difference. This potential difference is called bio potential. The bio-potential can be measured using electrodes, amplified using instrumentation amplifiers and monitored to study functioning of various organs like heart, brain, eye, muscles etc.

II TYPES OF BIO-POTENTIAL

Bio-potentials are of two types. They are

1. Action potential
2. Resting potential.

Action potential is basically experienced by nerve cells or neurons. It helps them to communicate with each other. A neuron consists of cell body, dendrites and axon. Cell body has a nucleus that controls flow of ions inside and outside cell membrane. An axon acts as transmitter while dendrites act as receiver of action potential inside and outside cell membrane. Figure 1 shows a typical neuron.

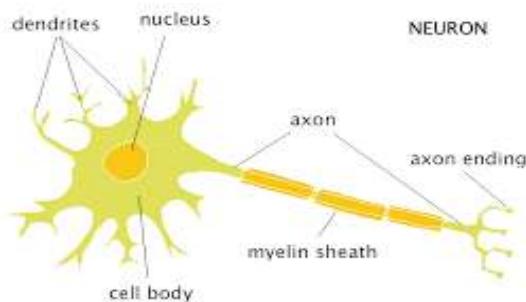


Figure-1: A Typical Nerve Cell

Proteins stuck over the cell membrane form ion channel. Some of them are known as gated channel while others are called resting channel along with pumps. Opening and closing of gate depends upon what chemical ion is attached to it. Hence there is sodium and potassium gate that respond i.e. open or close to maintain positive and negative imbalance. Cell membrane has sodium potassium pumps that supply energy into and outside cell in form of ions to maintain positive and negative imbalance. Sodium ions are pumped out while potassium ions are pumped in. Neurons have quite negative charge inside them called anions and sodium and potassium ions are positively charged.

There are two stages that are experienced. First stage is when axon is resting, all the sodium and potassium gates are closed, and there is higher concentration of potassium and lower concentration of sodium inside the cell while there is lower concentration of potassium and higher concentration of sodium outside the cell. Sodium is pumped inside and potassium is pumped outside the cell membrane. At this time anions give negative charge to maintain positive negative balance. The potential developed here is called resting potential. Due to this movement, a constant potential is maintained. Figure 2 shows condition of resting potential.

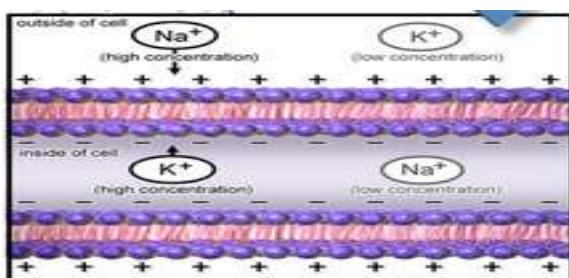


Figure-2: Resting potential stage

Second stage is when axon is active, that is a continuous ion exchange occurs along the length of axon. Sodium ions enter the cell creating a positive inside and negative outside. Now the sodium gate is closed and the potassium gate gets opens to supply more potassium outside. Due to this the inside becomes negative and the outside is positive. As to maintain a constant potential, sodium has to be outside and potassium to be inside, so now sodium pump pumps out the sodium outside the cell and potassium pump pumps potassium inside. This way the potential is maintained. This type of bio-potential is called action potential. Figure 3 shows condition of action potential.

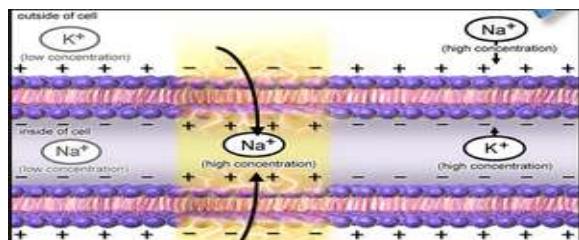


Figure 3: Action Potential Stage

The membrane potential is plotted against time to show voltage level of action and resting potential in a typical neuron. Figure 4 shows the graph of action and resting potentials.

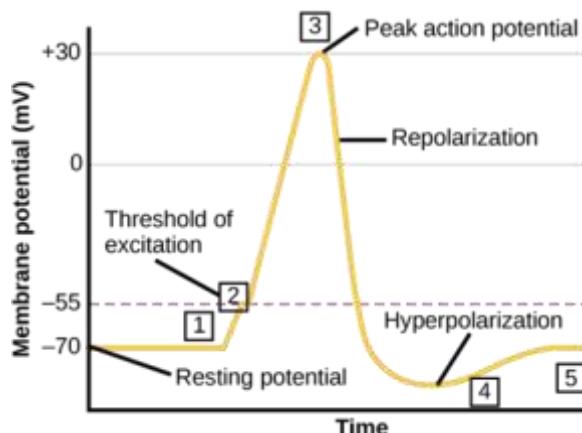


Figure-4: Graph of Action and Resting Potential

III CLASSIFICATION OF BIO-SIGNALS

According to existence of bio signals, they are classified as:

- Permanent bio signals
- Induced bio signals

Permanent bio signals are available inside the body and there do not require any artificial impact, trigger. Example: ECG signal.

Induced bio signals require artificial triggering or excitation. They exist for short duration. Example: electric plethysmography.

According to dynamic nature of bio signal, they are classified as:

- Static bio signal
- Dynamic bio signal

Static signal carry information in a static level. They do not change with time and are slow in nature.

Example: body temperature

Dynamic signal undergo changes with time. Example: heart beat

According to origin of bio signal, they are classified as:

- Electric bio signal (eg. EEG, ECG, EMG)
- mechanic bio signal (eg. mechanorespirogram)
- thermal bio signal (eg. core body temperature)
- magnetic bio signal (eg. MMG)
- optic bio signal (eg. optoplethysmogram)
- acoustic bio signal (eg. phonocardiogram)
- chemical bio signal (eg. cortisol secretion)

IV SOURCES OF BIO-POTENTIAL

4.1 Electroencephalogram (EEG)

Electroencephalography is an imaging technique used commonly in medical field, to study brain functioning. In this multiple electrodes are placed over the scalp and the voltage fluctuation resulting due to current flow in neurons. When neurons in brain get active, a current results due to exchange of ions. These ions are of sodium (Na^+), potassium (K^+), calcium (Ca^{++}), and chloride (Cl^-). A difference in potential is experienced across the channel in cell membrane. Neurons keep on maintaining its resting potential and create action potential. Ions have the property to repel similar type and attract the opposite one. In similar fashion, when more ions are pushed out of the neurons a wave like structure generates in the neurons which create voltage fluctuations. These waves when subjected to electrodes; its ions attract or repel the metal of electrodes. This pulling and pushing of ions to metal of the electrode create voltage differences that are recorded over to obtain an EEG signal.

An EEG signal consists of four different wave structures:

1. Gamma waves have frequency above 30 Hz and are not fit for medical purpose.
2. Beta waves have frequency between 14-30 Hz and are below 30 μV . These are resulted due to tension. They show attentive state and wakefulness.
3. Alpha waves have frequency between 8-14 Hz and are below 50 μV . They show relaxed and mentally inactive state.
4. Theta waves have frequency between 4-8 Hz
5. Delta waves have frequency between 0.3- 4 Hz

EEG signals are used to distinguish between non rapid eye movement stage and rapid eye movement stage. It is also helpful in diagnosing sleep disorders, head injuries, brain infection, brain death etc.

4.2 Electrocardiogram (ECG)

Electrocardiography is again one of the most useful techniques of medical field. In this electrodes are placed over the chest or thorax and heartbeat is continuously monitored. Heart is a four chambered organ having upper two atria and lower two as ventricles. The muscle cells of heart are negatively charged during the resting state. The exchange of sodium and potassium ions across the cell membrane results in decrease of negative charge of cells to zero. This is called depolarization and it results in contraction of muscles. A continuous high ion concentration across the cell membrane results into a current that creates an external potential field. This field excites the neighboring cell and this neighbor to neighbor transfer creates a good amount of electric potential that propagate into the body surface exciting muscular tissues. At each heartbeat, these wave spreads over the atrium and then to ventricle through atrioventricular node. A rise and fall of voltage creates the electrocardiogram signal.

An electrocardiogram consists of following waves:

1. P wave shows activation of the right atrium. It's duration is 80ms
2. QRS complex shows rapid depolarization between right and left ventricles. It's duration is 80 – 100 ms.
3. T wave shows repolarization of ventricles. It's duration is 160 ms.
4. U wave shows repolarization of interventricular septum.

ECG is used to diagnose blood clots, hypotension, Dizziness, high blood pressure congestive heart failure etc.

4.3 Electromyogram (EMG)

Electromyography is a technique used to record the electrical activities of skeletal muscles. Motor unit is the smallest unit that controls muscular contraction. Muscular membrane has resting potential maintained by ions inside and outside the membrane. Depolarization and repolarization are seen in motor neurons resulting in excitation and contraction of muscle fibers. In depolarization state, sodium ions get inside and potassium ions are pumped out of the muscle fiber membrane. In repolarization condition gets reversed i.e. sodium outside and potassium inside. This creates a potential difference along the length of muscle fiber. These potential differences are recorded to get electromyogram. EMG signal is algebraic sum of action potential of many muscle fibers as one motor unit.

EMG signal can be used in medical field, ergonomics, rehabilitation, sports science.

4.4 Electrooculogram (EOG)

Electrooculography is one of great medical technique in which electrodes are placed on forehead near the eyes to record eye movements. It records the resting potential between cornea and retina known as corneal retinal potential. Electrically active nerves in the eye produce potential difference. Cornea are said to be positive while retina is negative, as a whole eye acts as dipole. Eye movements can be recorded by placing electrodes either left or right of eye or above and below eye. When eye moves towards one of the electrode it is positive side of retina and to the other electrode it is negative side. Eye movement gives the positive and negative impulses due to presence of action potential which is about -0.06 to +0.06 volt. Four to five electrodes are used to record EOG signal. Two of them are

placed on sides of eye to detect horizontal movement while other two are placed above and below to detect vertical movement. EOG is used in ophthalmological diagnosis.

4.5 Mechanomyogram (MMG)

Mechanomyogram is a technique that uses mechanical signal to observe muscle activity. When a muscle is contracted, a peak is experienced in a MMG signal. As we know a muscle is combination of millions of muscle fibers. When these fibers are oscillated, vibration is experienced in muscles. In this technique, electrodes are placed over the skin surface. These vibrations create pressure wave showing muscle activity. An MMG signal can be recorded using an accelerometer or microphone, piezo electric contact sensors.

MMG is used to find muscular pain, fatigue, diseases etc.

4.6 Magnetoencephalography (MEG)

It is one of popular technique to record neuronal brain activity. Brain consists of millions of neurons that are responsible for transmission and reception of information from body. Neurons of brain undergo ions exchange chemically that creates a magnetic field across the cell membrane. Axon of the neuron has bidirectional current hence two dipoles of opposite polarity exist. This leads to cancellation of magnetic field. Post synapses of neurons have unidirectional current. Hence magnetic field persists here. Magnetic field of a single neuron cannot be measured so neurons of same spatial orientation are taken together and their combined magnetic field is measured using sensitive magnetometers. Superconducting quantum interference devices commonly known as SQUIDS are best suited to measure MEG signal. MEG provides high spatial and temporal resolution.

MEG is used to study brain processes, parts of brain, neuro feedback etc.

4.7 Galvanic Skin Response

Galvanic skin response is a method to study electrical properties of human skin. It is also called electro dermal response. When a human body comes under the interaction of environment, some changes are seen in person's psychological state. Due to this some changes are observed in electrical properties of its skin. As it is a known fact that human skin is a good conductor of electricity so ions exchange is experienced between external and internal environment of skin. This leads to flow of electric current in skin. Hence we can say that human skin possesses resistance or conductance. In GSR, a constant voltage is applied through electrodes on human skin. This leads to current flow that can be measured and then we can find resistance or conductance by simply dividing voltage applied by electrodes with current flowing in skin. Thus, skin observes two types of conductance, one is tonic and other is phasic. In tonic stage of conductance, there is absence of any external environment, hence a baseline conductance called skin conductance level is observed. In phasic stage of conductance, changes in external environment like some stimuli leads to changes in skin conductance. These are called skin conductance response.

GSR finds application in lie detection tests, hypnotherapy, psychotherapy, behavior therapy.

4.8 Electroretinogram (ERG)

Electroretinogram is another helpful technique to study electrical response of retina human eye. It helps in diagnosing status of retina in case of eye diseases. When a light stimulus is applied through LED or strobe lamp, an electrical activity takes place in neural and non- neural cells of retina. This produces a biphasic waveform comprising of three important waves known as

- a-wave
- b-wave
- c-wave

Due to sodium ion channel closure in outer membrane, there exists hyperpolarization of photoreceptors. a-waves are reflected from rods and cones of outer photoreceptor layers of the retina. When a light stimulus is applied on the retina, rhodopsin gets triggered leading to activation of transducin. This further activates cyclic guanosine monophosphate phosphodiesterase(cGMP). cGMP helps sodium ions to move inside the membrane. a waves are negative in nature and are measured from baseline to trough of a wave.

b-waves are positive corneal deflection from inner retina. Due to hyperpolarization of photoreceptors, there is decrease in number of sodium ions. This leads to depolarization of bipolar cells which further increases amount of potassium ions. This balancing of sodium and potassium ions across the cell membrane generates current. These are measured from trough of a-wave to the peak of b-wave.

c-waves are result of pigments of retina i.e. epithelium and photoreceptors

ERG is helpful in diagnosing retinitis pigmentosa, cone dystrophy, choroideremia.

V CONCLUSION

Bio potential is gaining importance in research in both medical as well as electronics field. They are hot topic of research today because they are concerned with human health and wellbeing. Signals like ECG, EEG, EMG, EOG, not only examine a person's health but also diagnoses illness of a person. In future, these signals can be helpful in finding various therapies for treatment of diseases that are still unknown.

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