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THE EFFECT OF EXCITATION CURRENT ON REFRACTORY PERIOD OF ACTION POTENTIAL AND ITS SIMULATION BY MATLAB SOFTWARE

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ABSTRACT

In this study, survey the effect of excitation current on refractory period of action potential have been explored. The simulation has been performed by using matlab software. At first, by using Hodgkin Huxley equations, action potential waveform is obtained. Then by changing the amount of excitation current and simulation action potential waveform in new conditions, we see that the more excitation current increases, the refractory period of action potential decrease and vice versa when reduce the amount of excitation current, refractory period increase.

Keywords: Excitation Current, Action Potential, Refractory Period, Hodgkin Huxley, Nerve signals, Axon

I. INTRODUCTION

Whatever happen in the body, breathing and eating up decision-making, perception and emotions are all controlled by the brain. Yet perhaps for many, the question is that how the brain transmits its message? If you're looking for answer in a few words, maybe this is your answer: chemical, electric mechanism .

However, if you want more accurate way to know how to transmit information in the brain need to be familiar with neurons and nervous urea message or neurotransmitters. Neurons are the basic structures of the brain. In fact, what form a large part of the brain, are neurons. Neurons are generally composed of three parts: Cell body or nucleus neurons, dendrites and axons. Nerve signals through neuronal dendrites come to the core, the nucleus of neurons affected and are processed through the axons and eventually transmitted to the next neuron. So in general, nerve signals are sent from the axon of one neuron and the dendrites of neighboring neurons are received.

However, in most cases, the relationship between two neurons through axons and dendrites can be done, but sometimes the relationship between a axons with another axons or axons to the cell nucleus there. What we call nerve messages, the electric current in the neurons. It flows through the action potential is generated. Stimulate the neurons, leading to generation of action potential .

As mentioned, this action potential or electrical current over the length of the axon and it reaches to the end. Between the axons and dendrites of one neuron to the next neuron is a gap called the synaptic cleft. Due to the synaptic cleft, an electrical current can be transferred directly from axons to dendrites. Thus, for data transfer mechanisms are different.This mechanism, transfer of information or action potential using a chemical called nerve messenger or neurotransmitter. At the end of axons there are bags called synaptic bags (vesicle). The bag containing the neurotransmitter. When an electrical impulse reaches the end of the axon and synaptic vesicles, as a result of neurotransmitters into the synaptic cleft enter. As previously mentioned, on the other hand the synaptic cleft, the dendrites of neurons are next. Neurotransmitters in the synaptic gap, reach to dendritic receptor of secondary neuron and causing ionic changes in it.

This effect leads to creation of current or electrical impulsive in dendrites and by transmission of electric current through the dendrite and reach the cell nucleus, the message transmit from one neuron to another neuron. This process continues in a similar way in different neurons so nerve signals to be transferred.

II. REFRACTORY PERIOD

A new action potential cannot occur in an excitable fiber as long as the membrane is still depolarized from the preceding action potential. The reason for this is that shortly after the action potential is initiated, the sodium channels (or calcium channels, or both) become inactivated, and no amount of excitatory signal applied to these channels at this point will open the inactivation gates. The only condition that will allow them to reopen is for the membrane potential to return to or near the original resting membrane potential level. Then, within another small fraction of a second, the inactivation gates of the channels open, and a new action potential can be initiated. The period during which a second action potential cannot be elicited, even with a strong stimulus, is called the absolute refractory period. This period for large militated nerve fibers is about 1/2500 second. Therefore, one can readily calculate that such a fiber can transmit a maximum of about 2500 impulses per second [1]**.**

In other word, we can say after one action potential, a time period that threshold infinity and cells do not respond to any excitatory that is called the absolute refractory period. This time for a nerve cell is one millisecond. In other case, the period that it takes time to reach the threshold of infinite to its normal value that is called the relative refractory period.

A.Mechanism of absolute refractory period

The absolute refractory period coincides with nearly the entire duration of the action potential. In neurons, it is caused by the inactivation of the Na_+ channels that originally opened to depolarize the membrane. These channels remain inactivated until the membrane hyperpolarizes. The channels then close, de-inactivate, and regain their ability to open in response to stimulus[2].

B.Mechanism of relative refractory period

The relative refractory period immediately follows the absolute. As voltage-gated potassium channels open to terminate the action potential by repolarizing the membrane, the potassium conductance of the membrane increases dramatically. K+ ions moving out of the cell bring the membrane potential closer to the equilibrium potential for potassium. This causes brief hyperpolarization of the membrane, that is, the membrane potential becomes transiently more negative than the normal resting potential. Until the potassium conductance returns to the resting value, a greater stimulus will be required to reach the initiation threshold for a second depolarization. The return to the equilibrium resting potential marks the end of the relative refractory period[2].

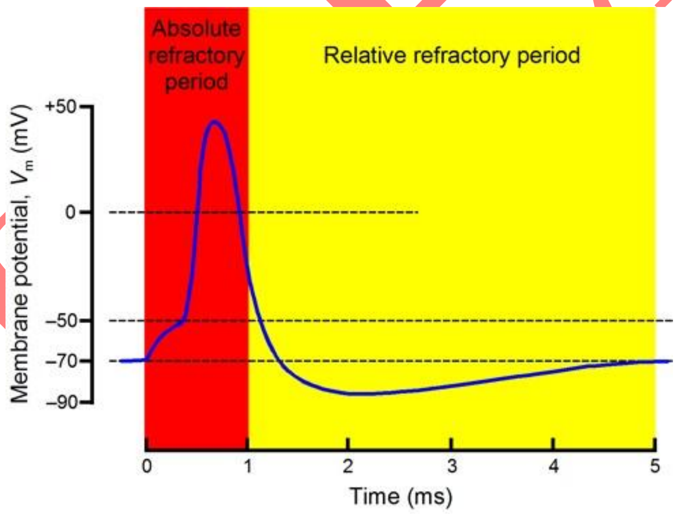

Fig1. Absolute and relative refractory periods [3].

If we want summarize the above steps, we can say:

In the absolute refractory period

1. Comes immediately after the AP
2. During this period it is impossible to excite the cell no matter how large a stimulating current is applied

In the relative refractory period

1. During which it is possible to trigger an AP, but only by applying stimuli that are stronger than normal.

III. HODGKIN HUXLEY MODEL

In 1952 , Hodgkin and Huxley provided a mathematical model to explain how to start and the distribution of the action potential in neurons that includes a set of non-linear ordinary differential equations that approximation the electric properties of excitable cells, such as neurons and cardiac muscle cells . Hodgkin and Huxley by presenting this model, received the nobel prize in physiology and medicine in 1963[4].

Hodgkin Huxley model made by electronic components such as resistors and capacitors is shown in the following figure. Each components of a cell irritable with a physical component is shown[5]. Lipid layer is shown as a capacitor. voltage ion channels shown with a resistance that they can be based on a nonlinear conductor, in other word can be said the conductivity depends on the time and voltage, which indirectly through voltage channels gate proteins have relation to the possibility of the opening of each that is proportional to the voltage.

Leakage channels have been shown with a resistance that It can also be indicated by a linear conductivit. Electrochemical gradient that causes a flow of ions with a battery E is also shown. V_m is the membrane potential that the difference between the internal and external potential[6].

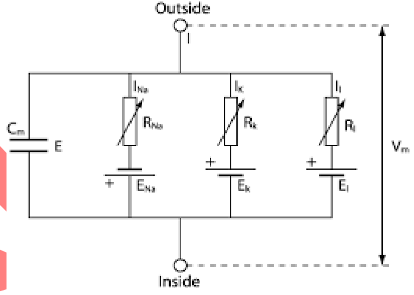

Fig2. Schematic diagram for the Hodgkin-Huxley model [7]

The Hodgkin-Huxley equations is as follows :

$$I = C_m \frac{dV_m}{dt} + g_k(V_m - V_k) + g_{Na}(V_m - V_{Na}) + g_l(V_m - V_l) \qquad (1)$$

$$\frac{dn}{dt} = \alpha_n(1-n) - \beta_n n \qquad (2)$$

$$\frac{dm}{dt} = \alpha_m(1-m) - \beta_m m \qquad (3)$$

$$\frac{dh}{dt} = \alpha_h(1-h) - \beta_h h \tag{4}$$

Also the currents influences on the production and propagation of action potential is as following [6],[8] :

Sodium channel current (I_{na})

Potassium channel current (I_k)

Leak channel current (I_{leak})

Capacitive current (Ic)

$$I_{Na} = g_{Na}(V_m - V_{Na}) \tag{5}$$

$$I_K = g_K(V_m - V_K) \tag{6}$$

$$I_L = g_L(V_m - V_L) \tag{7}$$

$$I_c = C\frac{dV_c}{dt} \tag{8}$$

Hodgkin Huxley equations parameters describtion presents in the following table :

Table1.Hodgkin Huxley equations parameters and their definition [6].

Parameters	**describtion**
I	total current of membrane [$\mu A/Cm^2$]
C_m	Membrane capacitance F/Cm^2
V_m	Membrane voltage[mv]
g_{Na}, g_K, g_l	channels conductance[$mmho/Cm^2$]
V_{Na}, V_K, V_l	nernst voltage[mv]

IV. SIMULATION

In this section, we simulate the Hodgkin Huxley equation under normal condition and action potential for excitation current of 10 micro amps obtains. In next step, we change the amount of excitation current and another action potential waveform in the new condition obtains. By observing the waveforms at different values of excitation current, we can see how to change the values of refractory period. Note that, in the following figure, AP is abbreviation of action potential.

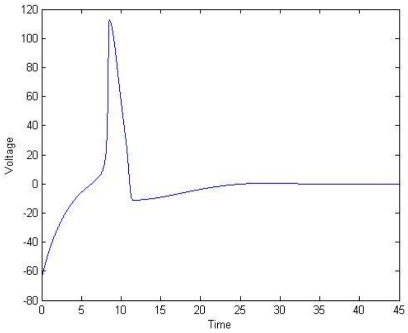

Fig 3. AP when excitation current= 0

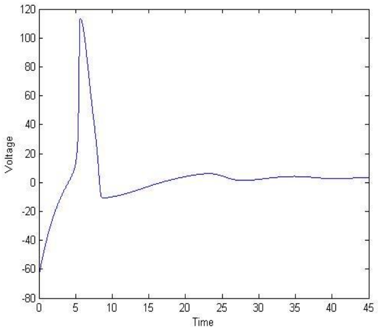

Fig 4.AP when excitation current= 5 mA

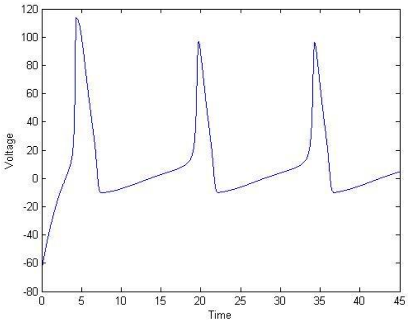

Fig 5. AP when excitation current= 10 mA

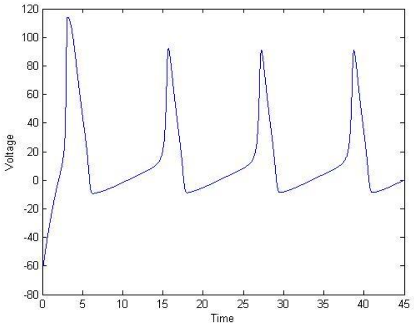

Fig 6. AP when excitation current= 20 mA

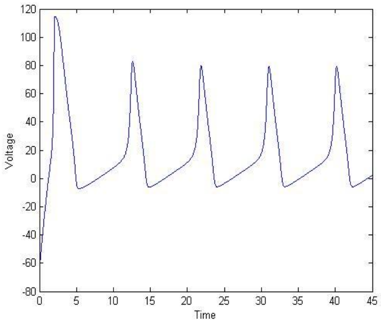

Fig 7. AP when excitation current= 40 mA

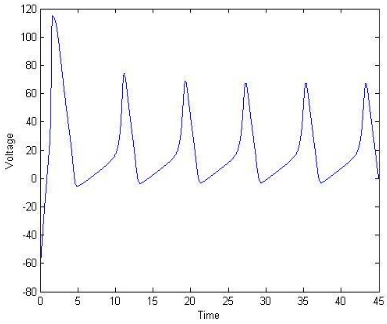

Fig 8. AP when excitation current= 60 mA

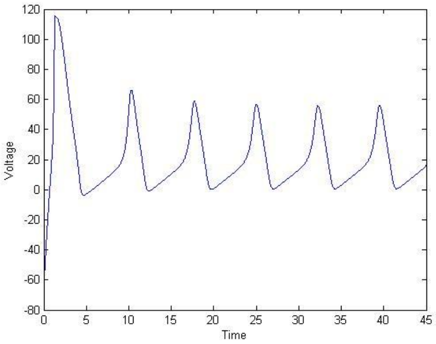

Fig 9. AP when excitation current= 80 mA

V. CONCLUSION

In this paper, with simulation of Hodgkin Huxley equation by matlab software and obtaining the action potential waveform at different values of excitation current, we see that the refractory period have relation with change of stimulate current in membrance . By observing the waveforms that obtained, we can understand this matter that the more we increase the amount of excitation current, refractory period decreases and second action potential in short time after the first waveform generated and vice versa when we reduce the amount of excitation current, refractory period increases. In this way, we can by change the amount of excitation current in membrane, effect on the refractory period.

REFERENCES

[1] Arthur C. Guyton , John E. Hall , the text book of Medical Physiology

[2] ©Physiology web at www.physiologyweb.com

[3] Schmidt, Robert F, Thews, Gerhard 'Human physiology'Springer-Verlag.p.725 (1983)

[4] Mostafa Mohammadi, Alireza Kashani Nia " Design And Simulation of an Acoustic Micro Prob Made of Piezoelectric Materials to Stimulate Nerve Tissue and Generate Action Potential" International Journal of Engineering Research & Technology (IJERT), Vol. 4 Issue 04, April (2015)

[5] Kenneth Leander Anderson Jr, Jackie Chism, Quarail Hale, Paul Klockenkemper, Chelsi Pinkett, Christopher Smith, and Dr. Dorjsuren Badamdorj"Mathematical Modeling Action Potential in Cell Processes" June 21, 2013

[6] Mostafa Mohammadi, Alireza Kashani Nia "Simulation of Voltage Change Effects in Ion Channels in order to Reproduction of Action Potential by MATLAB Software", International Journal of Advanced Engineering and Nano Technology (IJAENT), Volume- 2, Issue-6, May (2015)

[7] S. Alford, "The Hodgkin-Huxley equations.".Cell and Molecular Neurobiology.

[8] Hodgkin, A.L. and A.F. Huxley, A quantitative description of membrane current and its application to conduction and excitation in nerve. J Physiol, 1952. 117(4): p. 500-44.

Appendix

Table1. Constants for Hodgkin Huxley equations that used in the simulation[4].

Parameters	**Value**
V_{Na}	55 mv
V_K	-77 mv
V_L	-54.4 mv
g_{Na}	120 $mmho/Cm^2$
g_k	36 $mmho/Cm^2$
g_L	0.3 $mmho/Cm^2$
C_m	1 F/Cm^2