Chapter 1

Biomedical Signal Analysis and Its Physio–Clinical Perspectives

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ABSTRACT

The field of Biomedical engineering has brought two apparently diagonally placed poles of academia of excellence, i.e., field of medicine and the field of state of art engineering science to a closed proximity. Now a day most if not all of the state of art diagnostics in the field of medicine are almost totally dependent upon biomedical signal analysis. Whole of the biological systems are run by nothing but the bio-signals. The process of signal analysis depends upon the types of signals, recording methods, data types, need of compression and portability and possibility of artifacts. The important areas of the clinician’s prime concern are the reliability of the data generated, the utility of the data produced in the real clinical settings in making a diagnosis and interference of the diverse type of equipment’s signals with each other and its impact upon the final output. Physiologists act as a bridge between the biomedical engineering and the clinician’s need assessment and product delivery process.

INTRODUCTION

A signal in biomedical jargon is any physical quantity that varies as a function of one or more independent variables. According to the number of variables it may be one dimensional, two dimensional or even multidimensional signals.

Our biological system is a dynamic state device that works upon a complex pattern of multidimensional signals called biomedical signals. The basic source of the biomedical signals lies in the membrane properties of the various living cells of the biological system.

Objective of the chapter is to have an introduction to the clinician’s perspective of biomedical signals, address the issues related to patient care linked with the biomedical signal analysis and interpretation and the physiologists point of view regarding the alteration in the behavior of biological signal generators and its effect on the signal data output.

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CELL AS A SOURCE OF BIOMEDICAL SIGNALS

Most of the electrophysiological studies involve bioelectrical potentials generated by sources inside the body such as nerve, brain, pacemakers, muscles etc. The body as a whole acts as a volume conductor and it helps in the extracellular spread of current (i.e. volume conduction). The source of current lies in the cell membrane where millions of voltage gated and ligand gated ion channels are placed which is being operated under dynamic equilibrium with various neuro-hormonal regulatory systems of the body. The intricately tuned regulatory control system changes the behavior of the membrane property by changing the permeability of the membrane to a particular ion which in turn is being controlled by the variable expression of the channels for those particular substance or ions over the cell surface. The change in the channel behavior alters the potential difference between the two surfaces of the cells, alters the Calcium or other ionic level inside the cell and may also create a train of propagating impulse without any decrement in the voltage called action potential.

One of the important determinants of the current strength and its initiation is the intracellular versus extracellular ionic distribution and its balance. For example a small change in potassium concentration extracellularly may cause cardiac emergency or flaccid paralysis because of the change in the cardiac or skeletal muscle ionotropic properties. As many of the ion channels are voltage gated channels, a slight change in the ionic concentration gradient across the cell membrane may cause a significant change in the resting membrane potential or the threshold local potential to generate action potential. In other words, it may cause a change in the membrane excitability. Tetany may be cited as a good example of similar change in the membrane property. Tetany is a condition in which the skeletal muscle becomes hyperexcitable resulting in the spasmodic contraction of a group of skeletal muscles upon very trivial stimulation. The condition is caused by a slight decrease in the extracellular ionic Calcium concentration. The ionic Calcium in its normal extracellular concentration is responsible for the stability of the skeletal muscle membrane Sodium channels. When it decreases due to any reason, the membrane Sodium channel becomes unstable and even a trivial stimuli is capable of opening sufficient number of Sodium channels to create a threshold voltage for generation of action potential resulting in the hyperexcitability of the skeletal muscles.

Action Potential

The basic activity that is responsible for the generation of biological signals in almost every biological cell or system is action potential. This is defined as the change in the membrane potential across any semi permeable biological membrane, which can travel along the membrane without any decrement in the intensity and which follows all or none law. Another term that is often in use along with action potential is the graded potential or local potential, which is the local change in the membrane polarity which doesn’t follow all or none law and which can’t travel along the muscle or nerve membrane. As discussed above, the generation of action potential depends upon the membrane property which is the function of various ion channels present in the cell membrane, their permeability and the concentration gradient of various ions across the membrane. Besides it is also dependent upon the excitability of the membrane which is under dynamic control of various neuro-hormonal factors present in the biological system. The duration of action potential also determines the reactivity of the membrane to second successive stimuli. If the duration is longer, the membrane will remain in the period of relative or absolute