LECTURE I

TOPIC: BIOPHYSICAL BASICS OF ELECTROTHERAPY
TIME: 2 HOURS

electric current - is the flow of electric charges (electron beam in metal or ions in electrolyte).

TYPES OF CURRENT

It is distinguished three basic types of electrotherapeutic current which can be described as follows:

- direct current (DC) - is one in which undirectional current flows continously over time

- alternating current (AC) - is one in which bidirectional current flows continously over time

- pulsed current (PC) - is one in which unidirectional or bidirectional flow of current periodically ceases over time

CATHODAL AND ANODAL EVENTS

In electrode circuit, one electrode is positively charged (anode) and the other negatively charged (cathode). The cathode electrode is negatively charged. As depolarisation of the nerve membrane occurs under the cathode, it is therefore commonly termed the active electrode. As the electrical current flows from cathode to anode, negative charges tend to accumulate on the outer surface of the nerve fibre membrane as they will be repelled by the negatively charged cathode. This makes the outside of the nerve fibre membrane relatively more negative. Consequently the inside of the membrane becomes more positive due to accumulation of positive ions on the inside. Because of these events the resting membrane potential will change towards a more positive value, depolarisation occurs for instance. Remember that depolarisation is the loss of the normal negative value of the resting membrane potential.

The reverse occurs under the positively charged anode, negative charges tend to move from the outside of the membrane towards the anode because they are attracted to the positive charge of the anode. This makes the outside of the membrane relatively more positive, which has the effect of making the inside potential more negative and so hyperpolarisation occurs here. Hyperpolarisation is the change in membrane potential towards a more negative value.

On both electrodes is an electrochemical effect.This phenomenom is connected with the electrolysis process.

Electrolysis - is a distribution of the electrolyte and production the metal and gas on electrodes

Here are the following reactions:
$2\ Na + 2\ H_2O \rightarrow 2\ NaOH + 2\ H_2$ (cathode)
$2\ Cl + H_2O \rightarrow HCl + O$ (anode)

As a result of the chemical reactions on the cathode is produced a free hydrogen and sodium hydroxide. On the anode is produced free oxygen and hydrochloric acid. Next process is an electrolytic dissociation. Here is this process:

$$NaOH \rightarrow Na^{+} + OH^{-} \quad \text{(cathode)}$$
$$HCl \rightarrow H^{+} + Cl^{-} \quad \text{(anode)}$$

Then, as a result is produced on the cathode the alkaline reaction (OH) and on the anode the acid reaction (H)

AMPLITUDE/INTENSITY

Amplitude - is the measure of the maximum value of current with reference to the baseline

Amplitude is termed intensity.

Intensity - is the magnitude of current or voltage applied by the unit and can be measured in miliamps (mA).

VOLTAGE

Voltage - is the driving force required to move electric charges. It is measured in volts (V)

RESISTANCE (IMPEDANCE)

Resistance - is parameter which oposses the movement of electric charges
The relationship between current and resistance is provided by Ohm's law
$R = U/I$
Resistance is voltage across an intensity

WAVEFORM AND TIME - DEPEND PARAMETERS

The waveform - is the visual representation of the current or voltage.

The waveform of a current simply refers to its shape as seen on a graph of amplitude versus time.

Phase - is the current flow in one direction for a finite period of time
A monophasic waveform means that current flows in only one direction, therefore one electrode acts as the cathode (negative) and the other as the anode (positive).
A biphasic waveform means that current flows in both directions, thus each electrode acts as a cathode for some part of the waveform.
A waveform is termed symmetrical if the portion of the waveform in the first phase is an exact mirror image but opposite in direction to the portion of the waveform in the second phase
A waveform is called asymmetrical if the phases are not equal in shape

Phase duration - is the time elapsed from the beginning to the end of one phase

Interphase interval - is the time between two succesive components of a pulse when no electrical activity occurs

Pulse duration - is the time elapsed from the beginning to the end of all phases in one pulse

Interpulse interval - is the time between two succesive pulses

Rise time - is the time for the leading edge of the phase to increase from the baseline to the peak amplitude of the phase
Decay time - is the time for the terminal edge of the phase to return to zero baseline from the peak amplitude of the phase

FREQUENCY
Frequency - is the repetition rate of a waveform (number of pulses delivered per second).

Frequency is a time - dependent characteristic which is measured in Hertz (Hz) or in pulses per second (pps). A frequency of 150 Hz means that 150 pulses are delivered per second. The frequency of an alternating and pulsed current can be calculated using the following equation:
Frequency = 1 second/period

Period - is the time elapsed between a specific point on the waveform of the pulse to the pulse to the identical point on the next pulse.
In alternating current the waveform duration is equal to one period (one complete cycle). In pulsed current the period equals the pulse duration plus the interpulse interval

CURRENT MODULATIONS
Pulsed and alternating currents can be modulated, that is varied within a special time frame. These modulations may be used alone or in combination and they may be sequential or varied with respect to pulse per cycle or a series of pulses per cycle.

Amplitude modulation - is a variation in the peak intensity in series of pulses or cycle

Ramp - is increase and decrease in the phase charge over time

Train of pulses - is a continous repetitive sequence of pulses or cycles of pulsed current

TYPES OF STIMULATING ELECTRODES
The electrical stimulation may be applied to the patient with surface (transcutaneous) or invasive electrodes. Surface stimulating electrodes may be made of canvas, felt, metal, silicon or rubber, polymer. Surface stimulating electrodes may require the use of a coupling medium, such as an electrolytic paste or gel. The electrode shape and type of coupling medium are in part dictated by the tissue to be stimulated and the type and duration of the examination. For applications with a predetermined and relatively stable stimulation site (such as in somatosensory evoked potential), an adhesive - backed silver - silver chloride electrode with a concave well for the electrolyte is preferred. For some diagnostic purposes (as in peripheral nerve injury), a handheld stimulating electrode is chosen in which the stimulation site and applied pressure can be easily changed.

SIZE OF ELECTRODES
The size of the stimulating electrode depends in part on the area of excitable tissue to be stimulated. The stimulating electrode (active) is placed over the target area, where the greatest effect is desired. It must also be remembered that electrode of smaller size has higher impedance because electrode size is directly proportional to current flow. The smaller the electrode, the smaller the current flow for a given applied voltage to the stimulated area. A second electrode is at some distance from the target area. This electrode is often called the dispersive (inactive) electrode, because its larger size minimizes current density to the area to

which it is applied.

PLACEMENT OF ELECTRODES

The electrodes come into direct contact with patient, either on the skin (a surface electrode) or in a subcutaneus space. A subcutaneous electrode may be indwelling, as in the case of an intramuscular electrode or implanted, if it has been surgically placed on excitable tissue. Surface electrodes are used when the excitable tissue encompass a fairly large surface area, for example to record electromyogram signals from a large number of motor units and gross signals from a large superficial nerve. Wire electrodes are used to record EMG signals from deep small muscles whose potentials would be masked by overlying muscles when recording with surface. Needle electrodes are used for recording from small areas.

It is distinguished longitudinal or transverse placement:

LITERATURE

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