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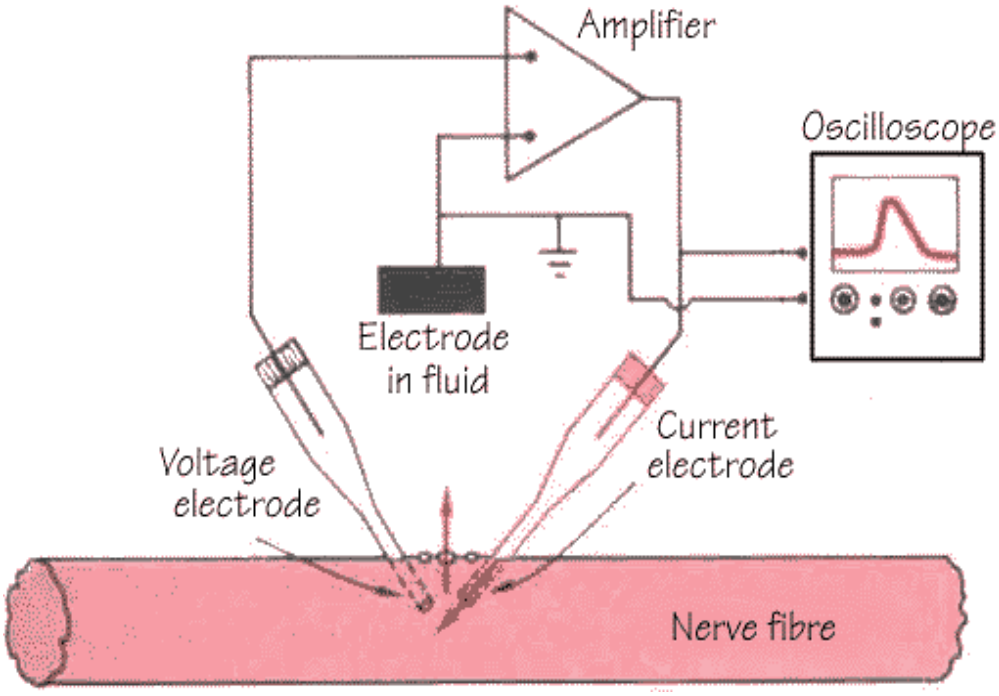
Physiological responses to Action Potential Stimulation

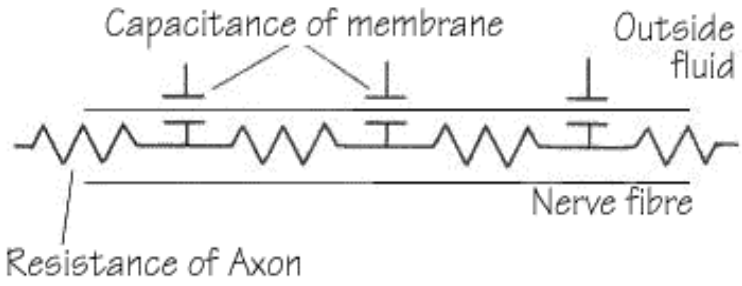
The aim of this article is to explain the how Action Potential Stimulation (APS) therapy affects the physiology (especially the biochemistry) of the body, how it affects the nerves and how it operates electronically. APS Therapy can be used to treat many painful inflammatory conditions such as arthritis, gout, bone breaks, sprains etc. It has proven to be very effective and in many cases results in the patient no longer requiring medication for inflammation and pain.

'Action potential' is the name given to the electrical nerve impulse waveform that is generated by the neuron (nerve cell). The shape of an action potential can be seen using an amplifier circuit (voltage clamp) as shown in the diagram below, which measures the flow of ions using two electrodes inserted into the nerve fibre.



One of these is for the purpose of measuring the voltage of the membrane potential and the other conducts electrical current into and out of the nerve fibre. Current is applied via the current electrode until a rate is reached holding the voltage at steady at -90mV as measured by the voltage electrode.

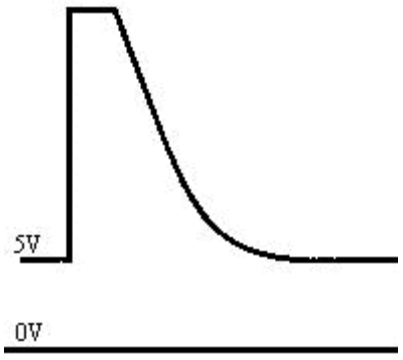
The nerve membrane potential is then adjusted from -90mV towards zero volts, the voltage gated sodium and potassium channel opens (between electrodes) and sodium and potassium ions begin to pour through the channels. The waveform can then be measured using an amplifier on an oscilloscope as shown above.



The resistor and capacitor network shown above illustrates an electrical analogy of a nerve fibre that carries the action potential signal. The nervous system generates billions of action potentials to control all physiological functions. The action potential waveforms generated in the cells of the nervous system are exponential in nature.

Coding of sensory information along nerves is by frequency modulation of the train of action potentials carried by the nerve, the more intense the sensation the higher the frequency of action potentials. The normal frequency of impulses passing along a single sensory or afferent nerve fibre may be one pulse per second. If the pressure sensor that supplies the nerve with its signal senses a higher pressure, the frequency of impulses may be increased to 100 pulses per second.

The frequency is important to the central nervous system to determine its reaction to the sensory input, producing a particular biochemical and electrical physiological response.



APS therapy is a type of electrotherapy that uses electrical currents conducting through the surface of the skin (transcutaneous) to treat inflammatory pain and inflammation, reducing both.

The waveform shape is the same as an 'action potential', hence the name 'Action Potential Simulation Therapy'. The waveform gradually creates a DC offset by charging the tissue in the first few seconds with the exponential pulses. The charge/offset then remains at approximately 5 volts until the end of the treatment with exponential pulses in the region of 25 volts peak for an average treatment (This can be measured between the negative and the positive electrodes using an oscilloscope as shown above).

Action potentials are produced to control all physiological functions. If a breakdown in these action potentials occurs, physiological functions will be impaired. Inputting an electrical waveform similar in shape to electrical pulses normally found within the

human body (action potentials) creates a physiological effect and this effect has be clinically and scientifically tested in controlled studies. Due to the highly capacitive nature of human tissue, it will present a very high impedance to a fixed DC potential.

The only effective way to deliver a polarised current into a load with capacitive reactance is by using a changing voltage that can overcome the blocking effect that capacitance has for direct current whilst biasing it with a DC offset. The current will then see the load as having a lower overall capacitive reactance and enable therapy to be delivered deeper into the treatment site.

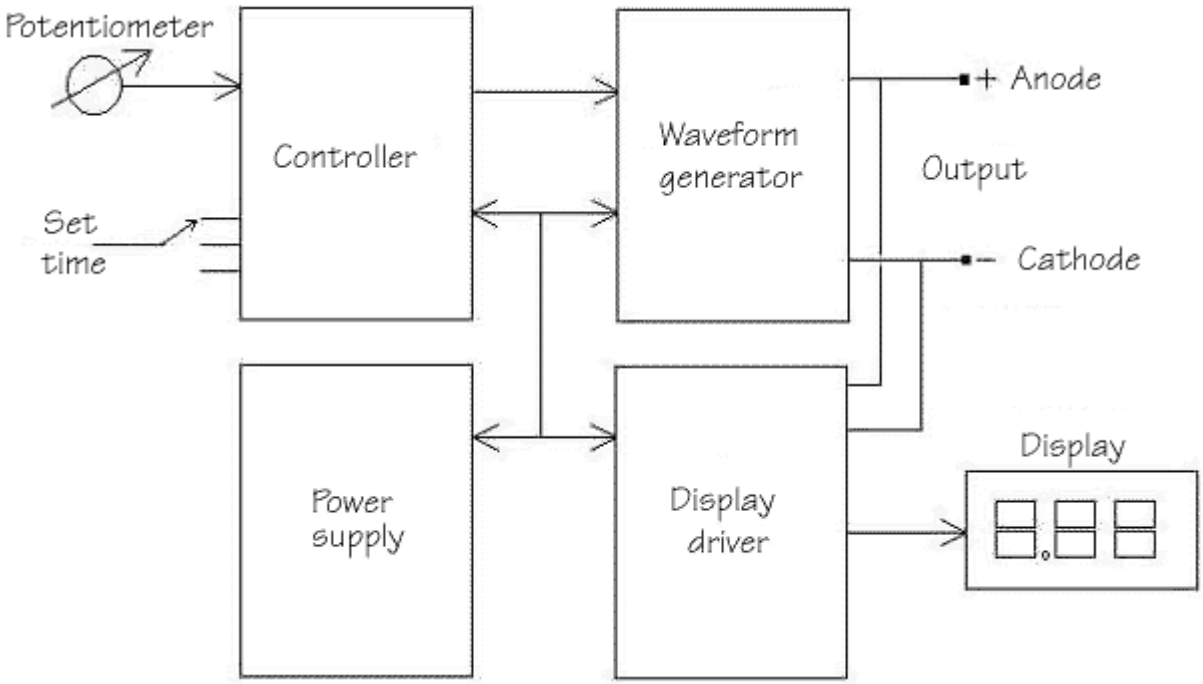
The APS waveform not only changes in amplitude against time, but also does this using a waveform mimicking the shape of natural electrical impulses that conduct within the body. It has been clinically shown that there are neuro-hormonal changes, which have a clinical effect on the biochemical balance in the area being treated.

The electronic delivery and the shape of the APS waveform has been designed to create an increase of specific neurohormones such as melatonin and leucine enkephalin reducing anxiety, pain, and aiding sleep. This is achieved without creating any clinically relevant changes in seratonin or cortisol concentrations which are important hormones to maintain other important neural functions (There are dangers involved with elevated levels of seratonin, and cortisol is important for maintaining normal bodily functions, including glucose metabolism and anti inflammatory mechanisms).

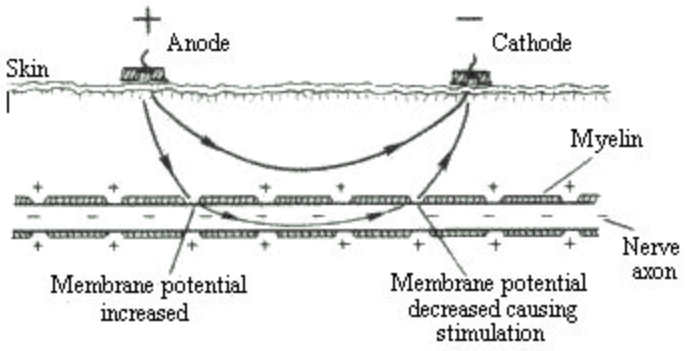
Where physiological functions are impaired due to a breakdown in biochemistry and nerve function, it is feasible to attempt to therapeutically re-activate those physiological functions electronically by the use of APS therapy. APS therapy has proven to be effective in treating many painful conditions, reducing inflammation and pain.

Circuit description

The output voltage can be adjusted using a potentiometer to produce currents up to 3 milliamps in the treatment area (load). The maximum voltage attainable is 47 volts to the peak of the exponential waveform with regard to zero volts. It has a timer giving 3 options of 4 mins, 8 mins, or 16 mins. The exponentially decaying waveform is produced by electronically switching a capacitor 150 times per second (waveform generator) into a resistor/capacitor network (skin and tissue). An alarm sounds at the end of treatment.



Skin is very resistive and a typical resistance of 1 M Ohm can be expected between 2 gel electrodes placed 15 cms apart on the surface of the skin (the electrodes have a conductive gel that sticks to the skin with a resistance of approximately 1 Kohm).



A typical capacitance between the same electrodes is 50 nanofarads. At a frequency of 150 Hz the reactance of this C-R circuit would be 21.2 Kohms. The exponentially decaying waveform decays to approximately 5 Volts in 6.6 milli-seconds due to the C-R time constant of the circuit. The DC level is never allowed to completely decay to 0 volts until the end of the treatment session. This enables a DC offset charge to be maintained in the tissue with a variable exponentially decaying waveform creating the voltage needed to drive polarised currents into the capacitive/resistive impedance of the load (which is the patient). These currents are required to alter the biochemistry in the tissue and stimulate the nerves.

Due to the polarised nature of the APS impulses, the current always flows in one direction. (Positive to negative-conventional current flow, negative to positive-electron flow). Using this method of delivery is a very effective way to transmit electrical currents deep into the tissue.

Biochemical effects

Breakdown of substances due to the electrolytic effect: Chemical reactions can be created in electrolytes liberating gases or depositing solids in amounts that are proportional to the amount of current passed (as discovered by Michael Faraday).

The current produced by the APS waveform can break down biochemical substances within the tissue, this process (electrolysisincreases availability of elements such as potassium, sodium, calcium, oxygen, nitrogen, and hydrogen (to name but a few). These elements are vital for the body's biochemistry to function normally. This process creates an increase of oxygen towards the positive electrode (anode) by breaking down elecolytes.

When AtrPS waveforms are used on the body there will be a different biochemical reaction under the anode as compared with the cathode. When an electric current is present, elements which have a negative charge would move towards the positive electrode (anode) and elements which have a positive charge (such as Ca2+, a free calcium ion found in the body and used for nerve conduction) will be drawn towards the negative electrode (cathode). There is a release of hydrogen ions (cations as a result of the electrical current breaking hydrogen bonds in electrolytes and amino acids, this will have implications for peptides and proteins, triggering other events. When acidified aqueous solution are electrolysed, chemical changes occur at the electrodes.

Since all chemical reactions involve changes to the electron structure of atoms, all reactions are now recognised as electrochemical in nature. Oxidation for example was once defined as a process, in which oxygen was combined with a substance, or hydrogen was removed from a compound, it is now defined as a process in which electrons are lost. The break down of biochemical substances will mean easier absorption of biochemical waste (smaller particles) through the blood vessel walls. There will be local heating due to the electrical current flowing between the electrodes (as there is with any electrical current in a conductor).

Amino acids are made up of mainly carbon, oxygen, hydrogen, and nitrogen. When 2 or more join together they form peptides. Proteins are formed from polypeptides (peptide chains consisting of more than 3 amino acids). The biochemistry of body produces electrical currents that can alter chemical bonds to produce a specific physiological reaction. The electron bonds that hold these substances together can be broken if targeted by an ionic flow of sufficient strength. There are many medical conditions related to the body's inability to operate correctly at a biochemical atomic level. APS therapy may tilt the balance in our favour enabling the body use the external electrons to break the atomic bonds and normalise physiological functions in that area.

Nerve stimulation

The APS waveform is also able to penetrate deep into the treatment area and directly stimulate the nerves due to its ability to conduct current through the capacitive tissue (due to the change in voltage with regard to time). The 150 APS pulses per second trigger the central nervous system, causing the release of neurohormones. Neurohormones are produced within specialised nerve cells and secreted from the nerve endings into the circulation to perform a particular function depending on the hormone released. Statistically significant changes in have been

measured in treatment groups as compared with placebo groups in double blinded studies carried out on osteoporosis sufferers.

Ionic potential gradients affect the flow of neuro transmitters and hormones through the sodium ion channels in nerve and muscle fibres, different ionic gradients cause different neuro transmitters and hormones to be released or inhibited depending on the gradient. The APS electron flow stimulates ionic gradient changes and this is one factor causing changes in neuro-hormonal levels.

What is this therapy being used for?

There are many people suffering from painful inflammatory conditions that have conventionally been treated with anti-inflammatory pain killers. These can have very unpleasant side effects and some people are unable to take this kind of medication. The action potential simulation therapy device is being used as an alternative to drugs for treatment of these conditions. This is a new and innovative type of electrotherapy, which may become a serious alternative to anti-inflammatory drugs.

This device is currently being used to treat:

- Acute and chronic pain
- Inflammation
- Immobility of stiff joints due to inflammation
- Tissue damage due to inflammation
- Poor local blood circulation

(There may be other conditions that APS could treat but have not been investigated.)

Comment

At some point in the future electrotherapy will be the first port of call for many conditions, not the last. It could treat a wide variety of medical conditions, (especially those, which are caused by biochemical imbalance or breakdown) without the dangerous side effects that many drug therapies have.

There is still very little research being carried out on the biochemical, physiological, and psychological effects of electricity on the human body, in comparison with pharmaceutical research. Much more investment is needed to encourage the medical profession to carry out more delving studies of how the body is affected at a molecular levels.

There are many conditions in which pathological studies reveal biochemical problems. One example is Alzheimer's where pathological studies have revealed excess amyloid protein in the brain.

Our ability to manipulate the body using electronic medical devices is improving slowly. As technology advances we should try to develop our skills in manipulating our physiology in new ways, freeing people of their reliance on pharmaceuticals.

Glossary

CATION: An ion with a deficiency of electrons (net positive charge).

ANION: An ion with an excess of electrons (net negative charge).

IONIC SUBSTANCE: A substance that, when separated, all the individual elements consist of cations and anions. Ionic substances are usually composed of metallic and non-metallic elements with zero net electric charge.

MOLECULAR SUBSTANCE: A substance consisting of molecules, which are electrically neutral, tightly bound groups of atoms.

ELECTROLYTES: These are substances containing free moving ions; examples include molten salts, aqueous solutions of acids, and salts.

ELECTROLYSIS: This is the decomposition of an electrolyte by electric current.