Physiotherapy and Electrotherapy Equipment

High Frequency Heat Therapy

These are therapeutic instruments based on heat generated due to electric current. This procedure of relieving pain through current was practiced in ancient Rome during 63 AD by standing on electric fish. The simple way to relieve pain has been heat therapy locally. Reaching to deep tissues under pain would not be possible using traditional methods of heating using hot water bottles, hot towels etc. The electric current induces heat in these deep seated tissues by properly placing the electrodes in the localised area. This is where electrical diathermy is used a physiothereuptic procedure.

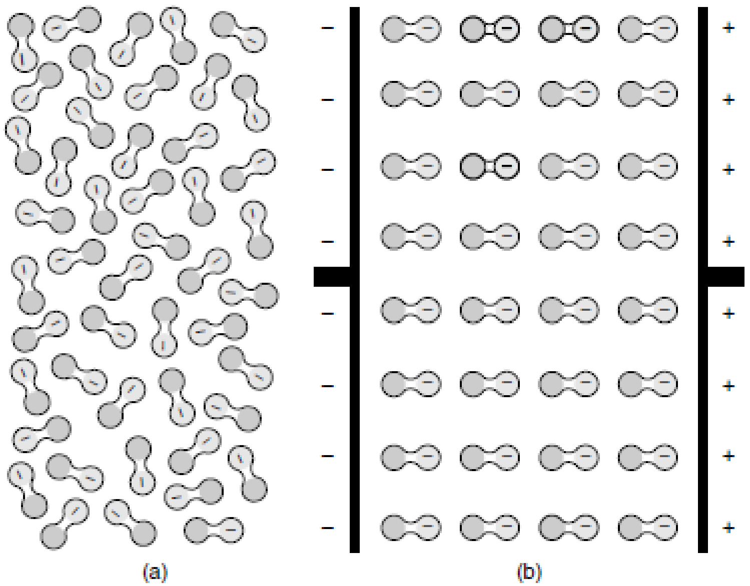
This is used commonly for bone and muscle tissues. Used to relieve pain by increasing the blood flow, increases mobility of the tissues etc. Diathermy does not apply heat to the body rather it develops heat within the body tissues as deep as two inches below the skin surface. Heat also stimulates neural receptors

Physical stimulus commonly employed in the practice of physiotherapy is in the form of heat, either by simple heat radiation or by the application of high frequency energy obtained from special generators. The use of high frequency energy in thermotherapy has the advantage of considerable penetration as compared with simple heat application. Thus, with high frequency energy, deeper lying tissues, e.g. muscles, bones, internal organs, etc. can be provided heat.

High frequency heat therapy is based on the fact that the dipole molecules of the body are normally placed randomly. Under the influence of an electric field, they rotate according to the polarity of their charge in the direction of the field lines (Fig. 29.1). The positively charged end of the dipole then orients itself to the minus pole and the negatively charged end to the plus pole. Since the polarity of the electric field alternates, a micro-heating effect results from the continuous re-alignment of the molecules.

High frequency energy for heating is obtained by various ways. It may be from the short-wave therapy unit making use of either the condenser field or the inductor field method. Microwaves and ultrasonic waves are also used for heating purposes in special cases.

Dipole Alignment under External Field

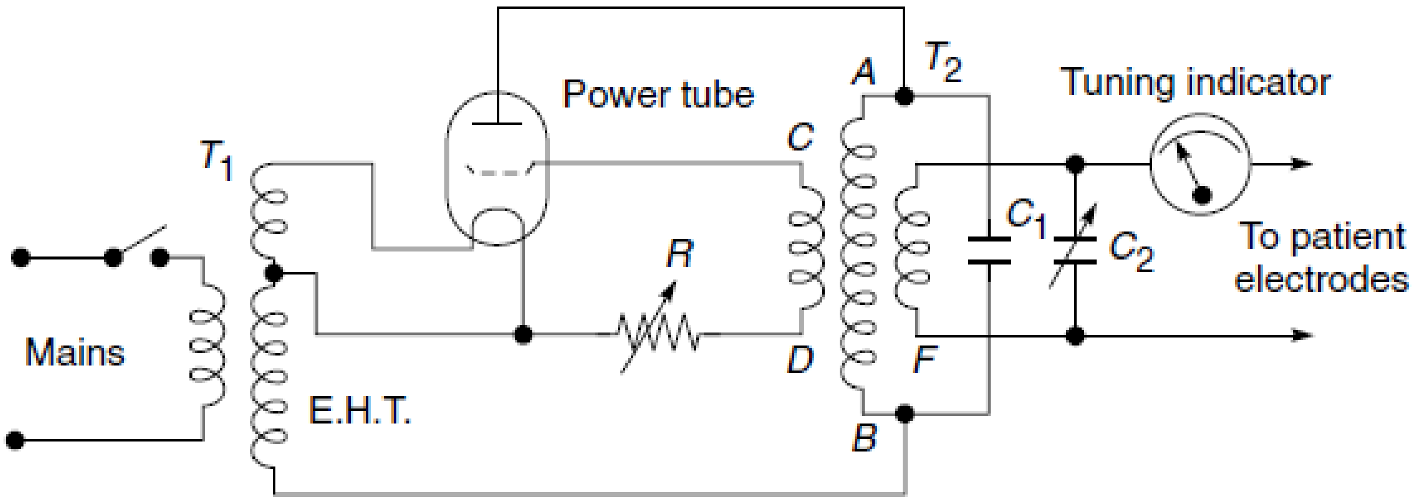


➤ Fig. 29.1 *Principle of high frequency heat therapy units*
(a) *The dipole molecules of the body are at first ordered completely randomly*
(b) *Under the influence of an electric field, they rotate according to the polarity of their charge in the direction of the field lines*

Short Wave Diathermy SWD

- The term 'diathermy' means 'through heating' or producing deep heating directly in the tissues of the body. Externally applied sources of heat like hot towels, infrared lamps and electric heating pads often produce discomfort and skin burns long before adequate heat has penetrated to the deeper tissues.
- But with the diathermy technique, the subject's body becomes a part of the electrical circuit and the heat is produced within the body and not transferred through the skin. **Another advantage of diathermy is that the treatment can be controlled precisely.** Careful placement of the electrodes permits localization of the heat to the region that has to be treated.
- The amount of heat can be closely adjusted by means of circuit parameters. The heating of the tissues is carried out by high frequency alternating current which generally has a frequency of 27.12 M Hz. Currents of such high frequencies do not stimulate motor or sensory nerves, nor do they produce any muscle contraction. SWD converts the electromagnetic energy to heat energy
- Thus, when such a current is passed through the body, no discomfort is caused to the subject. The current being alternating, it is possible to pass through the tissues currents of a much greater intensity to produce direct heating in the tissues similar to any other electrical conductor.

Short Wave Diathermy



➤ **Fig. 29.2** *Simplified circuit diagram of a short-wave diathermy unit*

Basically the circuit has two parts

1. Oscillator producing frequency of 27.12 MHzs.
2. Tuning circuit coupled to the Oscillator through the transformer action which is connected to the patient. The tuning circuit can be exactly tuned to the same frequency.

Circuit Working

A vacuum tube Triode based circuit was used in the early days. Works on very high voltage in terms of 4 K V. The LC oscillator is used to generate the high frequency in the range of 27 M Hz. The typical frequency used in medical application is 27.12 M Hzs,

The transformer T1 supplies the cathode and the anode voltage. The grid in between the cathode and anode which acts as the stopping electrode for the electrons emitted from the cathode in reaching the anode. Anode is given with around 4000 V. The anode current is controlled by the voltage applied to the grid through the resistor R.

The second coil of the transformer T2 AB, along with the capacitor C1 acts as the LC circuit to produce the signal. The coil EF and capacitor C2 is the tunable circuit which delivers the signal to the patient. Maximum power is transferred to the electrode only when both the set of LC coils resonate to each other. When they match maximum current flows in the circuit.

This kind of tuning arrangement through inductive action provides electrical isolation between the diathermy machine and the patient.

Working Continued…

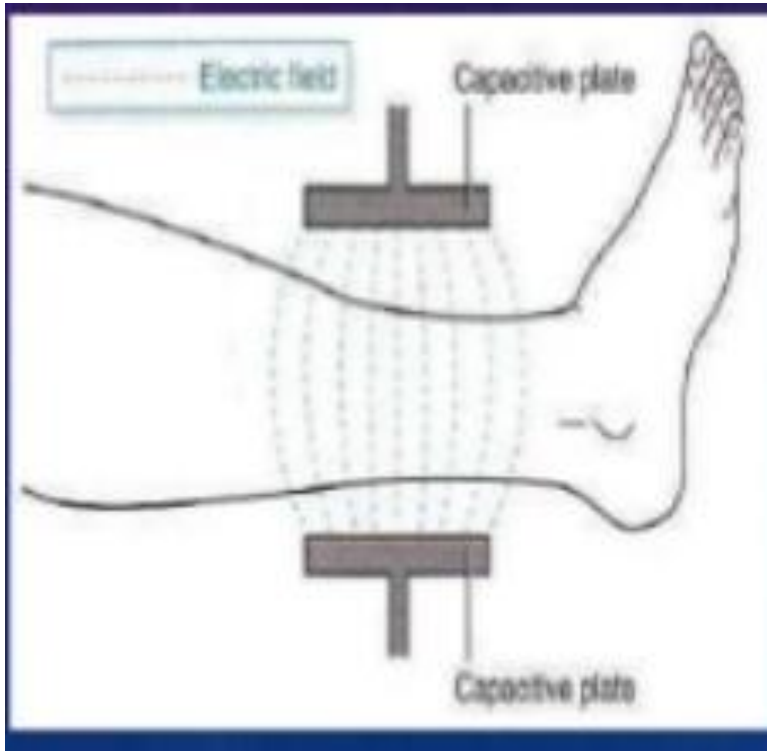
The meter on the patient side checks for the tuning of the patient to the signal applied, if the patient side does not get tuned to the oscillations the heating effect will not be produced. Hence during the treatment a detuning capacitor C2 is used to vary the frequency delivered to the patient, in most cases tuning will be done automatically through a servomotor. This is continuously monitored through the tuning indicator meter connected in the output. The tuning meter will record a maximum current when both the circuits match. Indicator lamps will glow.

Application of SWD

There are two types of applications of SWD:

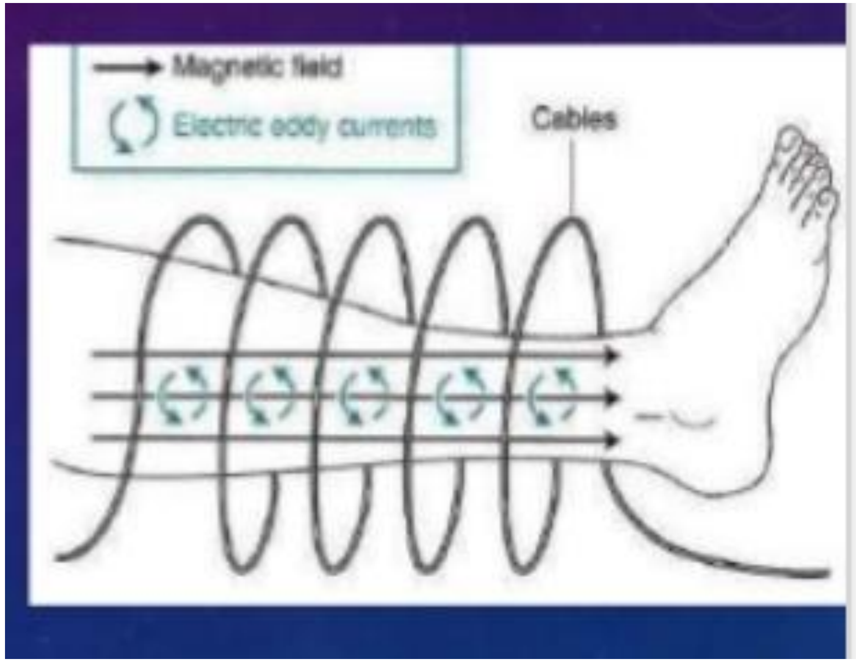
Capacitive application and Inductive application

<ins>Capacitive Application</ins>: The two electrodes
Form the capacitive plate and the fat tissue
Under the skin provides resistance and the
heat is generated in the tissues as a result
Of the resistive dielectric losses.



Inductive Application

The radiation energy is applied through a coil with arrangement as shown in the fig. The inductive current induces eddy current losses in the tissues and heat is generated.



Microwave Diathermy

MWD

- Microwave diathermy utilizes electromagnetic radiation in the range of 918 MHz-2456 MHz The microwave frequency range is 300 MHz-30000 MHz
- Microwave radiation has unique property that can be used for clinical advantage is that it has selective affinity to water. So tissues with high water content such as muscle and the adjacent fat tissues can be more easily focused than that with SWD.
- The microwaves can be focused more easily than SW hence the tissues can be heated more efficiently without any leakage.
- Patients with edema, blisters should not be treated with microwave as it might boil the water content in that and cause burns. People with obesity have the risk getting burns due to the heavy fat content.
- About 50% of the heat gets reflected and only the remaining 50% gets focused on the patient body, it can penetrate to a depth of 6-12cms.

- Though both SW & MW gives the same heating effect, in some case MWD has better results
- Application of SWD needs electrodes or pads and also tuning. Microwaves are directly radiated through radiators or applicators and tuning is not required.
- Application of microwaves is much simpler

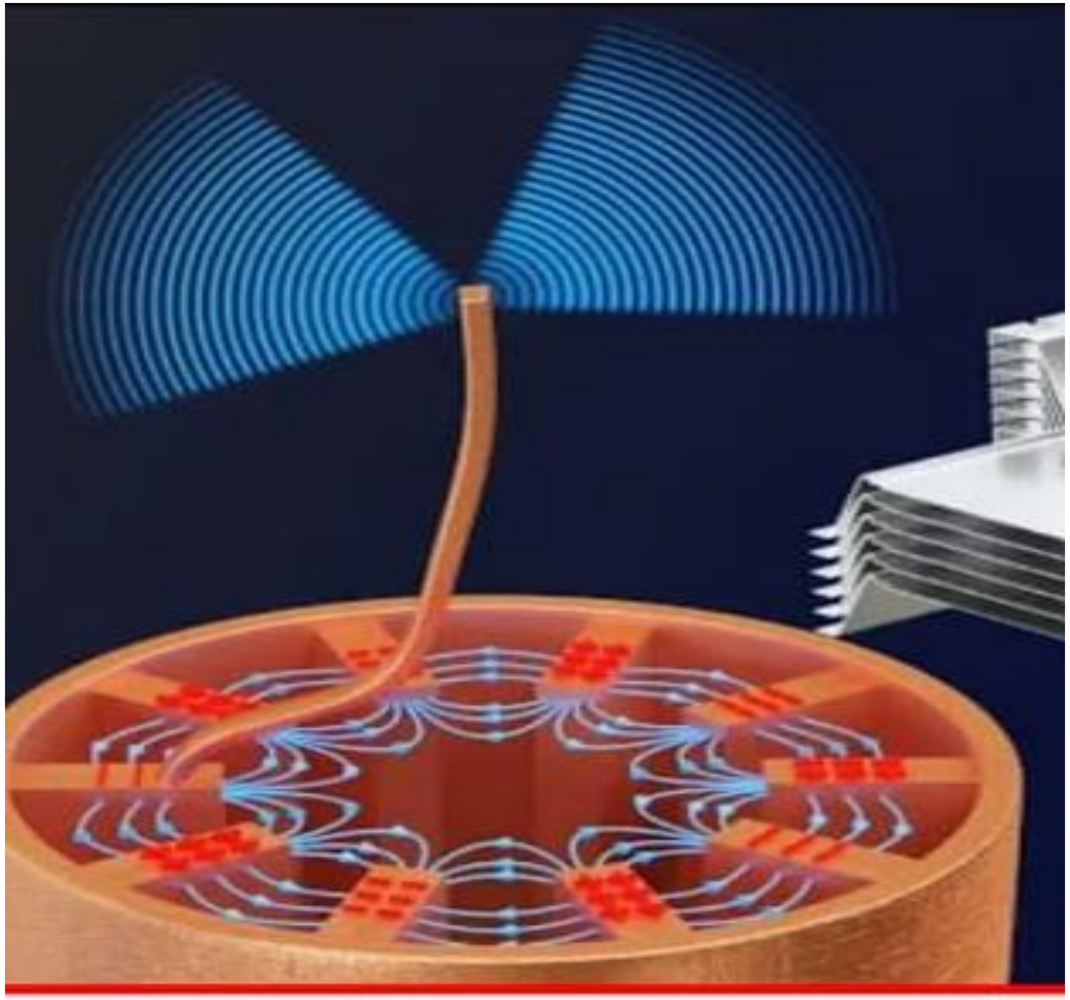
Production of Microwaves

Microwaves are generated in magnetron cavity, where both electric and magnetic fields are applied. Special type of device called ‘magnetron’ is used for the production of high frequency currents of high power. The magnetron consists of a cylindrical cathode surrounded by an anode structure that contains cavities opening into the cathode-anode space by means of slots. Permanent magnet fitted onto the cylindrical anode. The output energy is derived from the resonator system by means of a coupling loop which is forced into one of the cavities. The energy picked up on the coupling loop is carried out of the magnetron on the central conductor of a co-axial output tube through a glass seal to a director. The director consists of a radiating element of antenna and a reflector which directs the energy for application to the patient. The electrical current is transformed into electromagnetic radiation and radiated through the antenna.

Magnetron Structure

The magnetron consists of a cylindrical cathode surrounded by an anode structure that contains cavities opening into the cathode-anode space by means of slots. The output energy is derived from the resonator system by means of a coupling loop which is forced into one of the cavities. The energy picked up on the coupling loop is carried out of the magnetron on the central conductor of a co-axial output tube through a glass seal to a director. The director consists of a radiating element of antenna and a reflector which directs the energy for application to the patient. The electrical current is transformed into electromagnetic radiation on passing through the antenna.

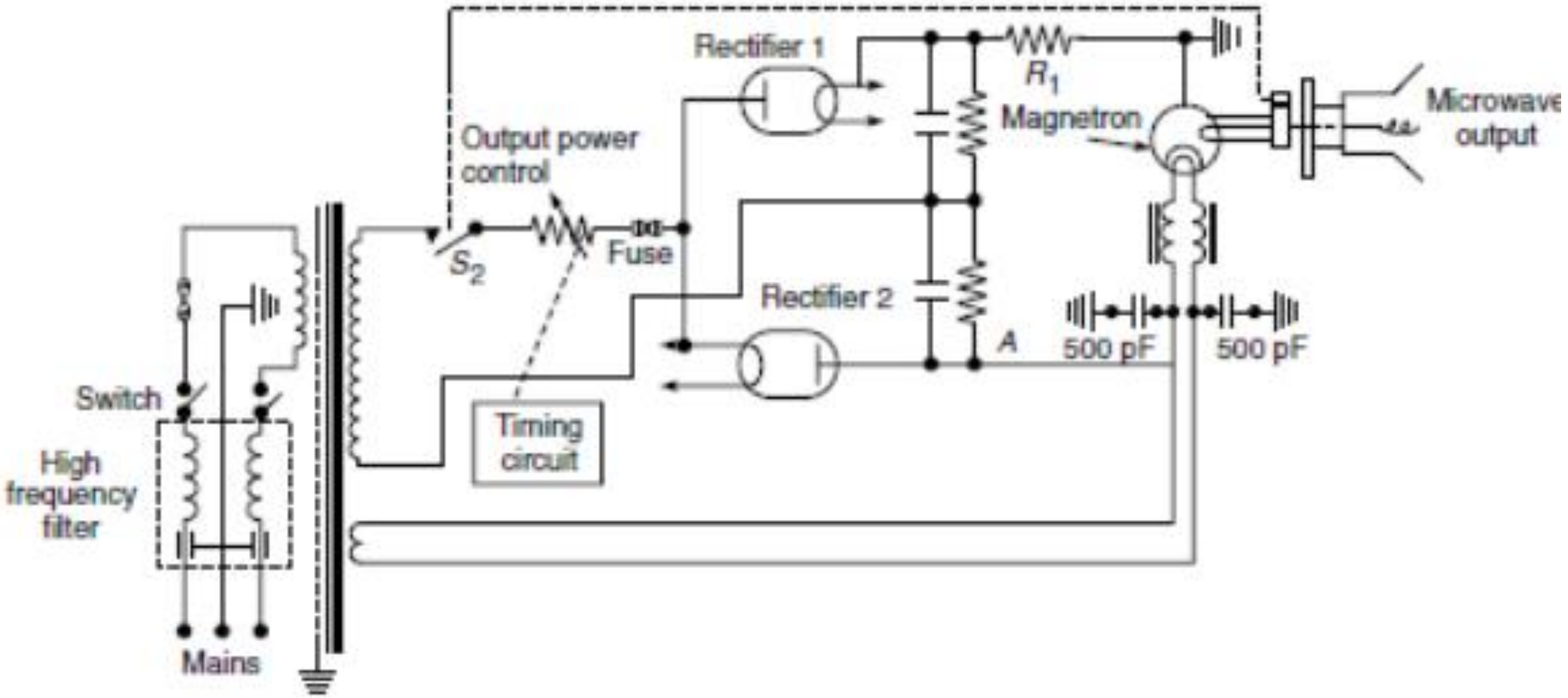
Magnetron



The slotted cylindrical anode is seen. The circular electric field lines formed under the combined influence of electric and magnetic filed lines can be noticed. On close observation you can see the alternate + ve & - ve charges formed due to the circulating electrons this behaves like a series of capacitors. And the circular wall of the anode cavity in between the induced capacitive plates acts as the inductor. This effectively creates a series of resonating LC circuits. And a pick up coil is connected to one of these cavities will pick up the oscillations and radiate. This is connected to the coaxial cable and fed to the applicator.

The reflector then focuses this electromagnetic energy and beams it to the tissues where it is subsequently absorbed, reflected or refracted, according to the electrical properties of the tissue. Tissues of lower water content (i.e., subcutaneous) are penetrated to a greater depth but little is absorbed, whereas tissues of high water content (i.e., muscle) absorb more of the electromagnetic energy but allow little penetration. The output power of a magnetron depends upon anode voltage, magnetic field and the magnitude and phase of the load impedance to which the magnetron output power is delivered. Therefore, the cable used to carry the energy from the magnetron to the director is always of a definite length for a particular frequency. A part of the energy fed to the magnetron is also converted into heat in the anode on account of the collision of the electrons with the anode so that the output energy is considerably less than the input energy. The efficiency of a magnetron is usually 40 to 60%. The heat produced at the anode must be removed which is usually done by using water or air as a means of cooling.

Schematic Diagram



➤ **Fig. 29.5** *Simplified circuit diagram of a microwave diathermy machine*

Schematic Diagram and Working

The transformer primary has a LC filter to stop the oscillations generated from the equipment in reaching the secondary. The cathode of the magnetron is heated through the small secondary coil. A DC voltage is applied to the anode using full wave rectifiers. The current to the anode is controlled by the variable resistor. The magnetron has to be heated for about 3-4 minutes before deriving the power from its output. A timer is incorporated to introduce the delay and connect the output of the magnetron after the anode is switched on (S2) delay time.

A fuse is included in the circuit to limit the current to a maximum of 500 mA for safety aspects. The general time of radiation is around 20 minutes.

No electrodes are used the rf wave is focused using spherical or circular applicators

MWD units

Circular Applicators

Spherical Applicator

Ultrasonic Therapy

Ultrasonic Therapy

Ultrasonic frequency range is above the audible range, above 20 KHz.

Ultrasonic therapeutical unit works similar to SWD. The heating effect produced in the body is due to the absorption of the ultrasonic waves by the body tissues. The vibration of the waves gives the effect of massage to a greater depth which is not possible manually. The thermal effects of the ultrasonic heating depends upon the length of exposure, the absorption capability of the tissues and the frequency of the waves. The power requirement is 3 W/Cm^2 of the transducer area.

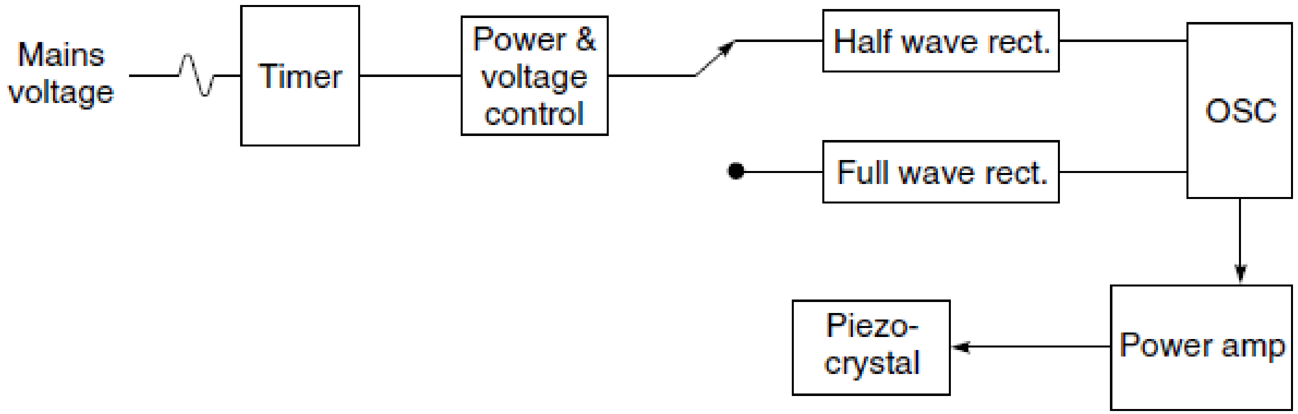
Ultrasonic generators work on the principle of Piezoelectric effect.

Piezoelectric effect produces mechanical vibrations when a piezoelectric crystal is applied with alternating current. And when the crystal is subjected to a mechanical vibrations charges are induced on the surface.

A high frequency in the range of .75 to 3 MHz. is applied to the ultrasonic crystals and the resulting vibrations are picked up by the metallic plates coupled to the crystal and passed to the body tissue through a coupling medium. The applicators range from 70-130 mm diameter.

Schematic Diagram

768 *Handbook of Biomedical Instrumentation*



➤ **Fig. 29.6** *Block diagram of an ultrasonic therapy unit*

Working

The oscillations produced by the oscillators are in the range of 1 MHz, using LC oscillators. The oscillations are modulated by 100 Hz from mains. The oscillators can be continuous or pulsed. If it is continuous then the supply to the oscillator is dc connected through full wave rectifier. If it has to be operated in pulsed mode then the dc supply is connected through half wave rectifier. The pulses or bursts of frequency modulated by 100 Hz is generated. The oscillator output is delivered through power amplifier.

The transducer is Barium Titanate or lead Zirconate Titanate crystal having 5-6 Cm^2 area. The length of the cable should not be altered. The voltage is applied to the metallic plates pressed to the crystal. The amount of energy absorbed is frequency dependent. With 1 MHz frequency about 50% of the energy loss takes place at a depth of 5 Cm. and with 3 MHz the same loss occurs at 1.5 Cm. Frequency lesser than 1 MHz, the energy gets dispersed and no effective heating takes place and hence the typical frequency of operation is 80 KHz to 1 MHz.

In order to have a effective treatment a correct output power and duration of exposure is necessary. Most of the equipment come with dose specification or dose tabulator, corresponding to a particular disease. And one needs to set the pointer correctly to deliver the desired output power.

Electrodiagnostic/Therapeutic Apparatus

Contents

- Electro diagnosis
- Electro therapy
- Electro therapy machine
- Interferential current

Electro Diagnosis

- When normal muscle cells are stimulated with adequate current they contract. When there is dysfunctionality of the tissues alterations will occur in response to the electrical stimulus. This is used in identifying the diseased tissues. There can be variation in the current either high or low when its diseased. This fact is used in the determination of degenerative or regenerative process of nerves or muscle tissues.
- The current intensity and time of the duration of application of the current gives an idea of the condition of the muscle or nerve tissue. This is done by applying various current pulses to the tissues. i-t curve helps in analysing the patient better.

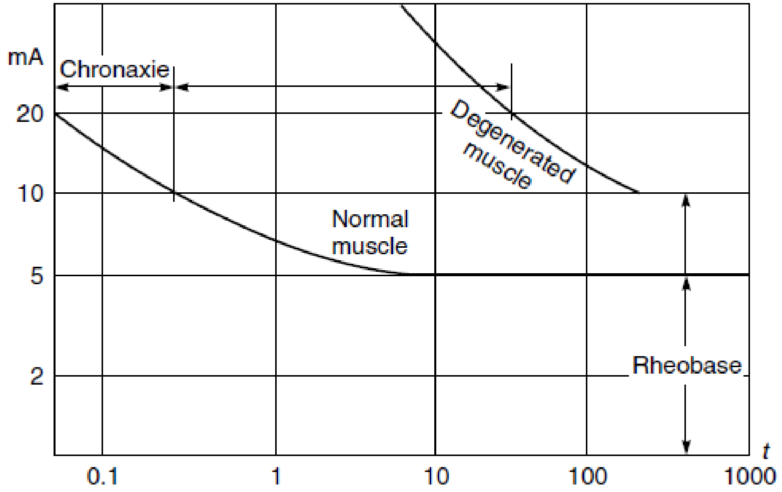
For diagnosing the muscle tissues. First it is stimulated with a long pulse of duration of 1s duration and then it is made shorter and shorter until 0.05ms. At each duration the current intensity is increased until the muscle tissue responds.

The typical response is shown in the figure. It can be seen that in degenerated neuro muscle the response comes for a prolonged & high intensity pulse compared to that of the normal muscle.

Rheobase: This is the minimum intensity of current needed to bring the stimulation for a pulse of infinite duration i.e usually 100ms.

Chronaxie: This is the duration in which the response comes when the current intensity if double that of rheobase

i-t curve



➤ Fig. 29.7 *Typical intensity time curves of a normal muscle and degenerated muscle. The curve shows that decreasing excitability with progressive degeneration requires extended stimulation times and increased current strength for achieving successful stimulation*

Accommodation: When a neuro muscular unit is excited with a slowly increasing current the threshold of stimulation increases. This is the accommodating property of the neuro muscular unit.

Electrotherapy ET

Applying low volt, low frequency impulse current is a practice in physiotherapy. This is used in treatment of partial or total paralysis, muscular pain, muscular spasm and disturbance in peripheral circulation. ET is also used to strengthen weak muscles.

This is a process of applying electric impulses to the affected parts of the body, through pads attached to the body. You feel a tingling sensation then it starts feeling comfortable. The electrical impulses block the impulses going to the brain and the spinal cord and relieve the pain. They also improve the blood supply. They may also stimulate the production of endorphins, which are the natural pain killers of the body. They are safe to use without any side effects but they can not be used with patients with pace makers or with history of epilepsy.

ET is also used for drug administration by a process called as Iontophoresis.

Different Current Waveforms

Electrotherapy is generating different current waveforms and applying. The different current waveforms are:

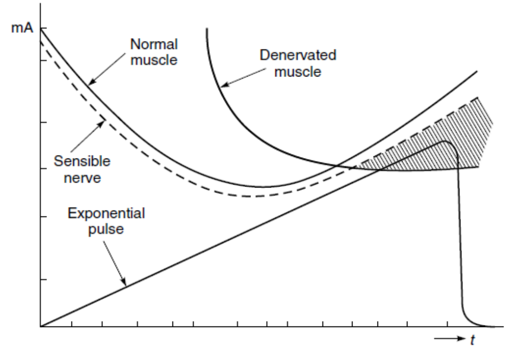
Galvanic Current: In this procedure a direct current to the order of 0.3 to 0.5 ma/sq.cm. of the electrode area is made to flow through the electrodes. The ions are collected underneath the skin where the electrode is being placed. And this results in a higher blood flow, the area becomes red and this is Hyperaemia. And the reaction is chemical. Galvanic current may be used for the preliminary treatment of atonic paralysis and for the treatment of disturbance in the blood flow. It is also used for iontophoresis, which means the introduction of drugs into the body th rough the skin by electrolytic means.

Faradic Current: Faradic current is a sequence of pulses with a defined shape and current intensity. The pulse duration is about 1 minutes with a triangular waveform and an interval duration of about 20 minutes. Faradic current acts upon muscle tissue and upon the motor nerves to produce muscle contractions. There is no ion transfer and consequently, no chemical effect. This may be used for the treatment of muscle weakness after lengthy immobilization and of disuse atrophy.

Surging Current: If the peak current intensity applied to the patient increases and decreases rhythmically, and the rate of increase and decrease of the peak amplitude is slow, the resulting shape of the current waveform is called a surging current. The main field of application of the Faradic surge current is in the treatment of functional paralysis. The surge rate is usually from 6-60 surges per minute in most of the instruments. The ratio of interval to the duration of the surging is also adjustable so that graded exercise may be administered. This type of current is usually required for the treatment of spasm and pain.

Exponentially Progressive Current*:* This current is useful for the treatment of severe paralysis. The main advantage of this method lies in the possibility of providing selective stimulation for the treatment of the paralysed muscles. This means that the surrounding healthy tissues even in the immediate neighbourhood of the diseased muscles are not stimulated. The slope of the

exponential pulse is kept variable.



➤ **Fig. 29.8** *Principle of selective stimulation of the denervated musculature. Selective stimulation of the denervated muscle without irritation of the sensible receptors is possible in the shaded area of the graph.*

Biphasic stimulation: Here immediately after applying the electric current an opposite polarity current of low amplitude and prolonged duration is passed. This helps in neutralizing the electrodes as well as the skin surface.

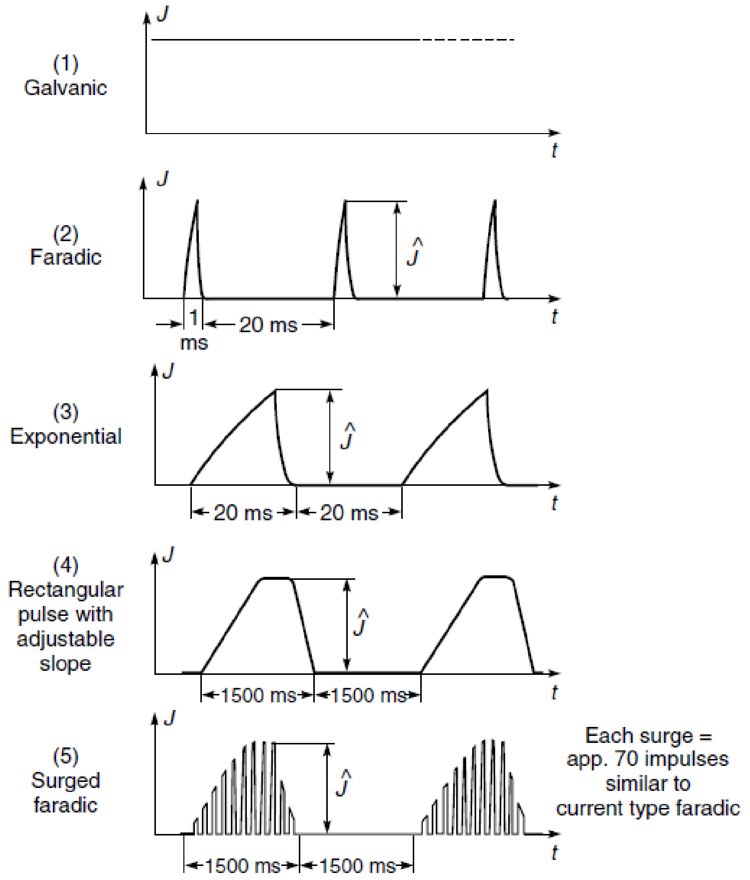


Fig. 29.9 *Current waveforms normally employed in electrodiagnosis and electrotherapy*

Schematic Diagram of Diagnosis/Therapeutic Unit

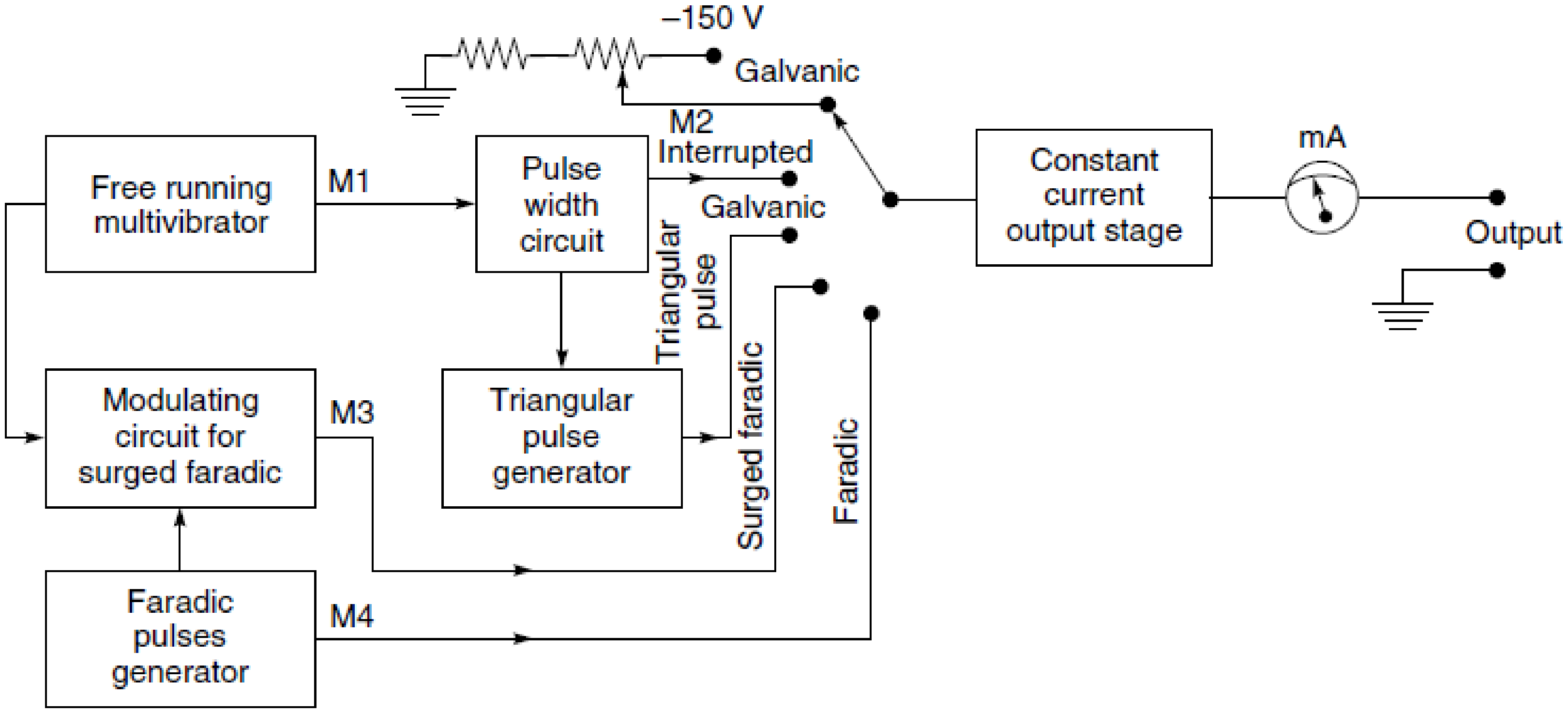


Fig. 29.10 *Schematic diagram of a diagnostic/therapeutic stimulating unit*

Working

The schematic shows multi vibrator circuit. A free running multi-vibrator M1 produces triggering pulses for a monostable circuit M2. The output of this is used as an interrupted galvanic output, whose rate as well as duration can be independently controlled. M4 another multi vibrator produces faradic pulses of short duration. The faradic pulses are modulated at M3 to produce surged faradic pulses.

The monostable output of M2 is given as input to produce triangular pulse generator.

The output is a constant current output stage. Isolation techniques will be used for safety of the patient. A floating ground or isolation transformer will be used at the output stage.

A selection switch will enable proper input selection for the particular application

Interferential Current Therapy IFC

This is a unique way of applying electric current to the tissues. TENS (Transcutaneous Electrical Nerve Stimulation) or NMES Neuro Muscular Electrical Stimulator delivers pulses at low frequencies 2- 200 Hz to the skin surface. However interferential circuits uses two different frequencies one fixed at 4000 Hz. And another varying between 4001-4400 Hz. These two frequencies are mixed to produce beat frequencies. The two frequencies produces interference at the point of intersection of electrodes deep under the tissue. The current perfuses to a greater depth and covers larger volume of tissue than any other electrical therapy. Current intensity can be increased and the perfusion depth can be controlled. At higher frequencies the capacitive resistance of the body decreases allowing higher interferential current to flow through the body.

Interferential currents are produced by using two-channel stimulators and four electrodes. Each channel produces a sinusoidal, symmetrical alternating current at a high frequency (2000–5000 Hz). The electrodes are used in a quad-polar arrangement and the AC frequencies are set at slightly different frequencies but at similar amplitudes. The currents from the two waveforms interface with each other in the tissue, giving constructive (when the two waveforms add to each other) or destructive (when the circuits tend to cancel each other) interference.

Interference Waveform

The two channels at two different frequencies one fixed at 4000 Hz and variable is shown at 4100 Hz. The two different frequencies create a net interference pattern shown in fig. c This will be the current intensity in the deep tissues. The benefit of this method is that the interferential current is generated within the tissues and this gives the therapeutical effect.

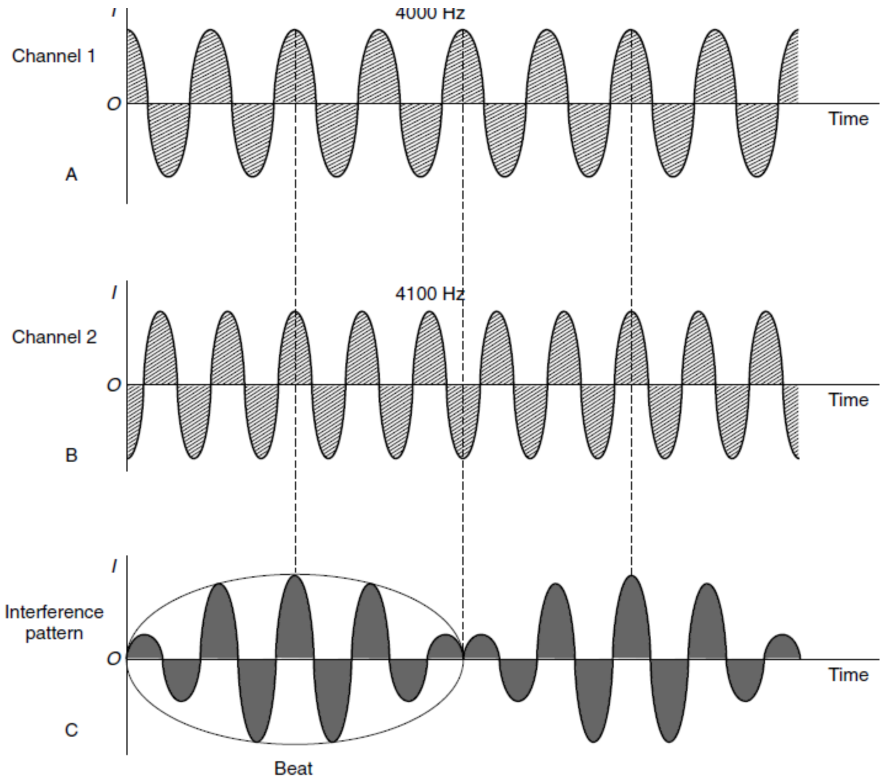


Fig. 29.11 *Principle of generation of interference currents*

IFC Electrode Arrangement

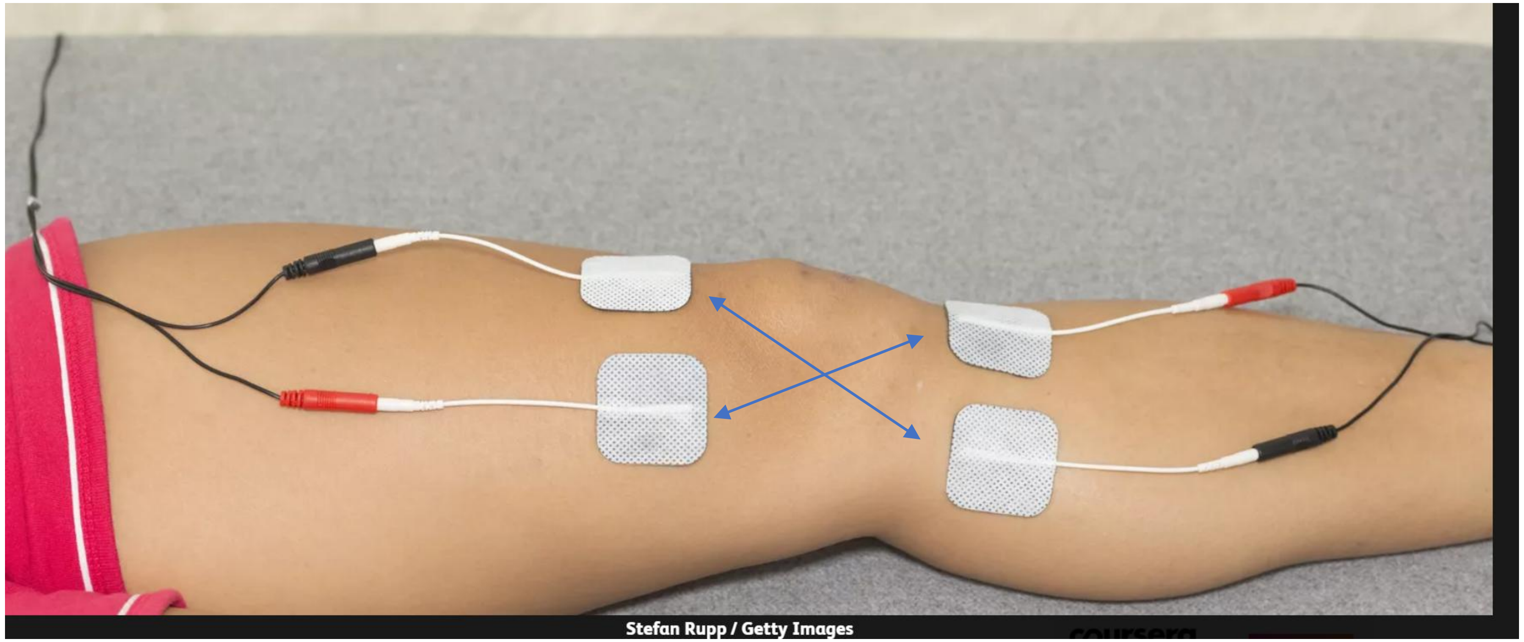


Figure from internet (The cross lines are marked to indicate the criss -cross arrangement of the electrode)

Pain Relief through Electrical Stimulation

Contents

- Pain blocking Mechanism
- Spinal Cord Stimulator
- Bladder stimulator
- Cerebral stimulator

Pain Blocking Mechanism

The electrodes when placed over the skin with the painful portion underlying the skin, will block the nerve impulses by sending electrical impulses. The electrical signals jam the nerve signals along its pathway.

The pain control is explained by

1. The Gate Control Theory which suggests that by electrically stimulating sensory nerve receptors, a gate mechanism is closed in a segment of the spinal cord, preventing pain carrying messages from reaching the brain and blocking the perception of pain

2. The Endorphin Release Theory which suggests that electrical impulses stimulate the production of endorphin and enkephalins in the body. Endorphins & enkephalins are neurotransmitters found in the brain, they act as natural, morphine-like substances in the body ehich block pain messages from reaching the brain. It works in a similar fashion to conventional drug therapy, but without the danger of dependence or other side-effects.

TENS (Transcutaneous Electrical Neuro Stimulator)

The stimulations are provided through these stimulators TENS. The variable current in the range of 0-75mA and an adjustable frequency of 12-100 Hz pulse width from 0.1 to 1.0 ms and pulse amplitude of 0–120 V with maximum output current of 25 mA. The skin impedance should be constant, this can be provided by avoiding movements and also providing maximum surface contact.

Transcutaneous electrical nerve stimulation (TENS) electrodes are commonly moulded from an elastomer such as silicon rubber, loaded with carbon particles to provide conductance. Conformability is achieved by making the electrode thin. Useful carbon-loaded silicon rubbers have a minimum resistivity near 10 Ω-cm

Spinal Cord Stimulator

Spinal cord stimulation is a term relating to the use of electrical stimulation of the human spinal cord for the relief of pain. This is accomplished through the surgical placement of electrodes close to the spinal cord, with leads extending through the skin and with the leads connected to an implanted source of electrical current. The applied electrical impulses develop an electrical field in and around the spinal cord, which then causes depolarization or activation of a portion of the neural system resulting in physiological changes. This blocks the pain signals from reaching the brain.

The stimulus source provides stimulation pulses at frequencies ranging from 10 to 1500 Hz, with pulse widths from 100 to 600 μs and controllable amplitude from 1 to 15 mA delivered into a load from 300 to 1500 Ω. The pulses can also be derived from an implant. An implant derives its power and RF control from an external power unit.

Spinal cord implants are not life support systems and hence there is no hazard if there is failure. But the implant pulses should not interfere with the pacemaker pulses and also should not be exposed to external RF fields

Figure showing spinal cord implant with leads running from the wires to the spinal cord (Internet images)

Magnetic Stimulators

The implant will be a radio receiver and the transmitter will generate pulses with varying duration of muscle contraction typically of 1.6 seconds and a rest period of 9sec. The burst of pulses are generated and modulated for transmitting through the skin with a carrier frequency of 460 kHz. The receiver is a passive device demodulates the received signal and applies it to concerned muscle.

Magnetic stimulators are also under consideration for stimulating both the nerve and brain. This produces magnetic pulses by passing high current pulse through a coil of wire. Its use and safety issues are still under consideration.

Bladder Stimulators

Bladder stimulators are used when the bladder can not be emptied on their own. Reflex actions controlling the bladder muscles protects against any urinary tract infection and also protects the kidney from malfunctioning. This condition happens in people with paraplegia (Dysfunctional lower part of the body)and could be life threatening. Some patients need catheters. But the electrical stimulation of detrusor muscles (Muscle around the bladder that helps relaxation and contraction of the bladder)can be helpful but it also produced side effects by sending high current to the surrounding pelvic muscle.

A technique has been developed to activate the micturition reflex(autonomic reflex that controls the release of urine) by remote electronic stimulation of a permanently implanted spinal electrode, with which the paraplegic is able to empty the bladder completely without the use of a catheter.

Bladder Stimulator (SNS)

The pulses provided are 0.5 to 25 V with A pulse rate of 10-50 Hz. The sacral nerve stimulator (SNS)is a set of two insulated platinum wires of 2.5 mm length with a conical bare tip 1.5 mm mounted 2.5 mm apart on a Epoxy strip to deliver the pulses. The wires are connected through Leads to the neuro modulator receiver. The receiver (neuromodulator)

is mounted under the subcutaneous surface on the left or right side of the

waist. The power unit for the implant will be provided outside.

Bladder is emptied 10-15 sec. after the stimulation

(Sacral nerve carries the signal between the bladder, spinal cord and brain)

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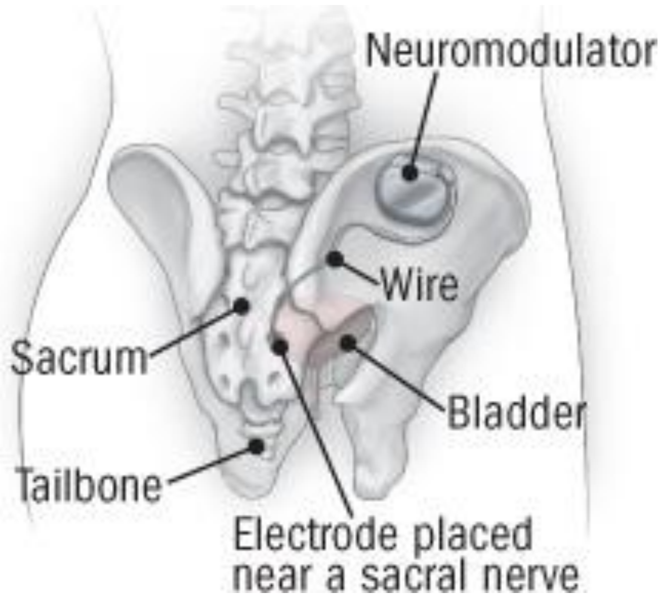

(Figure from internet)

Cerebral Stimulation

Cerebellar stimulation is given to patients in modifying or inhibiting epilepsy. Stimulation to the cerebellum is provoked by transcutaneous inductive coupling, through an antenna (receiver wire) fixed subcutaneously (surgical implant) on the chest. The impulses are delivered through four pairs of platinum discs fixed on a plate of silicon-coated mesh. The electrodes are applied beneath the tentorium to the cortex of an anterior lobe of cerebellum or directly to the posterior lobe. In some cases, electrode bearing plates are placed on both the anterior and posterior cerebellar cortex. The parameters of stimulation vary from person to person, and are adjusted depending upon the effects noted in individual cases. Rectangular pulses of 1 ms width, with a rate of 7-200 Hz and an intensity of 0.5–14 V are generally used for the stimulation.

Exercise

- Compare the different electrical therapeutical techniques studied based on their effects, frequency, volt/current and pulse width requirements

Thank You