SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I - Therapeutic Instrumentation – SBM1403

1. Cardiac Pacemakers

1.1 Need for Pacemakers

Rhythmic beating of heart is due to the triggering pulsed generated at the SA node. If the SA node ceases to function, or if pulses do not reach the heart muscles, the normal heart action gets disturbed.

An external electrical stimulation can regulate the heart rate. These pulses are given by an electronic instrument called pacemaker. A pacemaker is a small device that's placed in the chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate.

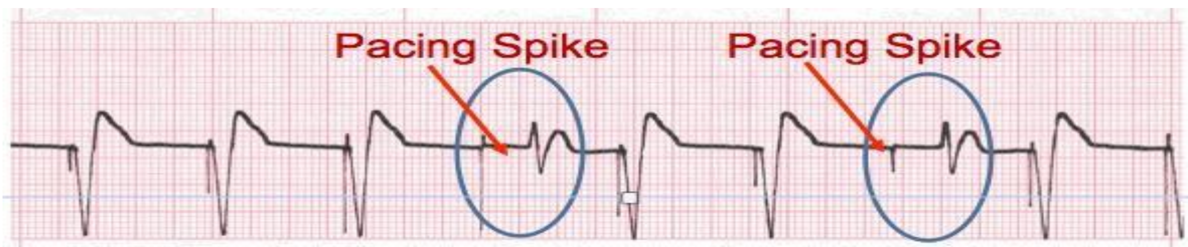

Fig 1.1 Pacing ECG

Pacemakers are used to treat arrhythmias. Arrhythmias are problems with the rate or rhythm of the heartbeat. During an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm.

Pacemakers have 2 parts:

All artificial cardiac pacemakers have a pulse generator (a device that gives off an electrical impulse at prescribed intervals), electrical leads (which transmit the impulse to the myocardium), and a battery (usually made of lithium iodide) encased in titanium and implanted surgically in a subcutaneous pocket (usually in the chest). A small incision (cut) is made, most often on the left side of the chest below the collarbone. The pacemaker generator is then placed under the skin at this location.

The battery most commonly used in permanent pacers has a lifespan of five to nine years.

Types of pacemaker – External pacemakers and internal pacemakers

1.2. External Pacemakers

External pacemakers are a temporary means of pacing a patient's heart during a medical emergency. It is accomplished by delivering pulses of electric current through the patient's chest, which stimulates the heart to contract. The most common indication is an abnormally slow heart rate.

Fig 1.2 External pacemaker

During external pacing, pads are placed on the patient's chest, either in the anterior/lateral position or the anterior/posterior position. The anterior/posterior position is preferred as it minimizes transthoracic electrical impedance by "sandwiching" the heart between the two pads. The pads are then attached to a monitor/defibrillator, a heart rate is selected, and current (measured in milliamps) is increased until electrical capture (characterized by a wide QRS complex with tall, broad T wave on the ECG) is obtained, with a corresponding pulse.

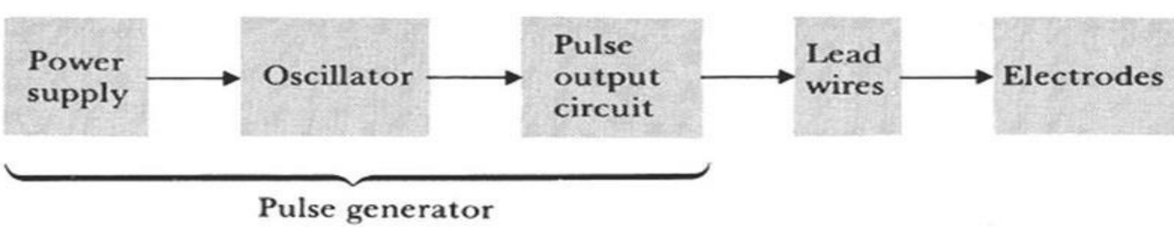

Fig 1.3 Block diagram of external pacemaker

1.3 Implantable Pacemakers

An internal pacemaker is one in which the electrodes into the heart, the electronic circuitry and the power supply are implanted (internally) within the body.

Pacemakers may function continuously and stimulate the heart at a fixed rate or at an increased rate during exercise. A pacemaker can also be programmed to detect too long a pause between heartbeats and then stimulate the heart.

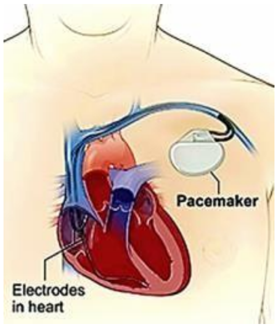

Fig 1.4 pacemaker placement

Types of pacemakers

1. Fixed rate pacemakers
2. Demand pacemakers
3. R wave triggered pacemakers
4. R wave inhibited pacemakers
5. Atrial triggered pacemakers
6. Single chamber pacemakers
7. Dual chamber pacemakers

Pulse generators

The pulse generator is internal in permanent pacemakers (subcutaneously or submuscularly) and external in temporary pacing.

It can be set to a fixed-rate (asynchronous) or demand (synchronous) mode.

In the fixed-rate mode, there is a small risk of producing dangerous dysrhythmias if the impulse coincides with the vulnerable period of the T wave.

On-demand pacemakers detect spontaneous ventricular activity and the output of the pacemaker is either suppressed or discharged in order to make the impulse fall within the safe period of the QRS complex.

Demand pacemaker generator stimulus is inhibited by a signal derived from the heart's electrical activation (depolarization), thus minimizing the risk of pacemaker-induced fibrillation.

Most pacemakers are programmable, and many are rate responsive.

1.3.1 Ventricular synchronous demand pacemakers

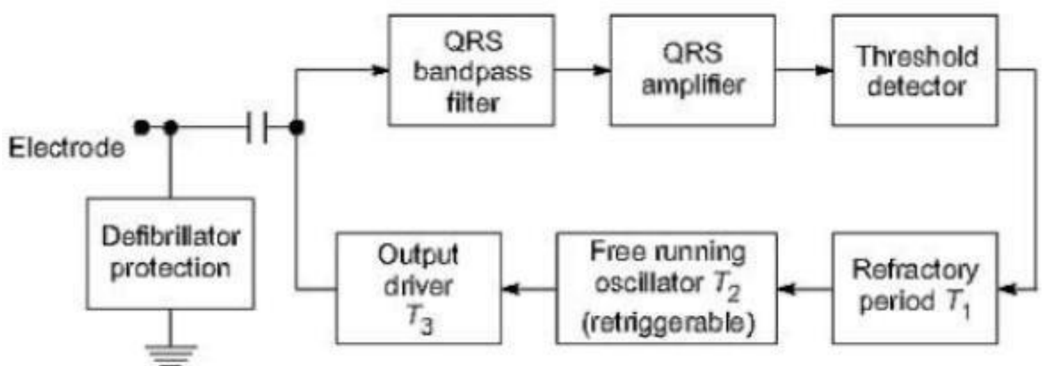

Fig 1.5 Ventricular synchronous demand

1.3.2 Programmable pacemaker

An electronic permanent pacemaker in which one or more settings can be changed electronically.

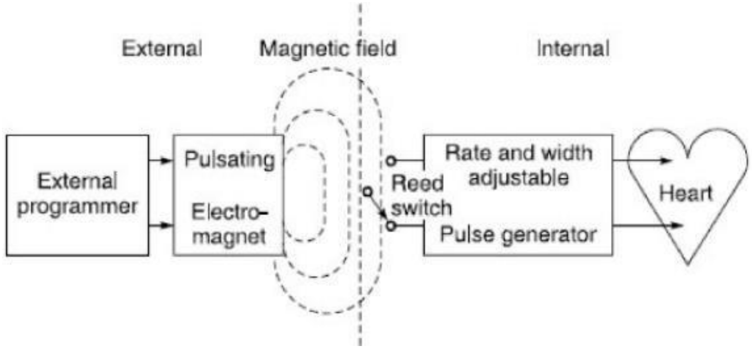

Fig 1.6 Programmable pacemakers

1.3.3 Rate-responsive pacemaker

An electronic pacemaker that senses changes in the body's need for adjustment of the cardiac rate as can occur in sleeping, waking, sitting, walking, or running. The device alters cardiac rate by sensing body motion, changes in breathing, or slight changes in blood temperature, which improves the quality of life for active patients. It is also called a rate-adaptive pacemaker.

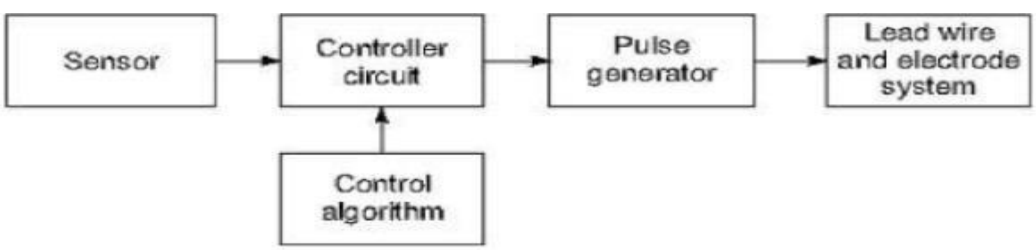

Fig 1.7 Rate-responsive pacemaker

1.4. Recent Developments in Pacemakers

1. A new pacemaker that can be implanted into the heart without the necessity for surgery to test its safety and efficacy in fragile patients who require permanent pacing for normal functioning of the heart.

The device, the Nanostim from St. Jude Medical, which only measures 6mm in diameter and 42mm in length, can be implanted into either side of the heart using a catheter inserted via the leg arteries, similar to how stents are currently placed. Moreover, unlike traditional pacemakers, the device does not need an external generator or wires to function. Instead, a small battery with an estimated lifetime of 15 years is built into the device.

2. His bundle pacing is a new treatment option for patients with heart failure. It helps to implant pacemakers that provide greater longevity. The pacemaker lead is put on directly on the His bundle, which is the junction between the upper and lower chambers of the heart. This replicates the physiological functioning of the heart as the heart's natural electrical impulses travel in normal human hearts.

3. Pacemakers could soon be powered by energy from the beating heart, finally ending the need for a battery. A prototype of a battery-free cardiac pacemaker has been developed by a Swiss researcher based on an automatic wristwatch. The technology harvests energy from the motion of the heart with the help of 200-year-old principles used to power self-winding watches.

4. About the size of calcium pills, this new one was the Medtronic Micra, the world’s smallest pacemaker. In clinical trials at the time of Mary Lou’s procedure, Micra was approved for use in the United States on April 6, 2016. Revolutionary not only for its size, Micra is implanted inside the heart. Small tines then attach it to the heart wall.

1.5. Pacemaker Analyser

The microprocessor-based analyzer enables measurement and display of pacing pulse rate, height and width as well as A-V interval, refractory period, R, S and T wave sensitivity, long term stability, and susceptibility to 50/60 Hz interference.

The External Pacemaker Analyzer is an advanced microprocessor-based, compact, high performance external pacemaker tester designed for accurate testing of all types of external pacemakers, including invasive and transthoracic. The device is menu-driven and simple to operate. All functions are set from a 2-line, 16-character LCD display and a keypad with 8 tactile keys. It provides superior accuracy and performance.

1.6 Cardiac Defibrillator

1.7 Need For Defibrillator

Cardiac arrest is when someone’s heart stops pumping blood around the body and they stop breathing normally.

The most common cause of a cardiac arrest is a abnormal heart rhythm called ventricular fibrillation (VF). Ventricular fibrillation happens when the electrical activity of the heart becomes so chaotic that the heart stops pumping and quivers or 'fibrillates' instead.

Defibrillator is the machine used to deliver the shcck. The electrodes are placed at the sternum and apex.

During defibrillation and cardioversion, electrical current travels from the negative to the positive electrode by traversing myocardium. It causes all of the heart cells to contract simultaneously. This interrupts and terminates abnormal electrical rhythm. This, in turn, allows the sinus node to resume normal pacemaker activity.

1.8 DC Defibrillator

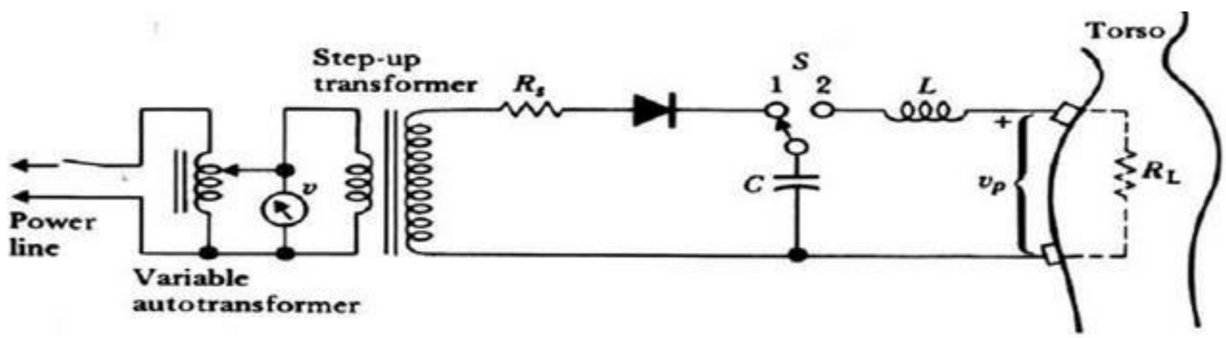

Fig 1.8 Circuit of dc defibrillator

A Variable auto transformer forms the primary of a high voltage transformer. The output voltage transformer is rectified by a diode rectifier and is connected to vacuum type high voltage change over switch. In position 1, the switch is connected to one end of an oil filled micro farad capacitor. In this position, the capacitor charge to a voltage set by the positioning of the auto transformer. When the shock is delivered to the patient, a foot switch or a push button mounted on the handle of the electrode is operated. The high voltage switch change over to position 2 and the capacitor is discharged across the heart through the electrode.

The inductor in the circuit slows down the discharge from capacitor by induced counter voltage. This gives the output pulse a physiologically favorable shape. The disadvantage of using inductor is that any practical inductor will have its own resistance and dissipates part of the energy during the discharge process. The shape of waveform that appears across electrodes will depend upon the value of the capacitor and inductor used in the circuit.

Using this design, external defibrillation uses:
–50 to 100 Joules of energy when electrodes are applied directly to the heart
–Up to 400 Joules when applied externally.

Capacitor is discharged through the subject by turning on a series silicon-controlled rectifier. When sufficient energy has been delivered to the subject, a shunt silicon-controlled rectifier short-circuits the capacitor and terminates the pulse, eliminating a long discharge tail of the waveform. Output control can be obtained by varying, voltage on the capacitor and Duration of discharge.

1.9 Implantable Defibrillators

An AID is a battery-powered device placed under the skin that keeps track of the heart rate. Thin wires connect the AID to your heart. If an abnormal heart rhythm is detected the device will deliver an electric shock to restore a normal heartbeat if your heart is beating chaotically and much too fast.

AIDs have been very useful in preventing sudden death in patients with known, sustained ventricular tachycardia or fibrillation.

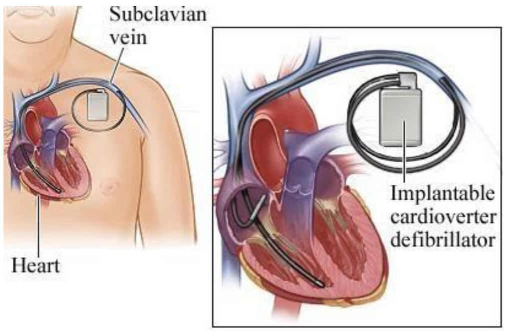

Fig 1.9 Defibrillator placement

The AID has two parts: the lead(s) and a pulse generator. The lead(s) are made up of wires and sensors that monitor the heart rhythm and deliver energy used for pacing and/or defibrillation (see below for definitions). The generator houses the battery and a tiny computer. Energy is stored in the battery until it is needed. The computer receives information from the leads to determine how the heart is beating.

A battery-powered pulse generator is implanted in a pouch under the skin of the chest or abdomen, often just below the collarbone. The generator is about the size of a pocket watch. Wires or leads run from the pulse generator to positions on the surface of or inside the heart and can be installed through blood vessels.

It knows when the heartbeat is not normal and tries to return the heartbeat to normal. If the AID has a pacemaker feature when the heartbeat is too slow, it works as a pacemaker and sends tiny electric signals to your heart. When the heartbeat is too fast or chaotic, it gives defibrillation shocks to stop the abnormal rhythm.

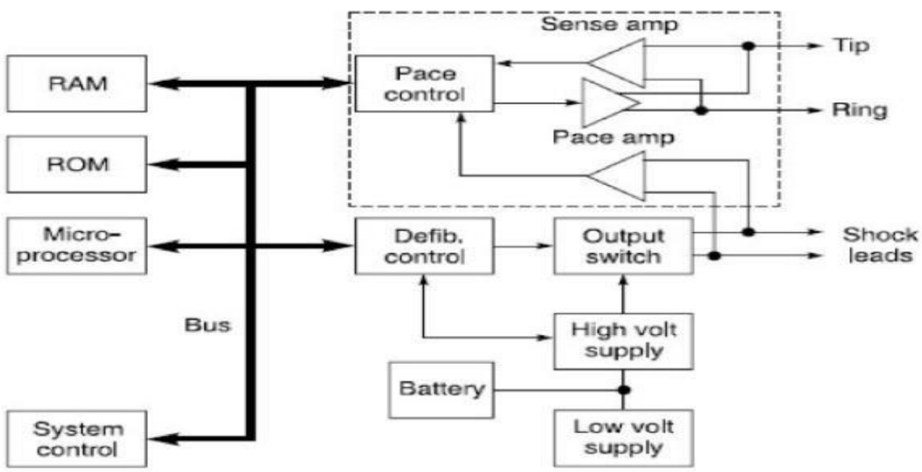

Fig 1.10 Pulse generator

1.10 Pacer Cardio Verter Defibrillator

These are used for patients having extreme brady arrhythmias. A multifunction defibrillator with external pacing. This has high output pacing function after defibrillator.

It has 5 battery powered units-sensing circuit, high voltage convertor, switching circuit, defibb control circuit and pacing control circuit.

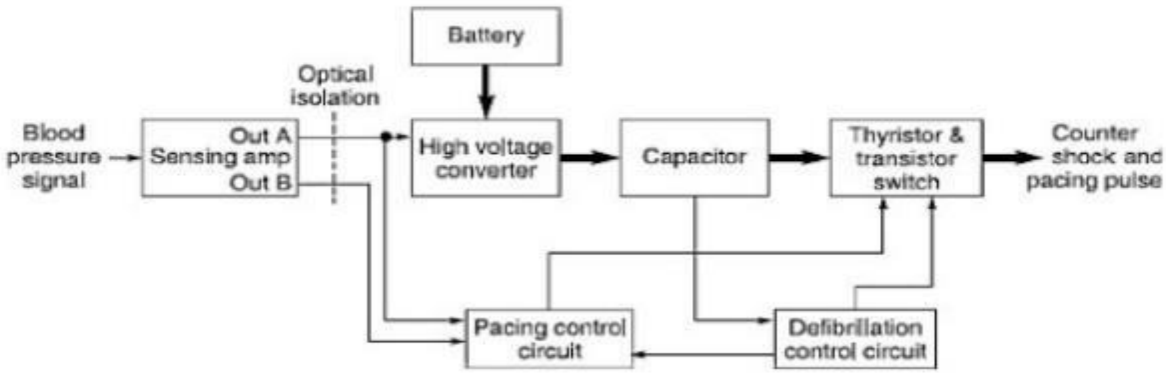

Fig 1.11 Pacer cardioverter defibrillator

Absence of heart beat for a specific time causes the circuit to deliver signals to the HV convertor and the capacitor discharges its current through the electrode. After defibrillation, high output demand pacing is activated. Uses LSVO cells and has a life of 4-9 years.

1.11 Defibrillator Analyser

Automatic and semi-automatic defibrillators recognize patient waveforms and provide a discharge energy pulse. It measures the energy content in the discharge pulse. The pulse is applied across a load and voltage developed is given to a squaring circuit. The analysers measure precisely the pulse energy and verifies and calibrates the output energy of all defibrillators.

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2. Joseph J. Carr, John Michael Brown, Introduction to Biomedical Equipment Technology, 4th Edition, Pearson Education, 2012.
3. John G. Webster, Biomedical Instrumentation, Wiley Publications, 2007.
4. Geddes L.A. and L.E.Baker, Principles of Applied Biomedical Instrumentation, 3rd Edition, 2008.

Question Bank

Part A

S.No	Questions
1.	What is the need of DC Defibrillator?
2.	Draw the block diagram of a Cardioverter.
3.	List the types of electrodes used for Defibrillator.
4.	Point out what causes fibrillation.
5.	Cite the need for cardiac pacemakers
6.	Discuss the merits and demerits of implantable Defibrillator
7.	How to measure the energy content of Defibrillator discharge pulse?
8.	List the different types of cardiac pacemakers depending on the clinical requirements.
9.	Mention few implantable pacemaker batteries.
10.	Compare internal and external pacemakers.

PART B

S.No	Questions
1.	Construct an Implantable Defibrillator for analyzing ECG and giving shocks.
2.	Categorize the Implantable Pacemakers and discuss about any two of them.
3.	A person is diagnosed with a faulty SA node. Recommend and design a device that can save the person for arrhythmias or related cardiac diseases.
4.	Elaborate on the specifications and circuit diagram of DC defibrillator
5.	Propose a design for AID and explain with a neat block diagram.
6.	Brief on a) External pacemakers b) Difference between internal and external PM’s.
7.	Outline on a) Cardioverter defibrillator b) Pacing system analyser

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – II - Therapeutic Instrumentation – SBM1403

Instruments for Surgery and Treatment

2.1 Principle of Surgical Diathermy

Surgical diathermy is the machine of high frequency currents, used in operating rooms for surgical purposes involving cutting and coagulation.

When high frequency current flows through the sharp edge of the point of a needle into the tissue there is a high concentration at this point. The cells which are immediately under the electrode are torn apart by the by the boiling of cell fluid. This type of tissue separation forms the basis of electro-surgical cutting.

Electrosurgical generators typically operate at frequencies between 400,000 Hz and 2.5 MHz, although some generators produce currents with frequencies as high as 3.5 MHz.

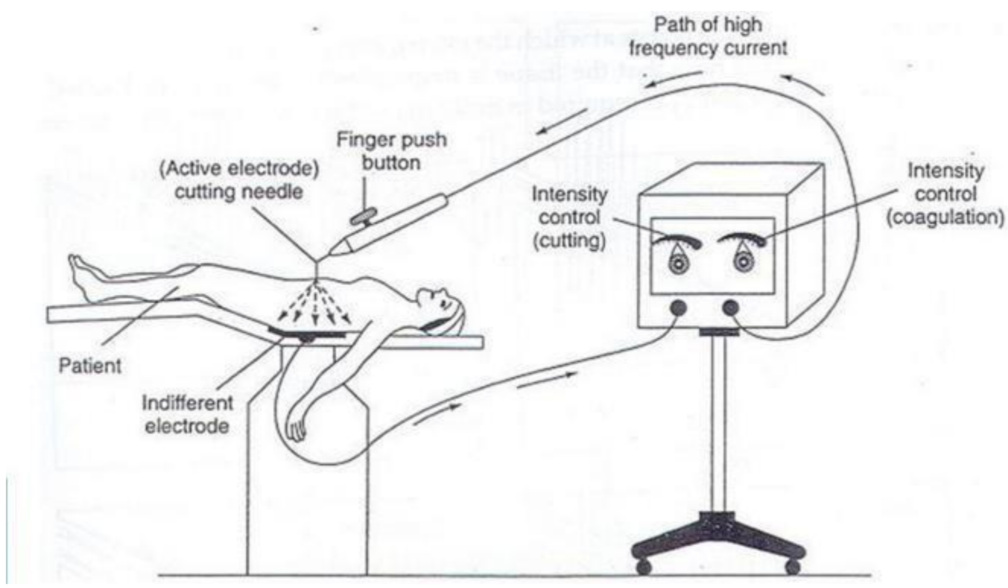


Fig 2.1 Surgical Diathermy Technique

2.2Types of currents

Cutting current

Cutting current uses a pure, non modulated sinusoidal waveform. This waveform achieves a higher average power when compared with any other alternating waveform of equal peak voltage, allowingthe voltage to be limited when compared with coagulation current. The high average power creates a higher current density than is allowed by other waveforms, facilitating a smooth cutting action without extensive thermal damage.

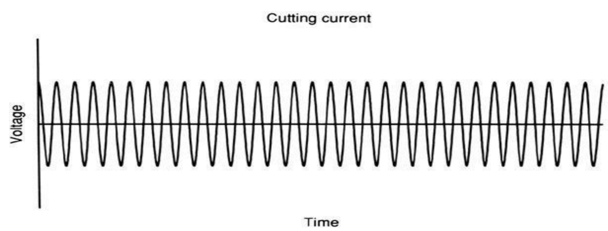


Fig 2.2 Cutting Waveform

Coagulation current

Coagulation current is characterized by extensive wave modulation, which produces intermittent bursts of damped sine waves of high peak voltages . These peak voltages result in high tissue temperatures, and hence significant thermal destruction, making this type of current particularly suited for the coagulation of bleeding vessels.

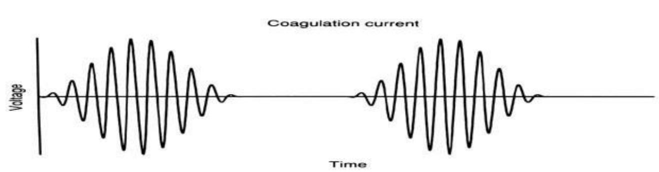


Fig 2.3 Coagulation Waveform

Blended currents

Blended currents allow the surgeon to cleanly divide tissue while maintaining a variable degree of hemostasis, depending on the amount of coagulating current used. Blended currents are created by modulating a second, lower frequency, higher amplitude sine wave with the sine wave from the cutting generator, producing a higher peak-to-peak voltage. The new waveform is then delivered in intermittent bursts at a rate determined by the settings of the electrosurgical generator (*i.e.*, Blend 1) .

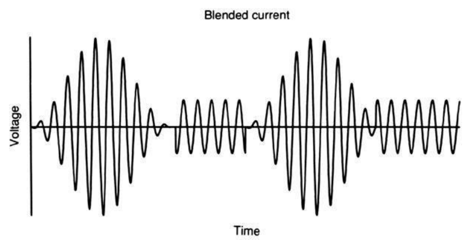


Fig 2.3 Coagulation Waveform

2.3Methods used in ESU's

Fulguration

Fulguration results from the action of electrical arcs striking the tissue at widely divergent locations, producing a high localized instantaneous current density, but a low average current density.

Desiccation

Desiccation is produced by low current and relatively higher voltage applied over a broad area, producing a low current density.

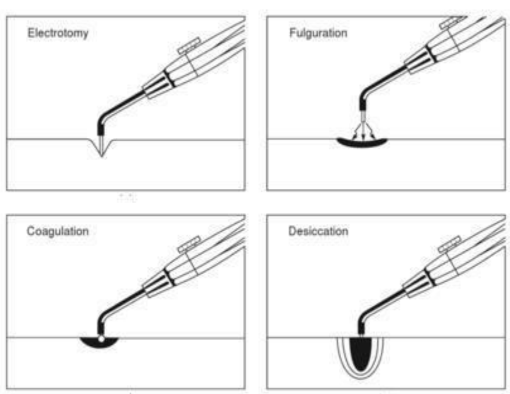


Fig 2.4 Methods

Coagulation

Coagulation occurs at higher current densities than are used in desiccation, resulting in higher tissue temperatures. The tissue fluids boil away and the proteins become denatured, forming a white coagulum similar to that produced when an egg white is boiled. There is loss of cellular definition as all tissue structures fuse into a formless, homogenous mass with a hyalinized appearance.

2.4 Surgical Diathermy Machine

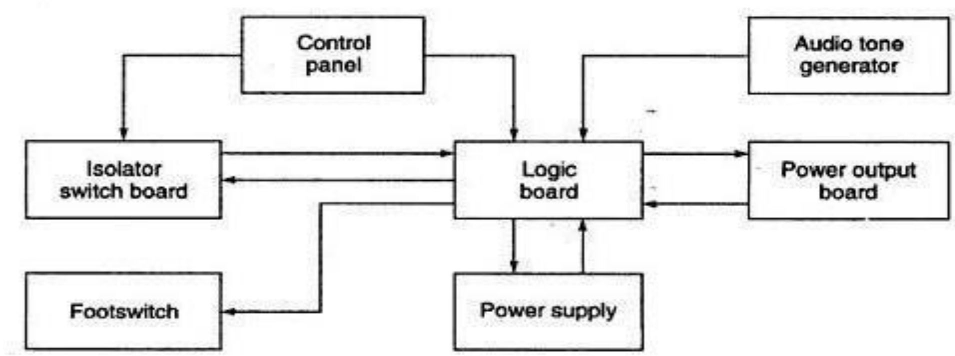


Fig 2.5 Block Diagram

Logic board: The heart of the system id logic and control part which produces the basis signal and provides various timing signal for the cutting, coagulation and haemostasis modes of operation.

Power output: The 250 kHz signal used for cutting is given to power output stage.

Audio tone generator: in order to facilitate identification of each mode of operation, the machine incorporates an audio tone generator. The tone signals are derived from the counter at 1 kHz (coagulation), 500 Hz (cutting) and 250 Hz (haemostasis).

Isolator switch: The isolator: The isolator switch provides isolated switching control b/w the active hand switch and the rest of the unit.

Footswitch: Besides basic function circuit, logic circuits are used to receive external control signals and to operate the isolating relays, give visual indications and determine the alarm conditions.

The logic circuits receive information from the foot-switch, finger switch and alarm sensing points. Solid state generators produce the coagulation waveform by using transistors and solid state components to produce high voltage bursts of current. Spark gap generators produce damped, high voltage bursts of current by discharge of air-spaced plates. Spark gap systems are incapable of producing undamped, cutting current. Cutting and coagulating currents are produced from two independent generators contained within the ESU.

2.5 Safety Aspects in Electro Surgical Diathermy Units

Complications of electrosurgery can be categorized as: the potential for the explosion of combustible gases, anesthetics or bowel gas, interference with pacemakers and monitors, neuromuscular stimulation including ventricular fibrillation, accidental burns, and the potential for the transmission of infection.

Burns

Burns to the patient's skin can occur in a variety of ways. The most common mechanism is the alternate site burn, which results from a high current density either at a poorly applied ground electrode, at the site of monitoring devices such as ECG electrodes or temperature probes, or at the sight of accidental contact with a grounded metal object. All electrosurgical burns are visible at the time of occurrence.

Most modern electrosurgical generators are isolated from earth ground, and have fault monitors that will disable the machine and sound an alarm if the ground electrode circuit is not intact.

Explosion

Explosive anesthetic gases posed the greatest explosion risk in the operating room. If they are used, the surgeon should be so informed, and use of the ESU avoided. Of greater concern is bowel gas, which frequently contains a mixture of methane and hydrogen which, when mixed with oxygen, even in low concentrations, are highly explosive. This is a real hazard when operating around the large bowel, or when performing anorectal surgery.

Nitrous oxide supports combustion, as well as pure oxygen. Many gynecologists use nitrous oxide as a laparoscopic distention medium to avoid the peritoneal irritation caused by carbon dioxide. If electrosurgery is to be used during a laparoscopic operation, the use of nitrous oxide to distend the abdomen should be avoided.

Pacemaker interference

Most modern cardiac pacemakers are resistant to interference by extraneous electromagnetic signals, several incidences of asystole and cardiac arrest have been reported when electrosurgery is used in patients with pacemakers. In these units, the electrosurgical signal may block the pacer's inhibition amplifier allowing an R-on-T phenomenon to occur, leading to ventricular fibrillation.

2.6 Physiotherapy and Electrotherapy Equipment

2.7 High Frequency Heat Therapy

The Diathermy energy field passes through softer surface tissues and turns to heat when reaching more dense tissues. The heat increases circulation and helps to speed the healing process.

Heat speeds up healing by increasing blood flow to the injury. Diathermy is a deep tissue heat treatment. The temperature of the injured tissues is raised by high frequency current, ultrasonic waves, or microwave radiation. Like surface heating, deep heat is used to:

* reduce pain,

* relieve muscle spasm,

* decrease soft-tissue contractures,

* resolve inflammation, and

* promote healing.

2.8 Short Wave Diathermy

High frequency (also called short-wave) diathermy operates at 13.5 or 27 MHz and generates a strong electromagnetic field by either a magnetic or capacitive applicator. Commonly used frequency (f) is 27.12 MHz and wavelength 11 m.

Fig 2.6 Short wave Machine

Short wave diathermy machines utilize two condenser plates that are placed on either side of the body part to be treated. Another mode of application is by induction coils that are pliable and can be molded to fit the part of the body under treatment. As the high-frequency waves travel through the body tissues between the condensers or the coils, they are converted into heat. The degree of heat and depth of penetration depend in part on the absorptive and resistance properties of the tissues that the waves encounter.

The frequency allowed for short wave diathermy operations is under the control of the Federal Communications Commission. The frequencies assigned for short wave diathermy operations are 13.66, 27.33, and 40.98 megahertz. Most commercial machines operate at a frequency of 27.33 megahertz and a wavelength of 11 meters.

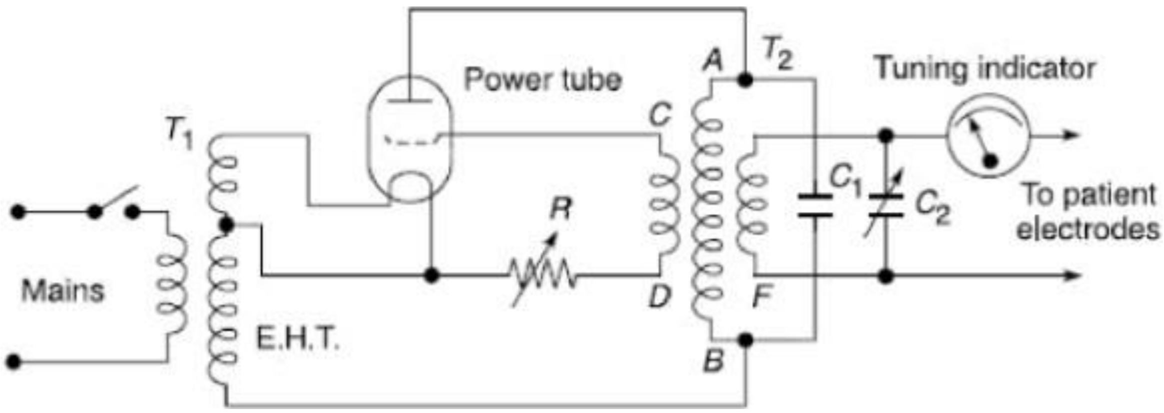


Fig 2.7 Short wave Machine Circuit

Short wave diathermy usually is prescribed for treatment of deep muscles and joints that are covered with a heavy soft-tissue mass, for example, the hip. In some instances short wave diathermy may be applied to localize deep inflammatory processes, as in pelvic inflammatory disease.

In this two circuits are used. Machine circuit is coupled with the patient circuit leading to resonance phenomenon.

A. Machine circuit:

The basic oscillator circuit consists of condenser, inductance, and the currents of different frequencies are obtained by selecting suitable condenser and inductance. It a current of very high frequency is required, the condenser and inductance are very small. While to produce a current of lower frequency a larger condenser and inductance is used.

B. Patient circuit:

When SWD is applied by the condenser field method, the electrodes in the patient tissues form a capacitor, the capacitance of which depends upon the size electrodes and distance material between them. When the oscillator and resonator circuits are in tune with each other there is maximum power transfer to the patient.

Indicator:

The indicator light on equipment either comes ON or changes color. An ammeter wired into the resonating current shows a maximum reading which is diminished by turning the knob controlling the variable capacitor

2.9 Microwave Diathermy

Microwave diathermy heats tissue by exposing the treated tissue to a strong electromagnetic field. A frequency of 2450 MHz is generated by most microwave diathermy units.

The high frequencies of microthermy are obtained from a unique device called the magnetron, which is perforated with tiny holes, through which the electrons flow into the treatment heads. The special design of the treatment heads shapes and focuses the field directly at the target area.

Fig 2.8 Micro wave Machine

The whole device is used to direct the waves onto the tissues. This device is sometimes termed the emitter, the director or the applicator.

Absorption of the waves results in production of heat in the tissues, but differs from other heat treatment methods in the distribution of heat. Microwave penetrates more deeply than infrared rays but not deeply as short wave diathermy, so microwave is not suitable for deeply placed structures. The effective depth of microwave penetration is about 3 cm, so the depth of heating is intermediate between that of infrared radiation and short wave diathermy.

Treatment by microthermy requires between 10 and 20 minutes. Generally, smaller target areas need less time, while larger ones need more. Treatment may be applied daily or every other day.

2.10 Ultrasonic Diathermy

Fig 2.9 Ultrasonic Machine

Ultrasonic diathermy refers to heating of tissues by ultrasound for the purpose of therapeutic deep heating. Ultrasonic diathermy heats tissue by transmitting a high frequency (approximately 1 MHz) physical wave into the tissue from an applicator.

The therapeutic ultrasound apparatus generates a high-frequency alternating current, which is then converted into acoustic vibrations. The apparatus is moved slowly across the surface of the part being treated. Ultrasound is a very effective agent for the application of heat,

2.11 Pain relief through Electrical Stimulation

2.12 TENS

TENS stands for (Transcutaneous Electrical Nerve Stimulation) which are used for nerve related pain conditions (acute and chronic conditions). TENS machines works by sending stimulating pulses across the surface of the skin and along the nerve strands.

The stimulating pulses help prevent pain signals from reaching the brain. Tens devices also help stimulate your body to produce higher levels of its own natural painkillers, called "Endorphins".

TENS is most commonly delivered from small, hand held, battery powered devices. The electrodes are often placed on the area of pain or at a pressure point, creating a circuit of electrical impulses that travels along nerve fibers.

Fig 2.10 TENS Machine

The current intensity (A) (strength) will typically be in the range of 0 - 80 mA, though some machines may provide outputs up to 100mA.

The machine will deliver discrete ‘pulses’ of electrical energy, and the rate of delivery of these pulses (the pulse rate or frequency (B) will normally be variable from about 1 or 2 pulses per second (pps) up to 200 or 250 pps . To be clinically effective, it is suggested that the TENS machine should cover a range from about 2 – 150 pps (or Hz).

In addition to the stimulation rate, the duration (or width) of each pulse (C) may be varied from about 40 to 250 micro seconds (ms). Usually uses stimulation at a relatively high frequency (80 - 130Hz) and employ a relatively narrow (short duration) pulses.

The type of stimulation delivered by the TENS unit aims to excite (stimulate) the sensory nerves, and by so doing, activate specific natural pain relief mechanisms.

2.13 Bladder Stimulator

Bladder control problems can be retention and overactive bladder. It prevents a person from controlling when and how much he can urinate and can make simple everyday activities a challenge and social lives very difficult.

Sacral nerve stimulation (SNS) involves the use of a device that can be thought of as a pacemaker for the bladder.

When the bladder begins to fill with urine, a message is sent along the sacral nerves to the brain telling the brain that the bladder is getting full. As the bladder fills, this message to the brain becomes stronger. When the message becomes strong enough, and a person decide to urinate, the brain sends a message back to the bladder along the sacral nerves telling the bladder muscle to contract and the pelvic muscles to relax to allow urine to empty from the bladder (urination).

The therapy uses a small implanted medical device to send mild electrical pulses to a nerve located just above the tail bone. These nerves are called sacral nerves. The sacral nerves [specifically S2, S3 and S4] activate or inhibited muscles and organs that contribute to urinary control-the bladder, sphincter and pelvic floor muscles. The electrical stimulation may eliminate or reduce certain bladder control functions in some people. This stimulation may facilitate the communication between the brain and bladder, and may relieve the symptoms of urinary retention or symptoms of overactive bladder, including urinary urge incontinence and significant symptoms of urgency-frequency in some patients.

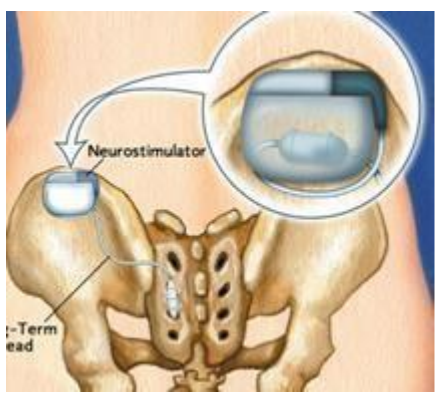


Fig 2.11Bladder Stimulator

A neurotransmitter device, implanted under the skin in the upper buttock area, transmits mild electrical impulses through a lead wire close to the sacral nerve. The impulses, in turn, influence the bladder sphincter and pelvic floor muscles providing bladder control.

2.14 Cerebellar Stimulators

An implanted cerebellar stimulator is a device used to stimulate electrically a patient's cerebellar cortex for the treatment of intractable epilepsy, spasticity, and some movement disorders.

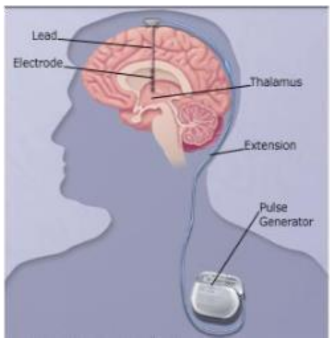


Fig 2.12 Cerebellar Stimulator

Electrical stimulation of the cerebellum using arrays of electrodes surgically implanted on the anterior surface of the cerebellum has been proposed as one way to treat certain neurological disorders. Leads connected to the electrodes emerge through small openings in the skull and are placed subcutaneously down the neck to a stimulator implanted in a subcutaneous pocket below the clavicle on the anterior chest.

References:

1. Khandpur R.S., Handbook of biomedical Instrumentation, Tata McGraw Hill Publication company Ltd, New Delhi, 2014.
2. Joseph J. Carr, John Michael Brown, Introduction to Biomedical Equipment Technology, 4th Edition, Pearson Education, 2012.
3. John G. Webster, Biomedical Instrumentation, Wiley Publications, 2007.
4. Geddes L.A. and L.E.Baker, Principles of Applied Biomedical Instrumentation, 3rd Edition, 2008.

PART A

S.No	Questions
1	Draw the circuit diagram of Short wave Diathermy.
2	Quote the full form of TENS
3	Give the frequency range of Microwave and Ultrasonic Therapy waves.
4	Summarize on electrotherapy.
5	Define the terms: electrotomy and desiccation in surgical diathermy.
6	What are the risks associated with surgical diathermy and the safety measures for them?
7	Mention the concept of High frequency heat therapy.
8	Draw the different modes of operation of an ESU.
9	List the differences between microwave and shortwave diathermy.
10	Name and draw the various electrodes used for surgical diathermy.
11	How does hemostasis work?
12	What is the principle behind high frequency heat therapy?

PART B

S.No	Questions
1.	Discuss the principle, working and applications of ultrasonic therapy unit.
2.	Illustrate the production of microwaves and the working of a Microwave Diathermy machine.
3.	Design a physiotherapy instrument that uses short waves as a diagnostic tool.
4.	Elaborate on any two types of physiotherapy equipment.
5.	Develop a equipment that aids in minimal blood loss during surgeries.
6.	Summarize on the working of a) TENS b) Bladder stimulator c) DBS
7.	How is pain relief achieved with electrical stimulation? Employ any two instruments used for the same.
8.	Discuss the safety aspects in electro-surgical units.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – III - Therapeutic Instrumentation – SBM1403

HAEMODIALYSIS MACHINES

3.1 FUNCTION OF KIDNEYS

The kidneys have three basic mechanisms for separating the various components of the blood: filtration, reabsorption, and secretion. These three processes occur in the nephron which is the most basic functional unit of the kidney. Each kidney contains approximately one million of these functional units.

Blood first enters the kidney through the renal artery, which branches into a network of tiny blood vessels called arterioles. These arterioles then carry the blood into the tiny blood vessels of the glomerulus. Filtration occurs in the renal corpuscle.

The tubule functions as a dialysis unit, in which the fluid inside the tubule is the internal solution and the blood (in capillaries surrounding the tubule) acts as the external solution. Particles may pass through the membrane and return to the blood stream in the process known as reabsorption.

3.2 ARTIFICIAL KIDNEY

When the kidneys do not function properly, dialysis must be performed artificially. Without this artificial kidney dialysis, toxic wastes build up in the blood and tissues, and cannot be filtered out by the ailing kidneys. This condition is known as uremia, which means urine in the blood. Eventually this waste build-up leads to death.

The artificial kidney uses cellulose membranes in place of the phospholipid-bilayer membranes used by real kidneys to separate the components of blood. Cellulose is a polymer of glucose molecules that form long, straight chains. Parallel chains form linkages with one another by hydrogen bonding to make strong fibers. These fibers in turn interact to form the strong, sheet- like structure of the membrane.

Hemodialysis uses a cellulose-membrane tube that is immersed in a large volume of dialysate.

The blood is pumped through this tubing, and then back into the patient's vein. The membrane has a molecular-weight cut-off that will allow most solutes in the blood to pass out of the tubing but retain the proteins and cells. The dialysate in which the tubing is immersed is a salt solution with ionic concentrations near or slightly lower than the desired concentrations in the blood.

Through diffusion excess substances in the blood are removed from the body. To maintain the blood's concentration of a species, the dialysate is made to have the same concentration of that species as the blood.

3.3 DIALYZERS

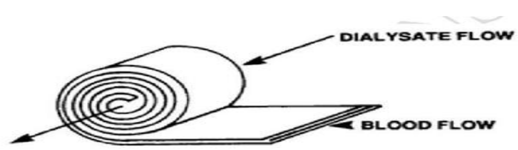
The dialyzer is a large canister containing thousands of small fibers through which your blood is passed. Dialysis solution, the cleansing fluid, is pumped around these fibers. The fibers allow wastes and extra fluids to pass from your blood into the solution, which carries them away. The dialyzer is sometimes called an artificial kidney.

Dialyzers, in routine clinical use, may be classified according to three basic design considerations :

(a)Coil Dialyser

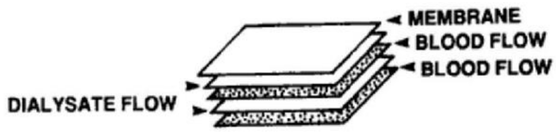
A coil hemodialyzer comprises a tubular membrane placed between flexible support wrapped around a rigid cylindrical core. The coil is immersed in a dialyzing bath. The tubular membrane can be of cellophane or cuprophan.

The coil membrane supports are woven screens or unwoven lattice. Usually, the 'twin-coil' is made with three layers of woven, polyvinyl chloride-coated fibre glass screen separated by four narrow strips of the same material, which are sewn into place with cotton thread.



(b)Parallel Plate

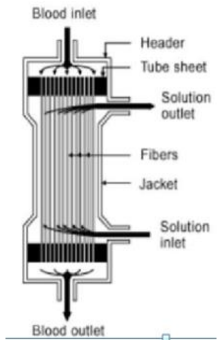
The Parallel Flow Dialyzer has a low internal resistance which allows adequate blood flow through the dialyzer with the patients arterial blood pressurey eliminating the need for a blood pump. The dialyzing surface area of parallel flow dialyzer is about 1 cm2. The rigid support used in parallel flow dialyzers permit negative pressure to be created on the dialysate side of the membrane for ultrafiltration.



The KI1L dialyzer has earlier been the most commonly used form of parallel flow dialyzer. It consists of polypropylene boards with dialyzing membranes laid between them. The boards are held firmly with a frame on the top and bottom are fastened by a series of bolts on the side. A rubber gasket runs along the periphery of the board, in a surface, to prevent blood and dialysate leakage. The dialysate enters through a SS port and is distributed to grooves running across the end of the board, both above and below the membrane of each layer. After flowing down longitudinal grooves in the board, it is collected and flowed out at the opposite end of the board. The KIIL dialyzer is not disposable. It needs to be cleaned and rebuilt after each dialysis operation.

(c)Hollow Fibre Type

The hollow fibre haemodialyzer is the most commonly used haemodialyzer. It consists of about 10,000 hollow de-acetylated cellulose diacetate capillaries. The capillaries are jacketed in a plastic cylinder 18 cm in length and 7 cm in diameter. The capillaries are sealed on each end into a tube sheet with an elastomer. The capillaries range from 200 - 300 mm internal diameter and a wall thickness of 25 * 30 cm.



The blood is introduced and removed from the hemodialyzer through manifold headers. The dialysate is drawn through the jacket under a negative pressure around the outside of the capillaries counter-current to the blood flow. The dialyzers are disposable.

3.4 MEMBRANES OF HAEMODIALYSIS

Ideal membrane should possess high permeability to water, organic metabolites and ions. It should have good strength to prevent tearing or bursting. Dialyzer membranes come with different pore sizes. Those with smaller pore size are called low-flux and those with larger pore sizes are called high-flux.

Cellulose was the first membrane material widely used for hemodialysis. It is a polymer of cellobiose and occurs in natural materials, such as cotton.

Cellulose membranes are hydrogels and can be made very thin (6–15 mm dry thickness) while retaining good mechanical strength. They allow high diffusive transport of small molecules.

Synthetic Membranes

These membranes were made of synthetic polymers. Synthetic membranes are thick (> 35 sq m) with cross-sectional structures that were either homogeneous or asymmetric.
Many synthetic membranes have large pore sizes allowing higher rates of water flux and permitting a higher ultrafiltration capacity as well as a better removal of high molecular weight solutes than membranes with smaller pore size.

Commonly used membrane is Cupraphan(Cupro-ammonium regenerated cellulose). It has natural cellulose, puncture proof and high elasticity.

3.5 HAEMODIALYSIS MACHINE

Hemodialysis is a type of dialysis that uses a special filter to cleanse the blood. During hemodialysis treatment, blood is passed from the body through a set of tubes to a filter. The cleansed blood is then returned to the body through another set of tubes.

The machine performs 5 basic functions:

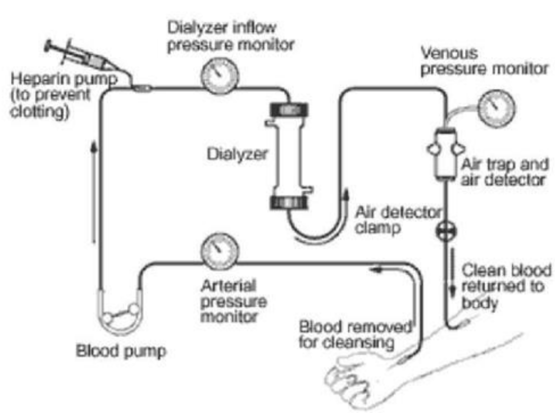
Mixes dialysate

Monitors the dialysate

Pumps blood and administers the anti coagulants

Monitors blood for presence of air

Monitors the UF rate



(i) Proportioning Pumps:

A motor driven displacement pump is used to mix water and concentrate (35:1). These are fed into a mixing chamber.

Proportioning pumps mix premade fresh dialysate acid (A) and bicarbonate (B) solution.

Acid solutions contain acid/chloride salts including sodium, potassium, calcium, magnesium, and acetate. Bicarbonate solutions are made fresh, since pre-prepared bicarbonate can release CO_2 and encourage bacterial growth

(ii) Dialysate temperature control and measurement:

Dialysis is done at body temperature. The Dialysate temperature is monitored and maintained before giving to the dialyser. If it is overheated system should stop the flow to the dialyser. The heaters are switched off if the temperature crosses 43oc. Thermistor senses the temperature and triac controls the power to the heater.

(iii) Conductivity Measurement:

The conductivity of the Dialysate has to be monitored continuously. It is done using a conducting cell. It is maintained at 1%. The effluent motor is switched off if there is change in conductivity.

(iv) Dialysate pressure control and measurement:

A negative pressure on the Dialysate is caused by the effluent pump. A valve limits the max negative pressure available. The pressure is measured using a strain gauge transducer connected downstream of the Dialysate return site. The gauge gives the Dialysate pressure and venous pressure

(v) Dialyzer and Dialysate:

The dialyzer is the key part of a dialysis machine where the cleaning of the blood takes place. The blood compartment of the dialyzer contains a membrane that does the filtering of wastes from the blood, using the dialysate solution.

The dialysate, also known as the bath, is made up of purified water, bicarbonate and a solution referred to as acid. This acidified fluid also contains minerals and electrolytes. Although the dialysate never actually mixes with the blood, it pulls the impurities from the blood through a membrane filter. Once the blood is thoroughly cleansed, it is then pumped back into the body. Only about a pint of blood is in the machine at any one time.

(vi) Blood Leak Detector:

A leak developing in the membrane separating the blood from the dialysate in an artificial kidney machine requires immediate corrective action.

Leakage of blood into the dialysate circuit is detected by the blood leak monitor, which is usually located downstream from dialyzer. Infrared or photoelectric cells detect decreases in light from source. Red blood cells scatter light and trigger alarm, which deactivates the blood pump

(vii) Blood Pumps:

Peristaltic pumps are commonly used for driving the various higher volume fluids in the machine: blood, dialysate, water, and saline. This type of pump is very convenient because it does not touch the fluids directly. Instead, a section of flexible tubing runs through the pump mechanism where it is compressed by rollers to push the fluid forward. These pumps require a significant amount of power and are driven by either DC or AC motors with variable speed control.

(viii) Sensors:

Dialysis machines require many different types of sensors to monitor various parameters. Blood pressure at various points in the extracorporeal circuit, dialysate pressure, temperature, O2 saturation, motor speed, dialyzer membrane pressure gradient, and air are all monitored for proper values during dialysis.

(ix) Heparin Pump:

Because blood has a tendency to clot when moving through the tubes, a syringe is attached to the dialysis machine tubing. This syringe contains a drug called Heparin, and this is pumped into the blood during the treatment. It is what prevents the blood from clotting.

(x) Cleaning system:

Between patient sessions, any reused components must be sterilized. One approach is to heat water or saline to a high sterilizing temperature and then run it through the machine, both through the extracorporeal circuit and through the dialysate circuit.

(xi) Microcontrollers:

Because of the large number of input signals to be monitored and the large number of pumps and other mechanisms to be controlled, many of these functions are performed with dedicated microcontrollers for that portion of the system. Controlling the overall system will be a main processor capable of running a full operating system and GUI. Communication between the controllers is required to send data, commands, and alerts.

(xii) Alarms:

Alarms are installed on a dialysis machine, in order to protect the patient from any errors in functioning. The things that are monitored with alarms include:

Blood pressure within the machine, Blood pressure of the patient, Blood flow, Temperature, Dialysate mixture

Each hemodialysis treatment normally takes four to five hours. Usually, a person needs three treatments a week. However, certain people may need more frequent treatments or longer treatments.

3.6 PORTABLE KIDNEY MACHINE

Peritoneal dialysis does not use an artificial membrane, but rather uses the lining of the patient's abdominal cavity, known as the peritoneum, as a dialysis membrane. Fluid is injected into the abdominal cavity, and solutions diffuse from the blood into this fluid. After several hours, the fluid is removed with a needle and replaced with new fluid. The patient is free to perform normal activities between fluid changings.

In Peritoneal dialysis, a sterile solution containing minerals and glucose is run through a tube into the peritoneal cavity, where the peritoneal membrane acts as a semipermeable membrane. The dialysate (1-3 L of prescribed solution) is left in the peritoneal cavity for a period of time to absorb waste products, and then it is drained out through the tube and discarded. This cycle is repeated 4-5 times during the day. Peritoneal dialysis treatment is used at home under the routine supervision of a dialysis facility. The types of chronic peritoneal dialysis are determined by various schedules:

CAPD- CAPD is a manual form of peritoneal dialysis, with no machine. During CAPD, the dialysate solution stays in the peritoneal cavity for about 4 to 6 hours. After this time, the solution is drained out of the cavity. The cavity is then is then refilled with fresh solution. This is the most commonly used form of peritoneal dialysis and employs 4-6 exchanges per day.
CCPD, also known as Automated Peritoneal Dialysis (APD), is a form of peritoneal dialysis using a cycler at night. During CCPD, a machine automatically fills and drains the dialysate from the peritoneal cavity. This process takes about 10 to 12 hours; therefore CCPD is performed at night. The cycler automatically makes 4-6 exchanges per day.

3.7 LITHOTRIPTERS

3.8 THE STONE DISEASE PROBLEM

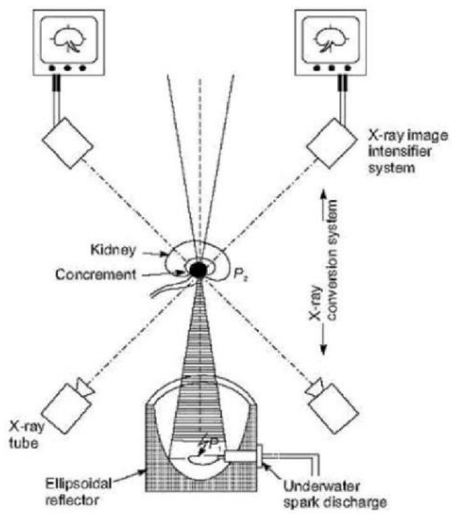
A kidney stone is a hard mass developed from crystals that separate from the urine within the urinary tract.
Small stones can be as tiny as a grain of sand and may remain in the kidneys without causing any symptoms. Pain can occur as stones get bigger.
Kidney stones may contain various combinations of chemicals. The most common type of stone contains calcium in combination with either oxalate or phosphate.
Kidney stones are classified by the substance that forms them. The main types of kidney stones are: Calcium stones, Struvite stones, Uric acid stones, Cystine stones

3.9 FIRST LITHOTRIPTER MACHINE

Lithotripsy is the use of high-energy shock waves to fragment and disintegrate kidney stones. The shock wave, created by using a high-voltage spark or an electromagnetic impulse outside of the body, is focused on the stone. The shock wave shatters the stone, allowing the fragments to pass through the urinary system. Since the shock wave is generated outside the body, the procedure is termed extracorporeal shock wave lithotripsy (ESWL). The name is derived from the roots of two Greek words, litho , meaning stone, and trip , meaning to break.

ESWL is used when a kidney stone is too large to pass on its own, or when a stone becomes stuck in a ureter (a tube that carries urine from the kidney to the bladder) and will not pass.

The original lithotripsy machines were commonly referred to as “stone baths” because the patient was placed on a supportive frame called a gantry and partially immersed in a tub of water which had been deionized to eliminate air bubbles



The gantry was positioned such that the patient’s stone was within the crosshairs of an aiming system (at the so-called F2 focal point) and electromechanical shock waves generated under water at the F1 point by a spark gap generator traveled through the body to fragment the stone.

Ultrasound or fluoroscopy is utilized during the treatment to monitor the fragmentation process. Once the stone or stones have been fragmented, the particles flush through the urinary tract and are eliminated.

3.10 MODERN LITHOTRIPTER MACHINE

The major components are

Focussed shock wave source

Acoustic coupling

Imaging

Patient table

Triggering and monitoring

1.Focussed shock wave source:

The shock waves are generated by an emitter outside the body and transmitted as pulsed waves through a fluid coupling medium.

There are three categories of shockwave generators:

a) Plasma explosion method/ Ellipsoidal reflector-

A capacitor is discharged across 2 opposing electrodes paced in a bath tub. A conducting channel is formed between the electrodes and expands with supersonic velocity. The shock wave is focused by a ellipsoidal reflector.

b) Electromagnetic/ Acoustic lens

The electromagnetic assembly produces an electric field in the coils, and the eddy currents produces a magnetic field.

c) Piezoceramic system/ self focusing source

This operated by driving several thousands of piezoceramic elements mounted on a spherical dish, thus giving self focusing waves. The wave field is focused with a lens. High voltage is generated by capacitors.

2. Acoustic Coupling

A medium is used for coupling shock waves to the human body to minimize the presence of air and give undisturbed propagation of acoustic pulses.

An open bath provides with warm water or oil gives optimal coupling.

3. Imaging

Imaging for stone localization can be done with ultrasound, fluoroscopy or the combination of both.

4. Patient Table

The shock wave sources are arranged below the structure supporting the patient. The table is motorized. The table has an opening that permits the lumbar area to be exposed to oil filled membrane.

5.Triggering and Monitoring

Monitoring of heat is done as a preventive measure when anesthesia is given.

The triggering of shock waves is gated to the respiratory cycle for efficient treatment. It is done so because the kidney is displaced during respiration. About 1-2 thousand shock waves are needed to crush the stones. The complete treatment takes about 45 to 60 minutes.

3.11 EXTRACORPOREAL SHOCKWAVE THERAPY

Extracorporeal Shockwave Therapy or ESWT is a treatment used in physical therapy, orthopedics, urology and cardiology. Extracorporeal means that the shockwaves are generated externally to the body and transmitted from a pad through the skin.
Extracorporeal Shockwave Therapy is used to treat a growing number of tendon, joint and muscle conditions.

ESWT is also used to promote bone healing and treat bone necrosis. It is an effective alternative to surgical treatment of non-healing fractures. ESWT is used for wound healing and has shown positive results in short-term and long-term outcomes in diabetic patients suffering from foot ulcers. The kinetic energy of the projectile, created by compressed air, is transferred to the transmitter at the end of the applicator and further into the tissue. Energy levels are between 0.03-0.5 MJ/mm$^{2.}$ 1500-2000 shock waves are applied to the highest point of pain.

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3. John G. Webster, Biomedical Instrumentation, Wiley Publications, 2007.

4. Geddes L.A. and L.E.Baker, Principles of Applied Biomedical Instrumentation, 3rd Edition, 2008.

Question Bank

PART A

S.No	
1.	Point out the principle of Dialysis.
2.	What are these components used for in a dialysis machine? a) Proportioning pump b) Blood leak detector .
3.	Compare parallel flow, coil and hollow fiber types of hemodialysers.
4.	Draw the structure of coil hemodialyser and hollow fiber hemodialyser.
5.	Outline on the Performance of Dialyzers.
6.	Why is Ultra filtration rate important in dialysis?
7.	List the disadvantages of the first lithotripter machine.
8.	Define ESWT.
9.	What is triggering in a lithotripter machine?
10.	Name the dialysis membrane and its composition.

PART B

S.No	Questions
1.	Recommend an equipment design to assist a person who has chronic kidney ailments.
2.	With necessary schematics, discuss about the principle of dialysis.

3. Demonstrate the functioning and working of a portable kidney machine.
4. Elaborate on the working of the first lithotripter machine emphasizing on its various parts.
5. The stone disease problem is becoming persistent in the recent years. Design a machine to destruct these stones in a minimally invasive method.
6. Summarize on a) Extracorporeal shockwave therapy b) Stone disease problem.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – IV - Therapeutic Instrumentation – SBM1403

ANAESTHESIA MACHINE

4.1 Need For Anaesthesia Machine

It Has 2 Functions

1. Ensures Patient Does Not Feel Pain And Minimizes Discomfort
2. Provides Surgeon With Favourable Condition To Work.

4.2 Anaesthesia Machine

A machine used to deliver a precisely known but variable gas mixture including anaesthetics and life sustaining gases to the respiratory system.

A variable concentration of oxygen, nitrous oxide and anaesthetic vapor like ether is obtained from the machine and made to flow through the breathing circuit to the patient.

Gas Supply System

Gases are provided to the machine from a central supply or using small storage cylinders.

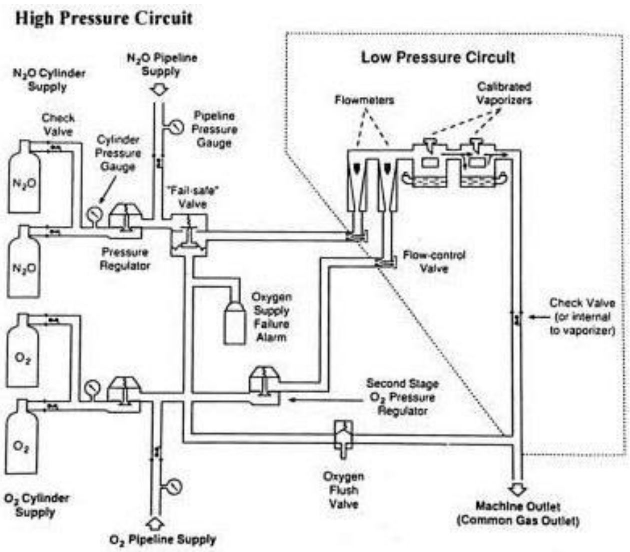
Centralized supply-

It consists of bulk or centralized storage for main and reserve supply, control equipments like valves and pressure regulators, distribution pipeline and supply outlets.

The oxygen-nitrous oxide gases are regulated and maintained at 275-345 K Pa.
Gases are supplied to the operating room through color coded hoses for each gas.
Each inlet is also provided with a non interchangeable connector. They incorporate a specialized male and female end for each gas.

Gas Cylinder –

Cylinders are attached to the yoke of the anaesthesia machine. It can be used as a reserve during



emergency situations.

Yoke – The machines are provided with one or two yokes which are exclusive for each cylinder. Two pins located in the yoke must fit into the corresponding holes in the tank neck.

Pressure Regulator – These reduce cylinder gas pressures to 275 KPa before it flows into the machine. It has non return valves which prevents the flow into empty cylinder or back into the central piping system.

Pressure Gauge System – This indicates the contents of the gases in the cylinder. For oxygen it is 0-150 kg/cm2. An indicator would give reading and if the falls below the standard values, the cylinder has to be replaced.

Fail Safe System – This system makes sure that the nitrous oxide doesn’t flow into the machine unless an oxygen supply pressure exists in the machine. It has a master pressure regulator valve located in the oxygen supply line. Oxygen –N2O ratios vary from 75:25 to 70:30.

Flow Delivery Units

Gas proportioning and gas mixing is used to accomplish delivery and control gas mixture.

***Gas Proportioning* –** The delivered concentration of each gas is a function of a pre determined precisely controlled ratio of proportionality which is independent of the total gas flow. The mass delivery is 7:3 irrespective of the total flow rate.

***Gas Mixing* –** The flow rate of each constituent is independently controlled and measured by a delivery unit consisting of a needle valve and a rotameter.

Vapour Delivery Unit

The liquids that posses anaesthetic properties are too strong to be used as pure vapors. They are diluted in a carrier gas.

Vapourizer is the device that allows the vapourization of liquid agent and the carrier gas. They have two designs- flowmeter controlled and concentration calibrated.
The vapors are picked from the vapourizer by the carrier gas by bubbling through the liquid or passing over the liquid.

The liquid temperature has to be maintained by using a water bath made of copper.

Patient Breathing System

It delivers the anesthetics and respiratory gases to and from the patient. It describes the mode of operation and the apparatus by which inhalation agents are delivered to the patient.

Humidifiers

The air or anaesthestic agents have to be humidified to prevent secretion of mucus or making the passage dry. The humidification measures used are heated air way humidifiers, nebulizers and heat and moisture exchangers.

In Heated airway humidifiers, air passes over the surface of heated water and vaporization takes place. Nebulisers supply moisture in form of droplets.

Heat and moisture exchangers conserve the patients own heat and moisture.

Ventilators

The ventilator provides a positive force for transporting the respiratory and anaesthetic gases into the patient. They are located in d machine or as an accessory unit. The output is connected to the patient breathing circuit.

Patient Circuit

It consists of a rubber tube, a tube fitting, a rebreathing bag, a valve and a mask.

4.3 Electronics in anaesthesia machine

The use of microprocessors allows integrating control and safety function and protects the patient from gas supply failure, electrical supply failure, disconnections, etc.

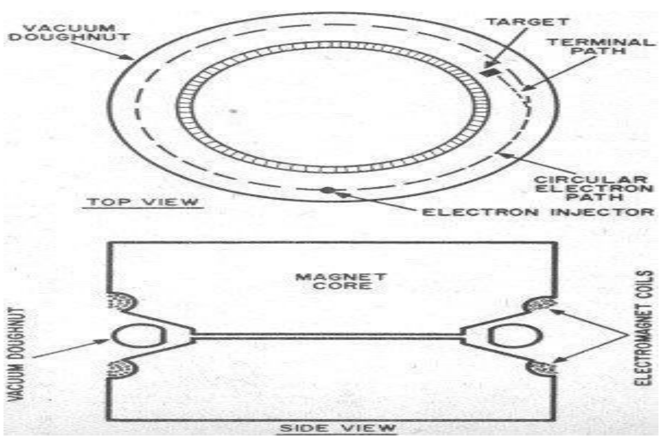
All abnormal conditions cause an alarm to ring.

4.4 Radiotherapy Equipment

Radiotherapy has a good success rate and lower cost treatment of cancer.

4.5 Development of Betatron

Betatrons were used in 1950’s for cancer treatment. They produce high energy X ray beams as high as 45 MeV.Betatron, a type of particle accelerator that uses the electric field induced by a



varying magnetic field to accelerate electrons (beta particles) to high speeds in a circular orbit.

The Betatron consists of an evacuated doughnut chamber in which electrons are produced by indirectly heated cathode. The doughnut tube is placed between two strong electromagnet such that, when the a.c current is passed in the electromagnets the flux increases in the centre of doughnut (single coil).

At the end of the quarter-cycle, the electrons are deflected onto a target to produce X-rays or other high-energy phenomena.

Betatron is actually a transformer. It has a torus shaped vacuum tube which acts as the secondary coil of the transformer. An alternating current is applied in the primary coil of the transformer. This accelerates the electrons in the vacuum tube around a circular path. Betatron works under constant electric field and variable magnetic field.

Because of their high penetration power, they were used to treat cancer in the trunk and pelvis. It was highly precise.

But it had its disadvantages as the machine being large and heavy. It did not have 360^o rotation. Compact machines could produce only very low X ray output.

4.6 Heart Lung Machine

A machine used to support the body during surgical procedure where the heart has to be stopped. The machine does the function of the heart and lungs. It maintains the circulation of the blood and oxygen content of the patient's body.

The heart-lung machine consists of a chamber that receives the blood from the body, which is normally the responsibility of the heart's right atrium. This blood is then pumped by the machine through an oxygenator, a function normally the responsibility of the right ventricle. The oxygenator removes the $CO2$ and adds oxygen, which is normally the work of the lungs. The pump then pumps this newly oxygenated blood back to the body, which is normally the work of the left heart. The heart-lung machine is connected to the patient by a series of tubes that the surgical team places. At the end of the operation, the surgeon gradually allows the patient's heart to resume its normal function, and the heart-lung machine is "weaned off".

Six main parts

- Cannulae
- Reservoir
- Oxygenator
- Temperature Control
- Filter
- Roller/Centripetal Pump

Multiple cannulae are sewn into the patient's body in a variety of locations, depending on the type of surgery. A venous cannula removes oxygen deprived blood from a patient's body. An arterial cannula is sewn into a patient's body and is used to infuse oxygen-rich blood. A cardioplegia cannula is sewn into the heart to deliver a cardioplegia solution to cause the heart to stop beating.

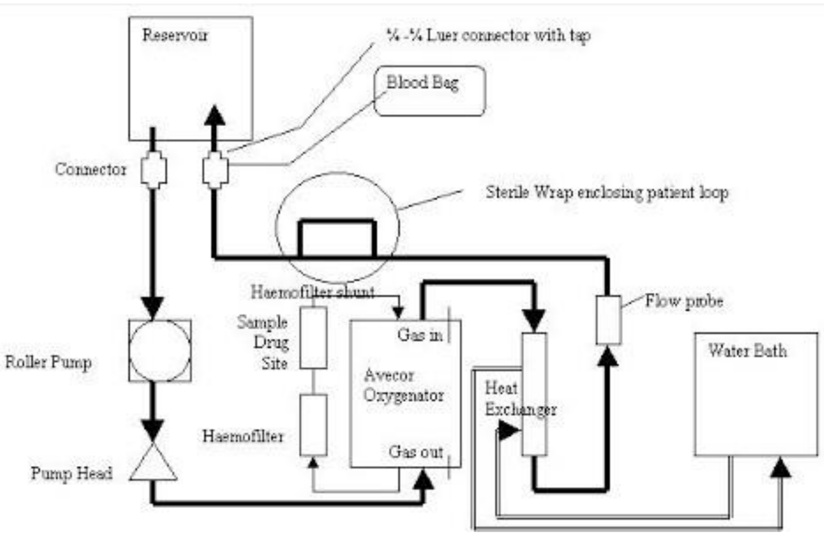
Cardiopulmonary bypass consists of two main components, the pump and the oxygenator which removes oxygen-deprived blood from a patient's body and replace it with oxygen-rich blood through a series of hoses.

The components of the CPB circuit are interconnected by a series of tubes made of silicone rubber or PVC. The pump console usually comprises several rotating motor-driven pumps that peristaltically massage tubing. This action gently propels the blood through the tubing. This is commonly referred to as a roller pump, or peristaltic pump.

Many CPB circuits now employ a centrifugal pump for the maintenance and control of blood flow during CPB. By altering the speed of revolution (RPM) of the pump head, blood flow is produced by centrifugal force. This type of pumping action is considered to be superior to the action of the roller pump by many because it is thought to produce less blood damage.

Oxygenator: The oxygenator is designed to transfer oxygen to infused blood and remove carbon dioxide from the venous blood. Cardiac surgery was made possible by CPB using bubble oxygenators, but membrane oxygenators have supplanted bubble oxygenators since the 1980s.Another type of oxygenator used is the heparin-coated blood oxygenator which is believed to produce less systemic inflammation and decrease the propensity for blood to clot in the CPB circuit.

A heat exchanger is included to maintain the desired temperature of the blood.



Heparin pumps prevent coagulation of the blood.

Suction pumps aspirate blood from the heart chambers when the surgery is on. An air bubble detector detects the presence of air n d blood and removes them. A roller pump delivers the blood back into the coronary artery. Filters are used to remove any debris.
Temperature sensors are used at different sites to measure the blood temperature.

4.7 Chemotherapy

Chemotherapy is the use of drugs to destroy cancer cells. It works by keeping the cancer cells from growing and dividing to make more cells. Because cancer cells usually grow and divide faster than healthy cells, chemotherapy destroys them more quickly than it destroys most healthy cells.

Chemo is considered a systemic therapy. This means it may affect your entire body. Chemo medications attack rapidly growing cancer cells, but they can also affect healthy cells that grow rapidly. The effect of these medications on normal cells often causes chemo side effects.

There are three main goals for chemotherapy (chemo) in cancer treatment:

- Cure- If possible, chemo is used to cure cancer, meaning that the cancer is destroyed – it goes away and doesn’t come back.
- Control - If cure is not possible, the goal may be to control the disease. Chemo is used to shrink tumors and/or stop the cancer from growing and spreading. This can help the person with cancer feel better and live longer.
- Palliation - Chemo can also be used to ease symptoms caused by the cancer. This is called palliative chemotherapy or palliation.

The chemotherapy drugs, dose, and treatment schedule depends on many factors. These include:

The type of cancer, the tumor size, its location, and if or where it has spread(stages), age and general health, how well a patient can cope with certain side effects, any other medical conditions the patient has, previous cancer treatments.

How is chemotherapy given

Intravenous (IV) chemotherapy- Many drugs require injection directly into a vein. Doctors call it intravenous or IV chemotherapy. Treatment takes a few minutes to a few hours. Some IV drugs work better if patient gets them over a few days or weeks. It is given through a small pump the patient wears or carries. This is called continuous infusion chemotherapy.

Oral chemotherapy - Some drugs are taken by mouth. They can be in a pill, capsule, or liquid. Oral treatment for cancer is now more common, since many drugs used for targeted therapy work this way. Some of these drugs are given daily, and others are given less often

Injected chemotherapy – Patient given chemotherapy as a shot. The shot is usually given in a muscle, the fatty part of an arm or leg, or the belly.

Chemotherapy into an artery - An artery is a blood vessel that carries blood from the heart to another part of the body. Occasionally, chemotherapy is injected into an artery that goes directly to the cancer. Doctor's call this intra-arterial or IA chemotherapy.

Chemotherapy into the peritoneum or abdomen - For some cancers, medication might be placed directly in the abdomen. This type of treatment works for cancers involving the peritoneum. The peritoneum covers the surface of the inside of the abdomen and surrounds the intestines, liver, and stomach. Ovarian cancer is one type of cancer that frequently spreads to the peritoneum.

Topical chemotherapy - You can take some types of chemotherapy in a cream you put on your skin.

Side effects of chemotherapy

The normal cells most likely to be damaged by chemo are:

Blood-forming cells in the bone marrow, hair follicles, Cells in the mouth, digestive tract, and reproductive system

Here are some of the more common side effects caused by chemotherapy:

Fatigue, Hair loss, Easy bruising and bleeding, Infection, Anemia (low red blood cell counts), Nausea and vomiting, Constipation, Diarrhea, Nerve and muscle problems such as numbness, tingling, and pain, Skin and nail changes such as dry skin and color change, Urine and bladder changes and kidney problems, Weight changes, Mood changes, Fertility problems

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Question Bank
PART A

S.No	Questions
1.	What does DISS stand for?
2.	Outline the role of scavenging in anesthesia machine.
3.	List the various anesthetic agents.
4.	State the need for anesthesia
5.	Give the types of oxygenators in heart lung machine.
6.	Infer the role of the heater in a heart lung machine.
7.	Discuss the working of a betatron.
8.	List the demerits of a betatron.
9.	Define chemotherapy.
10.	Indicate the methods to administer chemo agents.
11.	List the side effects of chemotherapy.
12.	What are the different patient responses to chemotherapy?

PART B

S.No	Questions
1.	With a neat schematic diagram , demonstrate the working of a anesthesia machine.
2.	Develop a design to construct a machine that temporarily takes over the function of heart and lungs during a surgery.
3.	What is the need for anesthesia? Brief about the various parts of an anesthesia machine and patient breathing circuit.
4.	Elaborate on chemotherapy, its goals, administration and side effects.
5.	How does a betatron produce high voltage X rays. Explain.
6.	Draw the schematic representation of CPB and explain its working.
7.	Summarize on a) Betatron b) Chemotherapy.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

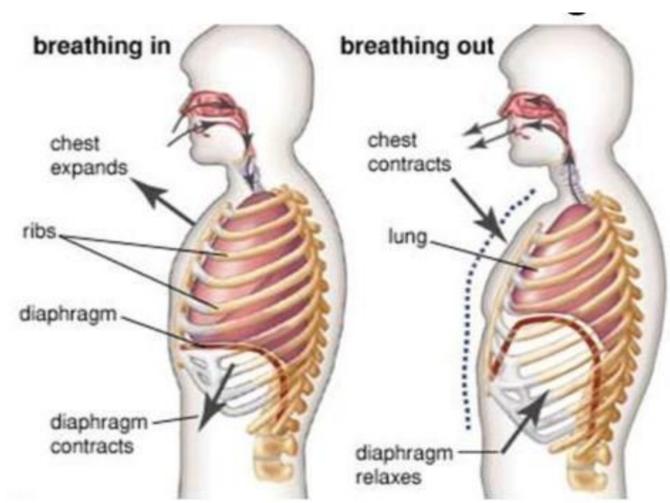
UNIT – V - Therapeutic Instrumentation – SBM1403

VENTILATORS

5.1 Mechanics Of Respiration

Every pulmonary cycle consists of the following phases: intake of breath (inspiration) and exhalation (expiration).

When we inhale, the intercostal muscles (between the ribs) and diaphragm contract to expand the chest cavity. The diaphragm flattens and moves downwards and the intercostal muscles move the rib cage upwards and out. This increase in size decreases the internal air pressure and so air from the outside (at a now higher pressure that inside the thorax) rushes into the lungs to equalise the pressures. When we exhale the diaphragm and intercostal muscles relax and return to their resting positions. This reduces the size of the thoracic cavity, thereby increasing the pressure and forcing air out of the lungs.



Only at the optimal course of pulmonary cycles, a sufficient extraction of CO_2 from the blood and its saturation by oxygen are provided.

There are two ways how the lungs can be shrunk or stretched:

The activity of the diaphragm

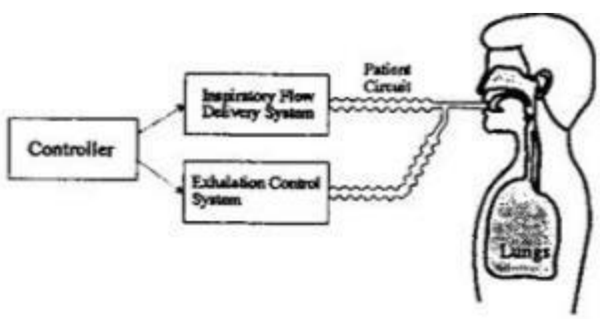
5.2 Artificial Ventilation

For reduced breathing or respiratory failures, mechanical devices are used. These devices supply enough oxygen and eliminate the right amount of CO_2 and maintain the desired arterial partial pressure of O_2 and CO_2. The aids are mask, breathing valves and self filling bags. The masks are held firmly over the patients mouth and nose. The breathing valve guides the air to the patient and removes the unwanted air. The bag acts as a pump and is squeezed by hand.

5.3 Ventilators

These are used when artificial ventilation is to be used for a long time. The main function is to ventilate the lungs close to the natural process.

Negative pressure ventilators generate a negative pressure inside the lungs or around the patient’s thoracic cage. This pressure moves the thoracic wall outwards, expanding the intra thoracic volume and dropping the pressure inside the lungs, giving a pressure gradient between the atmosphere and lungs which causes the flow of air into the lungs. These are not commonly used.



Positive pressure ventilators generate inspiratory flow by applying a positive pressure. They operate in mandatory or spontaneous mode.

5.4 Types Of Ventilators

Anaesthesia ventilators- Small and simple equipments used to assist during operations.

Intensive care ventilators- They are complicated and are used over a range of parameters. They incorporate patient triggering facility.

5.5 Ventilator Terms

IMV (intermittent mandatory ventilation) :

A breath sequence in which spontaneous breaths are permitted between mandatory breaths.

Tidal volume

The volume of gas/air delivered with each breath.

Inspiratory and expiratory times

The total time required for one complete respiratory cycle. Typically, patients are comfortable with an expiratory time two to three times longer than the inspiratory time.

Inspiratory reserve volume – IRV

This term means the maximal volume of air that can be inhaled after completion of resting inspiration. 3000ml

Expiratory reserve volume – ERV

It is the maximal volume of air which can be exhaled after the completion of the resting expiration. 1100ml

Residual volume – RV

Residual volume is the volume of air that remains in the lungs after a maximum forced expiration, thus the amount of air remaining in the maximally contracted lungs. For an adult 70 kg man is about 1200 ml.

Functional residual capacity – FRC

Functional residual capacity is the amount of air that remains in the lungs after completed resting exhalation and is equal to the sum of expiratory reserve volume and residual volume of the lungs.

FRC = ERV + RV

For an adult 70 kg man is thus about 2300 ml.

Vital capacity – VC

The maximal volume of air that can be exhaled after the completion of the maximal forced inspiration. In other words, it is the volume of air that the lungs are able to expel by maximum exhalation after maximal strenuous inspiration. It therefore represents a sum of inspiratory reserve volume, tidal volume and expiratory reserve volume.

VC = IRV + VT + ERV

For an adult 70 kg man comprises about 4600 ml.

Total lung capacity – TLC

Total lung capacity is the maximal volume of air that can be held in the lungs after maximal forced inspiration. It can also be said that this is the maximal volume which can somebody's lungs achieve. It is the sum of all four volumes described above, i.e. residual volume, expiratory reserve, tidal and inspiratory reserve volume. More often is expressed as the sum of vital capacity and residual volume of the lungs.

TLC = RV + ERV + VT + IRV = VC + RV

For an adult 70 kg man this value reaches about 5800 ml.

Lung compliance

A measure of the ease of expansion of the lungs and thorax, determined by pulmonary volume and elasticity.

Minute Volume

Respiratory minute volume is the volume of gas inhaled (inhaled minute volume) or exhaled (exhaled minute volume) from a person's lungs per minute.

Airway resistance

The ease with which air flows through the respiratory passage.

Respiration rate

The number of breaths per minute.

Synchronized Intermittent-Mandatory Ventilation (SIMV)

A combination of machine ventilation and spontaneous breathing.

Peak airway pressure

Peak inspiratory pressure (PIP) is the highest level of pressure applied to the lungs during inhalation

5.6 Classification Of Ventilators

Based on the method of initiating the inspiratory phase

Controller

It operates independent of the patient's inspiratory effort.

Assistor

It augments the inspiration of the patient by operating in response to the patient's inspiratory effort.

Assistor/Controller

It combines both the assistor and controller functions.

Based on power transmission

Direct power transmission

Delivers gas directly from the source to the patient.

Indirect power transmission

It separates the patient and power systems.

Based on Pressure pattern

Positive atmosphere

It produces a positive pressure in the patient's lungs during inspiration. The patient breathes spontaneously.

Positive – Negative

It produces a positive pressure in the patient's lungs during inspiration and the atm. Pressure lowers during the expiratory phase.

Positive-Positive

It produces a positive pressure in the patient's lungs during inspiration with the end expiratory pressure greater than atmospheric pressure.

Based on the type of safety limit

Volume limited

The ventilator in which the pre determined volume cannot be exceeded during inspiration

Pressure limited

The ventilator in which the pre determined pressure cannot be exceeded during inspiration.

Time limited

The ventilator in which the pre dtermined phase timee cannot be exceeded during inspiration.

Based on source of power

Pneumatic

Powered by compressed gas

Electric

Powered by electrical device like motors

Based on cycling control

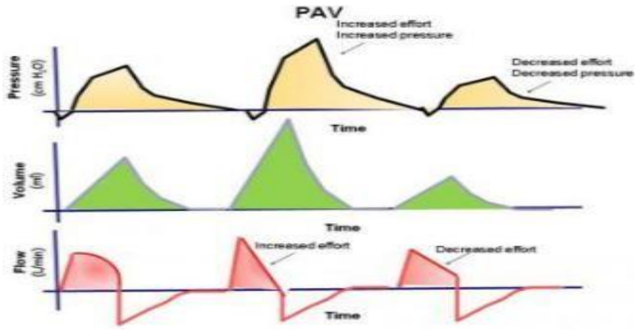
The cycling control determines the change from inspiratory phase to expiratory phase and vice versa.

5.7 Pressure Volume Flow Diagrams

Pressure-time, flow-time and volume-time diagrams are needed to understand the performance of ventilators.

The ventilated system comprises the patient circuit, airways and the alveoli having its own compliance.

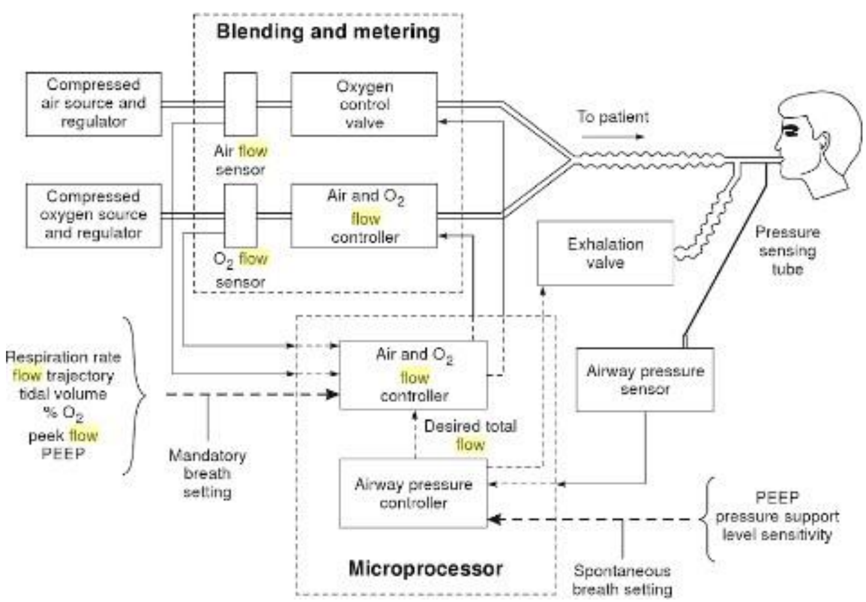
At the start of the inspiratory phase, a gas volume is given to the system which results in an pressure in the patient circuit and a flow through the airway. During this phase, the airway pressure and alveolar pressure increase gradually with airway pressure greater than alveolar pressure. The equal pressure of patient circuit and alveoli informs the end of the inspiratory phase and beginning of the expiratory volume.



The expiratory flow is the difference between alveolar pressure and pressure in the patient circuit. A pause time or time delay should be provided between the cycling of the ventilator and the change from inspiratory to expiratory flow.

5.8 Modern Ventilators

A ventilator is an electromechanical (or, possibly, completely mechanical) device designed to provide all or part of the effort required to move gas into and out of a person's lungs.



It has two interconnected systems – Pneumatic flow system and electronic control system.

Pneumatic flow system –

This device ensures proper level of O_2 in inspiratory air.

O_2 and medical grade air enters into the ventilator at 3.5 bar pressure through built in 0.1 micro filter. These gases enter the mixer and the 8 liters reservoir.

An electronically entered flow value proportions the gas flow from reservoir tank to patient breathing circuit. As the gases leave the ventilator, they pass by an O2 analyser, a safety ambient air inlet valve and back up mechanical pressure valve. The ambient valve provides the patient the ability to breathe room air when the machine fails or pressure in patient circuit decreases.

A bi directional flow sensor in the breathing circuit measured the gas flow. The exhaled gases flow through the electronically controlled exhalation valve.
The microprocessor controls each valve to deliver the desired inspiratory air and O2 for spontaneous and mandatory ventilation.

Electronic Control System

It uses one or more microprocessors and software to perform monitoring and control functions.

The parameters include setting of respiration rate, flow waveform, tidal volume, peak flow and PEEP. The PEEP controls the exhalation flow.

These parameters are used to compute desired inspiratory flow. The system consists of monitors for pressure flow and O2 flow sensors. These are connected to electronic processing circuits and values are displayed. The pressure sensors are strain gauges. Fuel cell type sensors are used to measure fraction of O2. Thermistors are used to measure temperature.
Ventilators need regular maintenance and calibration.

5.9 High Frequency Ventilators

High frequency ventilation is a type of mechanical ventilation which utilizes a respiratory rate greater than 4 times the normal value.

High frequency ventilation reduces ventilator-associated lung injury (VALI), especially in the context of ARDS and acute lung injury. This is commonly referred to as lung protective ventilation.

High frequency ventilation may be used alone, or in combination with conventional mechanical ventilation.

There are three distinguishing characteristics of high-frequency oscillatory ventilation: the frequency range from 5 to 50 Hz (300 to 3000 bpm); active inspiration and active expiration; tidal volumes about the size of the dead space volume.

There are four basic types of HFV: high frequency jet ventilation, high frequency oscillatory ventilation, high frequency percussive ventilation, and high frequency positive pressure ventilation. Among these, high frequency oscillatory ventilation is the mode that is used most often.

HFV provides adequate alveolar ventilation and oxygenation without high inspiratory pressure.

Babylog 8000 uses oscillating diaphragm mechanism which is computer controlled. It determines the shape of pressure swings and I: E ratio. HFV's are microprocessor controlled.

5.10 Humidifiers, Nebulisers and Aspirators

Humidifiers replace humidity in the upper air passages which has been lost due to intubation. It should be close to 100%. It prevents damage to the lungs and air passages. It is done by heat vapourization or bubbling air through a jar of water.

Nebulizers are used when any medication has to be administered as an aerosol. The water or medication is picked by high velocity jet of oxygen which causes droplets to be formed which are then given to the patient. Ultrasound nebulisers are also used.

Aspirators are used along with ventilators to remove mucus and other fluids from the airways. Suction devices are also used.

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1. Khandpur R.S., Handbook of biomedical Instrumentation, Tata McGraw Hill Publication company Ltd, New Delhi, 2014.
2. Joseph J. Carr, John Michael Brown, Introduction to Biomedical Equipment Technology, 4th Edition, Pearson Education, 2012.
3. John G. Webster, Biomedical Instrumentation, Wiley Publications, 2007.
4. Geddes L.A. and L.E.Baker, Principles of Applied Biomedical Instrumentation, 3rd Edition, 2008.

PART A

S.No	Questions
1.	Give the mechanics of respiration.
2.	List the components of an artificial ventilator.
3.	What are the types of ventilators?
4.	Define IRV and ERV.
5.	What is minute volume?
6.	Mention the difference between negative pressure and Positive pressure Ventilation.
7.	Abbreviate SIMV and define.
8.	Differentiate humidifiers and nebulisers.
9.	What are aspirators used for?
10.	List the types of HFV.
11.	Define tidal volume.

PART B

S.No	Questions
1.	Classify Ventilators based on method of initiation, power transmission, pressure pattern, safety limit, cycling control and source of power.
2.	Brief about a) Humidifier b) Nebuliser c) Aspirator
3.	Elaborate on the functioning of a machine that assists in overcoming respiratory failure .
4.	Summarize on a) Artificial respiration b) Pressure Volume Flow diagrams.
5.	Examine the various ventilator terms and elaborate on each.
6.	Describe a) HF ventilators b) Negative and positive pressure ventilators.