UNIT III

ASSIST DEVICES AND BIO-TELEMETRY

Cardiac pacemaker, DC Defibrillator, Dialyser, Heart Lung Machine

3.1 INTRODUCTION:

Physiological assist device are very helpful to the patients of different categories. Pacemakers are extending the life of cardiac patients having total bundle block. Implanted artificial heart valves are maintaining the circulation of blood in a normal manner.

3.2 PACEMAKER:

Pacemaker is an electrical pulse generator for starting and/or maintaining the normal heart beat. The output of Pacemaker is applied either externally to the chest or internally to the heart muscle. In case of cardiac standstill the use of pacemaker is temporary just long enough to start a normal heart rate. In long term pacing pacemaker is surgically implanted in the body and its electrodes are in direct contact with heart. In cardiac diseases where the ventricular rate is too low it can be increased to normal rate by using pacemaker.

Energy requirements to excite heart muscle:

The heart muscle can be stimulated with an electric shock.The minimum energy required to excite heart muscle is 10µJ. For better stimulation and safety purposes 100µJ pulse energy is applied on heart muscle. During ventricular fibrillation heart muscle contracts so rapidly and irregularly.The pulse to space ratio 1:10000

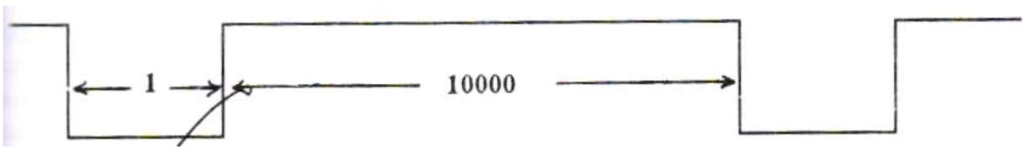


Fig : Pacemaker pulses

The negatively going pulses to avoid ionization of muscles. Pulse repetition rate is usually 70 pulses/min but many pacemaker s are adjustable in the range of 50-150pulses/min. The circulation of each pulse is between 1to2ms.

3.2.1 Methods of stimulation:

There are two types of stimulation

(i) Internal stimulation

(ii) External stimulation

(i)Internal stimulation: It is employed for long term pacing because of permanent damage. Electrodes in the form of fine wires of Teflon coated stainless steel. The current range is 2-5mA.Bipolar and Unipolar electrode are used.

Bipolar electrode : There are stimulating electrode and contact electrode which serves as a return path for current to pacemaker.

Unipolar electrode: There is only stimulating electrode and the return path for current to pacemaker is made through body fluids.

(ii) External stimulation : It is employed to restart the normal rate of heart in case of cardiac stand still.The paddle shaped electrode are applied on the surface of chest current in the range of 20-150mA

Based on the placement of pacemaker there are two types

(i)External pacemaker

(ii)Implanted (Internal pacemaker)

External pacemaker	Implanted(Internal)pacemaker
The pacemaker is placed outside the body.It may be in the form of wrist watch or in packet from one wire go in to heart through the vein.	The pacemaker is surgically implanted beneath the skin near the chest
The electrode are called endocardiac electrode and are applied to heart	The electrode are called myocardiac electrode and are in contact with heart muscle.
It does not the open chest surgery	It requires an open chest minor surgery
The battery can be easily replaced any defect or adjustment in the circuit can be easily attended without getting any help from a medical doctor	The battery can be replaced only by minor surgery.Further any defect or adjustment in the circuit cannot be easily attended. Doctors help is necessary to rectify the defect in the circuit.
During placement swelling and pain do not arise	During placement swelling and pain arise
There is no safety for the pacemaker particularly in the case of children	There is a cent percent safety
Mostly there are used for temporary heart dameges.	Mostly there are used for permanent heart dameges

3.2.2 Different modes of operation:

Pacing modes can be either competitive or noncompetitive. Asynchronous pacing is called competitive because the fixed rate impulses may occur along with natural pacing impulses and competition with them in controlling the heart beat.Non competitive pacemakers are programmed either in demand or synchronized mode

Based on the modes of operation pacemaker can be divided in to five types.

(i)Ventricular Asynchronous pacemaker (Fixed rate pacemaker)
(ii) Ventricular synchronous pacemaker
(iii) Ventricular inhibited pacemaker(Demand pacemaker)
(iv) Atrial synchronous pacemaker
(v) Atrial sequential Ventricular inhibited pacemaker

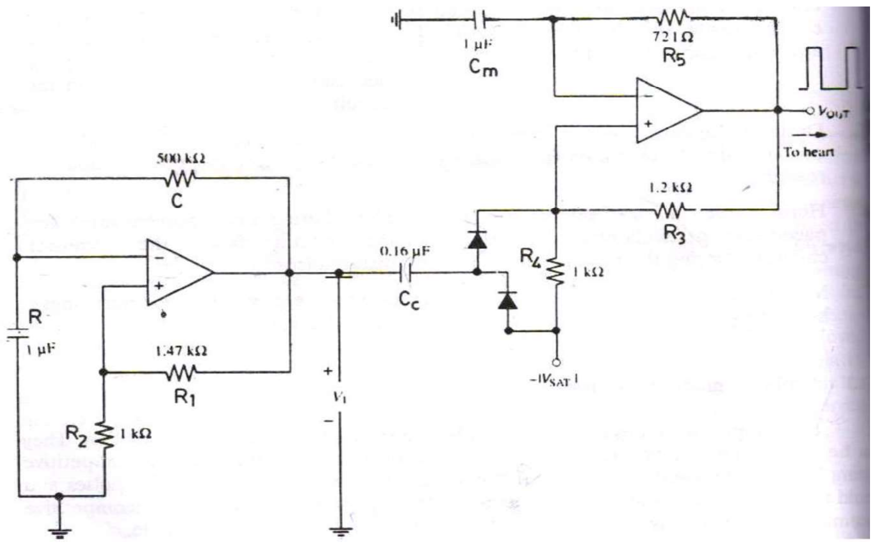
3.2.2.1Ventricular Asynchronous pacemaker (Fixed rate pacemaker):

It can be used in atrium or ventricle. It has the simplest mechanism and the longest battery life. This pacemaker is suitable for patients with either a stable, total AV block, a slow atrial rate. It is basically a simple astable multivibrator which produces at a fixed rate of heart . There may be competition between the natural heart beats and pacemaker beats.If the pacemaker impulses reaches the heart during a certain period,ventricular fibrillation may occur. Nowadays the fixed pacemaker is fabricated on a large scale integrated circuit are used.The circuit consists of a square wave generator and a positive edge triggered monostable multivibrator.The output of this com,bination provides a positively and negatively going square waves with equal duration for positive and negative pulses.The period of square wave generator is given by

$$T= -2RC \ln(1-\alpha/1+\alpha)$$

Where $\alpha=R_2/(R_1+R_2)$

α – feedback voltage fraction



Square wave generator Monostable multivibrator

Fig3.2.2.1 : Ventricular Asynchronous pacemaker

T can be changed by changing α or time constant RC. The square wave generator is nothing but astable multivibrator which switches the output voltage between $|V_{sat}|$and $-|V_{sat}|$. The output of square wave generator in coupled to the positive edge triggered monostable multivibrator circuit. A positive edge trigger input will pass through capacitor Cc and diode and will raise the voltage at non-inverting terminal of second amplifier.The capacitor Cc is chosen so as to make five time constants equal to pulse duration TD.Otherwise the trigger would still be present after TD has passed and second pulse would be wrongly generated.Normally the pulse duration should not be affected by the loading of heart tissue.

Disadvantages:

1. Using fixed rate pacemaker the heart rate cannot be increased
2. Simulation with a fixed impulse frequency results in the ventricles and atria beating at different rates.This varies the stroke volume of heart and causes some loss in cardiac output.
3. Possibility of ventricular fibrillation will be more.

3.2.2.2 Ventricular synchronous pacemaker (standby pacemaker):

This is used for patients with only short periods of AV block or bundle block. This type does not complete with the normal heart activity. A single transverse electrode placed in the right ventricle both senses R wave and delivers the stimulation.

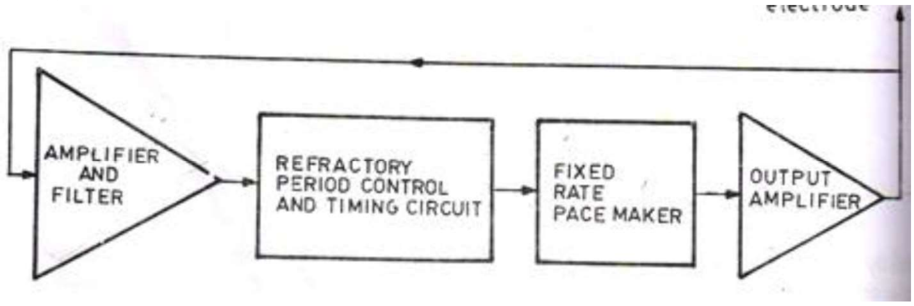


Fig3.2.2.2 : Ventricular synchronous pacemaker

Thus no separate sensing electrode is required. R wave triggers ventricular synchronized pacemaker which provide an impulses falling in lower part of normal QRS complex. Atrial generated ventricular contractions generates R wave. Impulses are provided only when the atrial generated ventricular contractions are absent.

Working:

Using the sensing electrode heart rate is detected and is given to the timing circuit in pacemaker. If the detected heart rate is below a minimum level the fixed rate pacemaker is turned on. If natural contraction occurs asynchronous pacer's timing circuit is reset so that it next pulse will detect heart beat. Otherwise asynchronous pacemaker produces at its preset rate. The pacemaker may detect noise and interpret as its ventricular excitation. This can be eliminated by refractory period or gate circuit. In heart blocks P waves with respect to ventricular excitation. P and R waves have different frequency bands. The high pass filter completely eliminates P-waves and the R-waves. Input amplifier increases peak-to-peak amplitude of R-wave.

Advantages:

1. It can be used to arrest ventricular fibrillation
2. If the R-wave occurs with its normal value in amplitude and frequency then it would not work. Hence the power consumption is reduced and no side effects.
3. When the R-wave is appearing with lesser amplitude
4. If the R-wave amplitude is too low or too high the asynchronous pacer works to return the heart in to normal one.

Disadvantages:

1. Atrial and ventricular contractions are not synchronized.
2. In olden type pacemaker the circuit is more sensitive to external electromagnetic interferences.
   - Patients could not work in TV or radio stations
   - Could not ride motor or scooters

3.2.2.3 Ventricular inhibited pacemaker(Demand pacemaker)

It is also known as R-wave inhibited pacemaker. If the normal heart rate falls below minimum the pacemaker will turn on and provide the heart a stimulus. Hence it is called as **Demand pacemaker.**

There is a piezoelectric sensor stielded inside the pacemaker. When the pacemaker can automatically increase or decrease its rate. Thus it can match with greater physical effort.

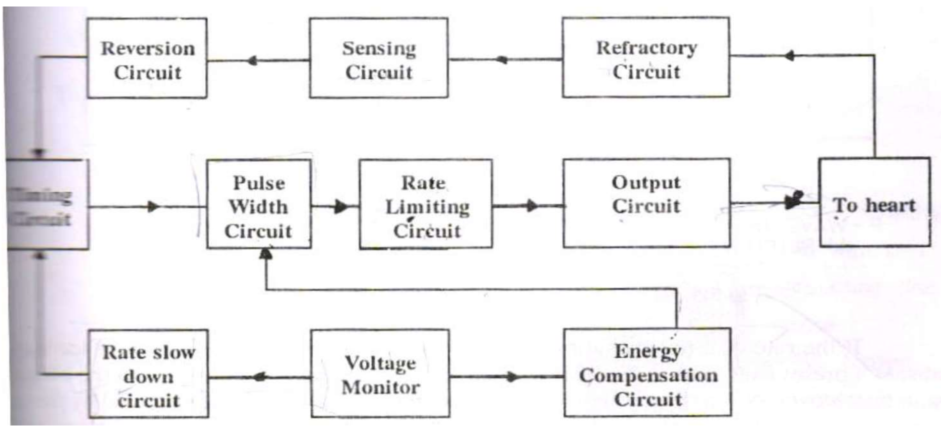


Fig3.2.2.3 : Ventricular inhibited pacemaker

The sensing electrode pick up R-wave. The refractory circuit provides a period of time for the sensed R-wave. The sensing circuit detects the R-wave resets the oscillator. The reversion circuit allows the amplifier to detect R wave in the low level SNR. IN the absence of R wave oscillator in timing circuit delivers pulses at its preset rate. The timing circuit determines the pulse rate of pulse generator. The output of timing circuit is fed in to the pulse width circuit which is an RC network. The pulse width circuit determines the duration of pulse delivered to heart. Rate limiting circuit limits the pacing rate to a maximum of 120pulses/min. Output circuit provides a proper pulse to stimulate the heart. The timing circuit, pulse width circuit, Rate limiting circuit and output circuit are used to produce the desired pacemaker pulses to pace the heart. A special circuit called voltage monitor senses the cell depletion and signals in rate slow down circuit energy compensation circuit. The rate slowdown circuit shuts off some of the current to timing network to slowdown 8±3beats/min during cell depletion. The energy compensation circuit increases the pulse duration to maintain constant simulation energy to heart.

3.2.2.4 Atrial synchronous pacemaker:

It is used for young patient with a mostly stable block. Atrial pacing is a temporary pacing and has many uses in physiologic investigation. It is used in stress testing and coronary artery diseases. It can act as a temporary pacemaker for atrial fibrillation. The atrial activity is picked up by a sensing electrode placed in the dorsal wall of atrium. The detected p wave is amplified and a delay of 0.12sec is provided by AV delay circuit. The signal is then used to trigger the resettable multivibrator. The output of multivibrator is given to amplifier which produce the desired stimulus to heart. The stimulus is delivered to the ventricle through the ventricular electrode. If the rate of atrial excitation becomes too fast or too slow a preset fixed rate pacemaker is used.

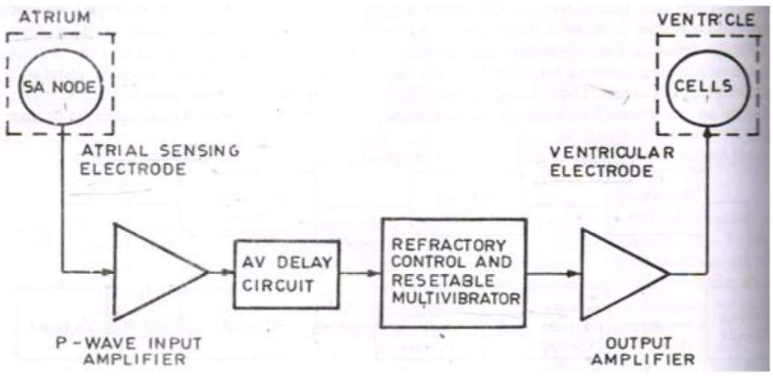


Fig3.2.2.4 : Atrial synchronous pacemaker

3.2.2.5 Atrial sequential Ventricular inhibited pacemaker:

It has the capability of stimulating both atria and ventricles. If atrial function falls this pacemaker will stimulate the atriam and then sense the subsequent ventricular beat. If atrial beat is not conducted to ventricle the pacemaker will fire the ventricle at a preset interval of 0.12sec.

3.3DEFIBRILLATOR:

A Defibrillator is an electronic device that creates a sustained myocardial depolarization of a patient’s heart in order to stop ventricular fibrillation or atrial fibrillation. Ventricular fibrillation is a serious cardiac emergency resulting from asynchronous contraction of heart muscles. This results from electric shock or abnormalities of body chemistry. Hence it cause a steep fall of cardiac output and can lead to death if adequate steps are not taken promptly. Ventricular fibrillation can be converted to a more efficient rhythm by applying a high voltage shock to the heart. This voltage causes all muscle fibers to contract simultaneously. The instrument for administering the electric shock is called defibrillator. The sudden cardiac arrest can be treated using a defibrillator and 80% of patient’s will be cured if the treatment is given within one minute of attack.. An atrial fibrillation causes reduced cardiac output but is usually not fatal. It happens for the young people who are always smoking and can even be cured by drug therapy.

3.3.1Types of defibrillators:

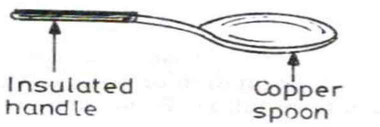
There are two types of defibrillators based on electrodes placement

(i)Internal defibrillator

(ii) external defibrillator

Internal Defibrillator:

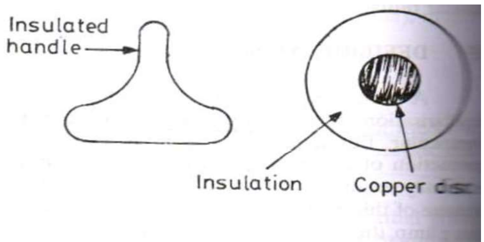
It is used when the chest is opened. It uses large spoon shaped electrodes with insulated handle. Since the electrodes are direct contact with heart the contact impedance is about 50Ω. The current passes through the heart is of 1 to 20A.



(a) Spoon shaped electrode

External defibrillator:

External defibrillator is used on the chest using paddle shaped electrodes. The bottom of the electrode consists of a copper disc and is attached with highly insulated handle. The required voltages are from 1000 to 6000V. when the electrodes are placed on the chest after the application of electrode gel the contact impedance on the chest is about 100Ω. The d.c defibrillator is designed to deliver 50 to 400J of energy through thorax. The duration of shock is about 1 to 5ms. The current flowing through the chest is about 10 to 60A.



(b) Paddle shaped electrode

*Depending upon the nature of voltage applied the defibrillators can be divided in to six groups.

1. A.C defibrillator
2. D.C defibrillator
3. Synchronised D.C defibrillator
4. Square pulse defibrillator
5. Double squre pulse defibrillator
6. Biphasic D.C defibrillator

3.3.3 A.C defibrillator:

It is the earlist and simplest type of defibrillator. It has appropriate voltages for both internal and external defibrillation. It consists of a step-up transformer with various tappings on secondary side.

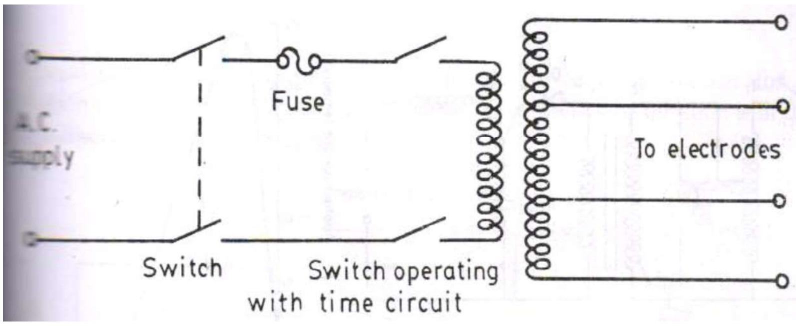


Fig3.3.3 : A.C defibrillator

An electronic timer circuit is connected to the primary of the transformer . The timer connects the output of the electrodes for a preset time. The timing device may be simple capacitor and resistor network which is triggered by a push button switch. The duration of shock may vary from 0.1-1sec depending upon the voltage to be applied. For safety the secondary coil of transformer should be isolated from earth so that there is any shock risk to anyone. For external defibrillation the voltages are in the range from 250 to 750V. For internal defibrillation the voltage is from 60 to 250 V. External defibrillation requires large currents for the simultaneous contraction of heart muscle fiber. This current also results in occasional burning of skin under the electrodes. Further it produces atrium fibrillation while arresting ventricular fibrillation.

3.3.4 D.C defibrillator:

D.C defibrillator would not produce undesirable side effects and at the same time it produces normal heart beat effectively. Ventricular fibrillation is terminated by passing a high energy shock through discharging a capacitor to exposed heart or chest of patient .A variable auto transformer T1 forms the primary of a high voltage transformer T2.

The output voltage of transformer T2 is rectified by a diode rectifier and is connected to a vacuum type high voltage change over switch. In position ‘A’ the switch is connected to one end of an oil filled capacitor. In this position the capacitor charges to a voltage set by the positioning of auto transformer. During the delivery of shock to patient a push button switch mounted on handle of electrodes operated.

The high voltage switch changes to position ‘B’ and the capacitor is discharged across the heart through electrodes. An inductor ‘L’ is placed in one of the electrode leads so that the discharge from the capacitor is slowed down by the induced counter voltage.

The shape of waveform that appears across the electrodes will depend upon the value of capacitor and inductor and it’s the amplitude depends upon the discharge resistance.

The success of defibrillation depends upon the energy stored in the capacitor and not with the voltage used. For internal defibrillation 100J of energy is required where as for external defibrillation 400J are required. The discharging duration is from 5ms to 10ms.

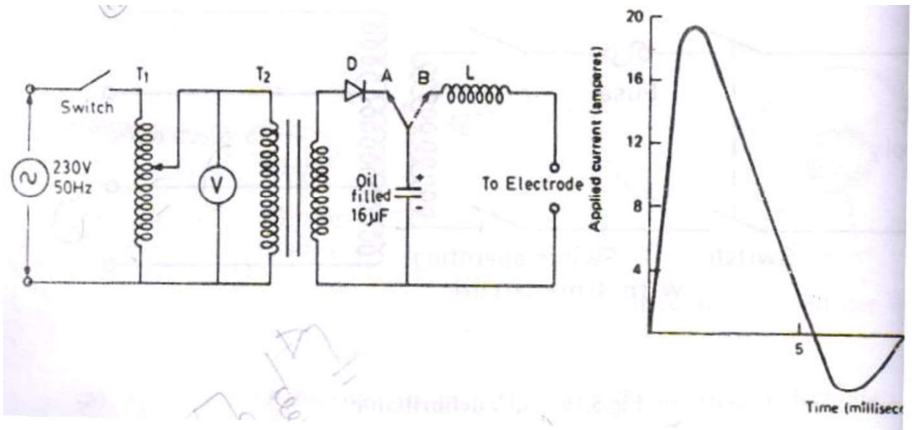


Fig 3.3.4(a): D.C defibrillator(ordinary type) and its output

Dual peak d.c defibrillator:

The passage of high current may damage the myocardium and the chest wall. To reduce this risk some defibrillators produce dual peak waveform this keeps the stimulus at peak for longer duration. Some energy can be applied to the heart with low current level such defibrillators are called dual peak defibrillators or delay line capacitance discharge d.c defibrillators.

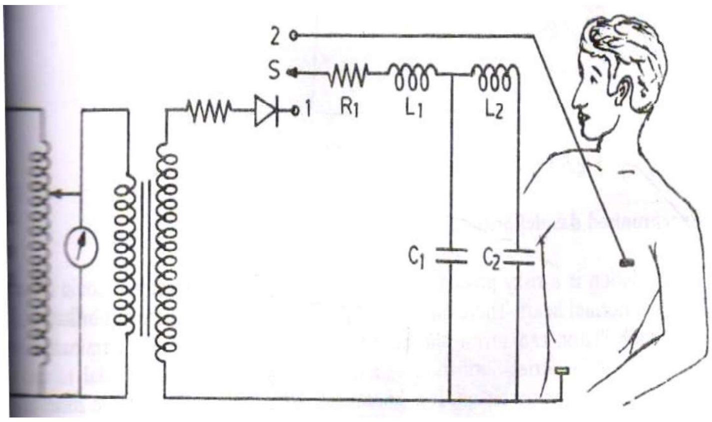


Fig3.3.4 (b) : Dual peak d.c defibrillator

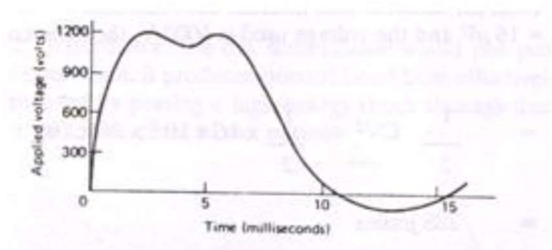


Fig3.3.4(b): output of Dual peak d.c defibrillator

Truncated defibrillator:

In this type the capacitor discharge is adjusted so that the effective defibrillation is obtained at the desirable low voltage level. The voltage level of the wave is almost constant but its duration is extended to obtain the required energy.

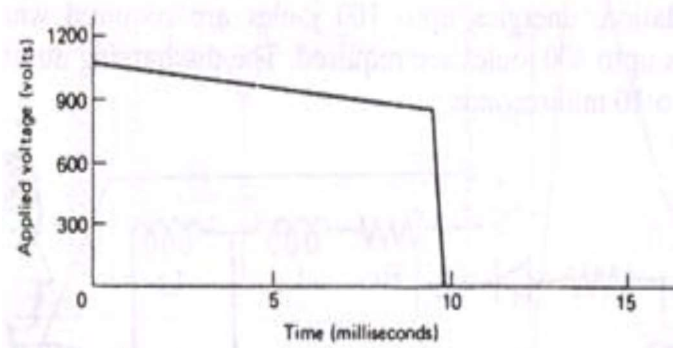


Fig3.3.4 (c) : Truncated defibrillator discharge waveform

3.3.5 Synchronised D.C defibrillator:

Defibrillator is a risky procedure since if it is applied incorrectly it could induce fibrillation in a normal heart. It is essential to use a defibrillator with synchronizer circuit. There are two zones in a normal cardiac cycle.T wave and U wave segments'. If the counter shock falls in the T wave segment then the ventricular fibrillation is developed. If the counter shock falls in the U wave segment then the atrial fibrillation is developed.

Fig. shows the modern d.c defibrillator circuit consisting of defibrillator electrocardioscope and pacemaker.

The pacemaker is used in case of emergency as a temporary pacing. It includes

- Diagnostic circuitry used to assess the fibrillation before delivering the defibrillation pulse.
- Synchronizer circuitry used to deliver the defibrillation pulse at the correct time so as to eliminate the ventricular or atrial fibrillation without inducing them.

Working:

1 The electrocardiogram is obtained by means of an ECG unit connected to the patient who is going to receive defibrillation pulse.

2. The switch is placed in the defibrillator mode if ventricular fibrillation is suspected.

3. The QRS detector in that mode consists of a threshold circuit that would pass the signal as output if R wave is almost in electrocardiogram. Otherwise it would not give any output if wave is present.

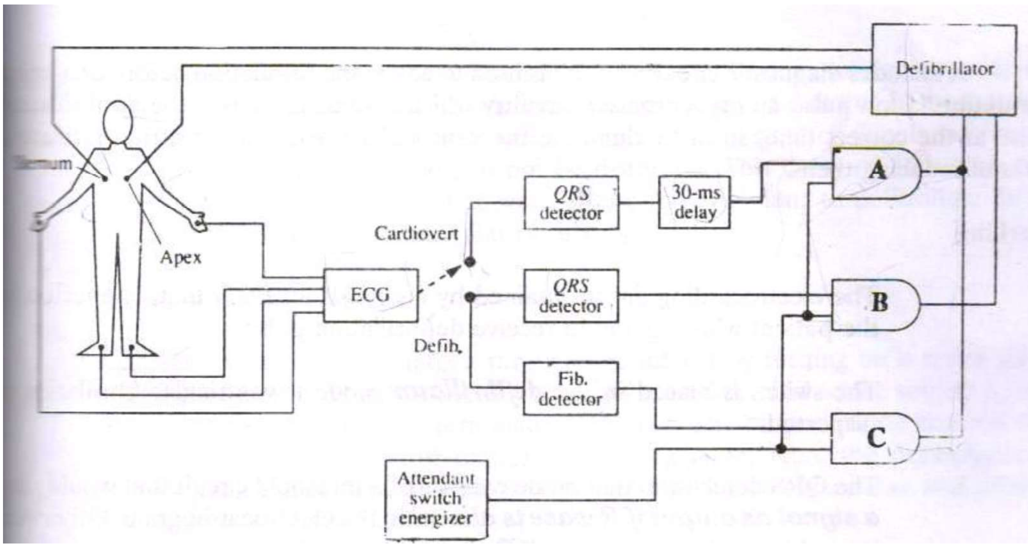


Fig3.3.5 : Modern d.c defibrillator circuit

4 Meanwhile the medical attendant energizes the switch to deliver the defibrillation pulse.

5 AND gate 'B' delivers signal to the defibrillator only when the R wave is absent, provided the signal from medical attendant is also present at one of the two inputs of AND gate 'B'.

6 If any one of the input is missing then it would not give any output. By this way defibrillator is inhibited and would not deliver the defibrillation pulse.

7 The fibrillation detector searches the ECG signal for frequency components above 150Hz. If they are present fibrillation is probable and detector gives an output signal. A defibrillator pulse is delivered only if the fibrillation detector produces an output at the same time that the attendant energizes the switch. This is provided by the AND gate 'C'.

8 When AND gate 'B 'and 'C' are simultaneously triggering the defibrillator the defibrillation pulse is delivered.

9 In cardioversion (or) synchronization mode the defibrillator is synchronized with ECG unit.Suppose a patient is suffered by atrial fibrillation the doctor first diagnose it correctly and then the treatment is initiated using this circuit.

10 The ECG signal is given to QRS detector Its output is delayed with 30ms. At this time the ventricles will be in uniform state of depolarization and the normal heart beat will not be disturbed. The delay of 30ms after the occurance of R wave allows the attendant to defibrillate atrium without inducing ventricular fibrillation.

3.3.6 Square wave defibrillator:

Here the capacitor is discharged through the subiect by turning on a series silicon controlled rectifier (SCR). When sufficient energy has been delivered to the subiect a shunt SCR short circuits the capacitor and terminates the pulse. The output can be contrilled by varying the voltage on capacitor or duration of discharge. Defibrillation is obtained at less peak current and so there is no side effect.

Analysis:

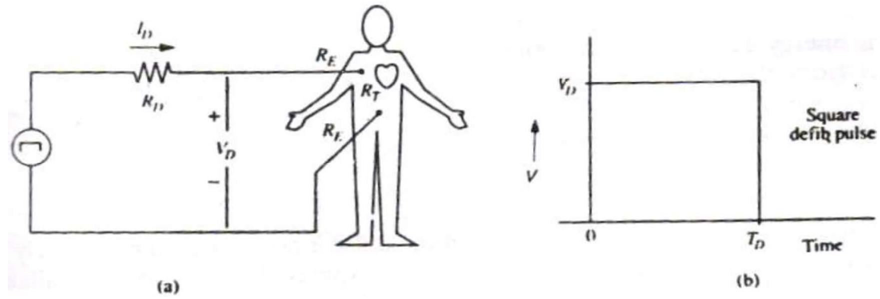


Fig3.3.6 : Equivalent circuit of square pulse defibrillator and its output waveform

In fig

R_D-Internal resistance of defibrillator

R_E-electrode skin resistance

R_T-Thorax resistance

The energy in the pulse

$$E_P = V_D I_D T_D$$

Where $V_D I_D$-Instantaneous voltage and current available from defibrillator pulse

T_D-Duration of pulse

Total circuit resistance

$$R=R_D+2R_E+R_T$$

Energy in the pulse can also be written in terms of voltage and resistance between the cable attached to patient such that

$$E_P=I_D^2 (2R_E+R_T)T_D$$

Energy loss in defibrillator

$$E_{DL} = I_D^2 R_D T_D$$

Energy loss in each electrode and skin

$$E_{EL} = I_D^2 R_D T_D$$

Energy delivered to thorax

$$E_T = I_D^2 R_D T_D$$

The energy delivered to the thorax can be expressed in the form of available energy from capacitor discharge whose output is assumed to be a square pulse.

Energy available from the capacitor

$$EC = E_T + 2\,E_{EL} + E_{DL}$$

Thus E_T is dismissed from available due to effects of R_D and R_E

3.3.7 Double Square Pulse Defibrillator:

It is used normally after the open heart surgery. Conventional A.C and D.C defibrillators are producing myocardial injury during the delivery of shock.

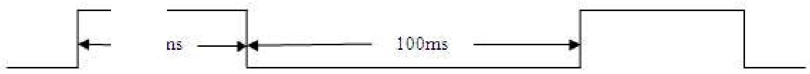


Fig3.3.7 : Double Square Pulse Defibrillator waveform

If the chest is opened only lower energy electrics shock should be given. Instead of 800-1500V in D.C defibrillators here 8-60V double pulse is applied with a mean energy of 2.4 watt-sec. When the first pulse is delivered some of fibrillating cells will be excitable and will be depolarized. Also cells which are refractory will continue to fibrillate. To obtain total defibrillation second pulse operates on this latter group of cells. The pulse amplitude and width together with interval should be such that the cells defibrillated by first pulse will be refractory to second pulse. The timing of second pulse should be such that those cells which were refractory to the first pulse are now excitable. Hus complete defibrillation can be obtained by means of selecting proper pulse space ratio.

Advantages:

- Using double square pulse defibrillator efficient and quick recovery of heart to beat in normal manner without side effect like burning of myocardium or inducement of atrial or ventricular fibrillation.
- The double square pulse with required pulse space ratio can be produced with the use of digital circuits.

3.3.8 Biphasic D.C defibrillator:

It is similar to double square pulse defibrillator such that it delivers D.C pulses alternatively in opposite direction. This type of waveform is found to be more efficient for defibrillation of ventricular muscles.

3.4 HEART LUNG MACHINE

3.4.1 Introduction

At the time of open heart surgery it is necessary to use the artificial heart lung machine. Because the doctor has to do the surgery in the heart. Hence the heart cannot maintain the circulation.it is necessary to provide extra corporeal circulation with a special machine called heart lung machine.

This heart lung machine can do all the operations similar to heart(pumping operation) and lungs(oxygenation operation). This machine is used to maintain the blood circulation throughout the body at the time of surgery.

3.4.2 CARDIOVASCULAR CIRCULATION

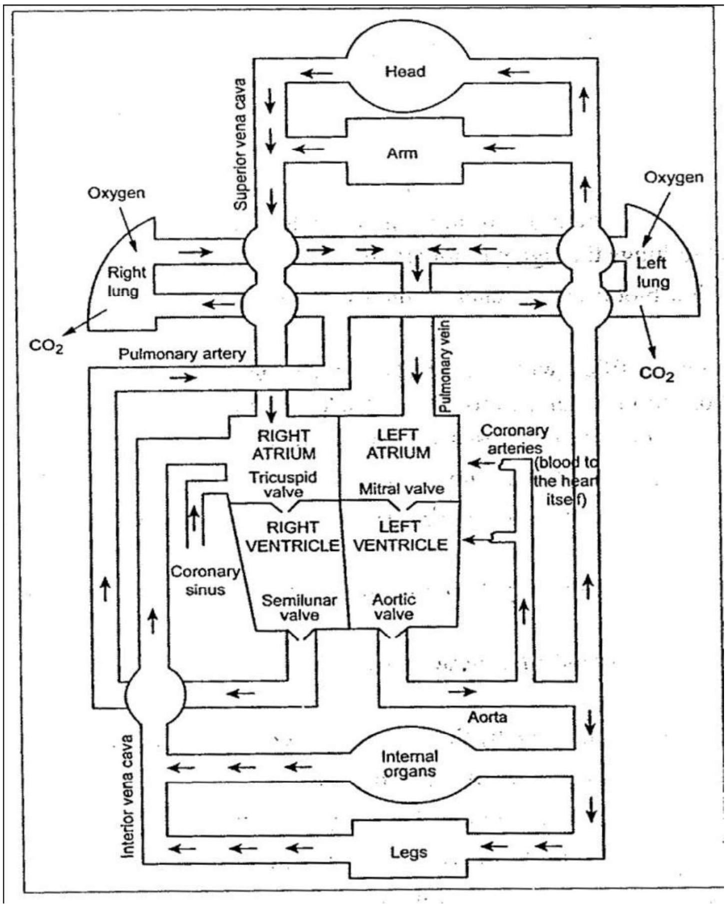


Fig :3.4.2 Cardiovascular Circulation

The circulatory path for blood flow through the lungs is known as pulmonary circulation. the circulatory path which supplies oxygen to the cell of the body is known as systemic circulation. heart is used to do the pumping action. It pumps the blood throughout the body. This pumping action is done by contraction of heart muscles that are surround the four champers of heart. These muscles receive the blood from coronary arteries. This coronary arterial system is a branch of systemic circulation. Blood enter in to the right atrium using inferior vena cava and superior vena cava.

inferior vena cava collects the blood from organs of the body and from the lungs. superior vena cava collects the blood from head, arms etc.

Coronary sinus collects the blood which is circulated in the heart and it is given to right atrium. If right atrium is filled with the blood then contraction is occur. so the blood is pumped to right ventricle using tricuspid valve.

When right ventricle pressure exceeds right atrial pressure than tricuspid valve is closed. But due to the pressure in right ventricle semilunar valve is opened. So blood is pumped to lungs through pulmonary artery.

In lungs this blood is oxygenated then it is given to left atrium through pulmonary vein. If left atrium is filled with the pure blood then mitral valve is opened. So blood is pumped to left ventricle. When left ventricle is filled then mitral valve is closed due to high pressure in left ventricle and low pressure in the left atrium.

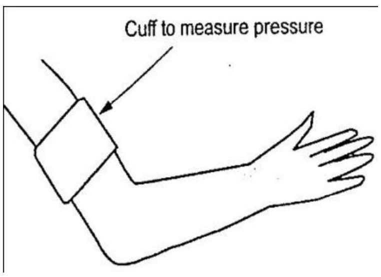
When left ventricle is filled with the blood then aortic valve is opened and blood is pumped to various parts of the body like head , arms, legs,and various interval organs and pulmonary arteries.

Based on the pumping action of the heart pumping cycle is divided in to two parts namely systole and diastole.

Systole: It is the period of contraction of the heart muscles. Here the contraction of ventricles.

Diastole: It is time taken by the heart chambers to fill the blood.

Generally heart pumps 5 litre of blood per minute. Systole pressure is 95 to 140 mm of Hg for normal adults(average=120mm of Hg). Diastole pressure is 60 to 90 mm of Hg for normal adults(average=80mm of Hg). Usually pressure is measured in brachial artery in the arm.



Systole/ diastole pressure in some parts are given below
130/75 mm of Hg in aorta
130/5 mm of Hg in left ventricle
9/5 mm of Hg in left atrium
25/0 mm of Hg in right ventricle
3/0 mm of Hg in right atrium
25/12 mm of Hg in pulmonary artery

3.4.3 Hearty Lung Machine –A model

Cardio vascular circulation is maintained externally by using this machine. In this machine oxygenator is used to do the function of the lungs. Blood pump is used to do the operation of the heart.

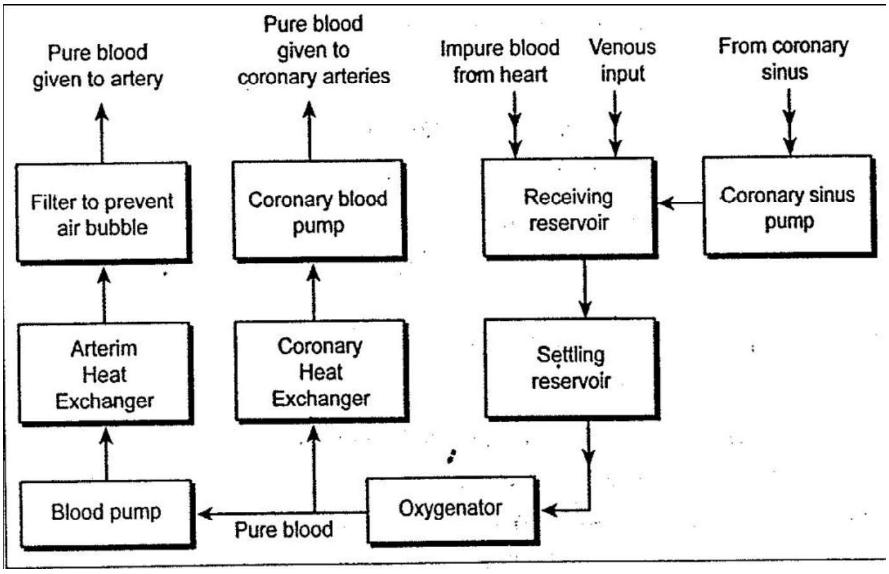


Fig:3.4.3 Hearty Lung Machine –A model

Working

Blood is received from the heart by using suction device and it is to receiving reservoir. Blood is received from the vein separately and it is stored in the receiving reservoir. During surgery the accumulated blood is received by the receiving reservoir through coronary sinus pump.

The blood from receiving reservoir is give to settling reservoir. The other name is debubbling reservoir. Then the blood is given to oxygenator .

Oxygenator is used to oxygenate the blood. The blood is purified by the oxygenator. The blood from the oxygenator is given to the arterial heat exchanger through arterial blood pump .

Usually the operation is conducted at low temperature due to the reduction of body metabolism and to increase the operation time. Brain damage is also avoided by doing operation at low temperature. Because brain is easily damaged by the insufficient oxygen content.

If the temperature is decreased by 1^0C then oxygen consumption is reduced by 7%. If the operation time is extended beyond certain limit then it leads to ventricular fibrillation and break down of RGB.

Heat Exchanger

The heat exchanger is maintain the body temperature at 37^0C. It is used to reduce the blood temperature in preparation for the surgery. After completing the operation blood is rewarmed(because the operation is conducted at low temperature). Heat exchanger is integrated with the oxygenator . The helical shape tube is used. In the helical tube the heat exchange fluid is circulated . So heat is exchanged. The output blood fro the arterial heat exchanger is given to the filter circuit.

Filter Block

Some times air bubbles may be introduced in the blood which is to be circulated. So filter is used to avoid such a air bubble. These air bubbles are avoided from the blood before reaching the blood circulation. The output of the filter circuit is given to artery. The output of coronary pump is given to coronary arteries. So systematic blood circulation is maintained by using this heart lung machine. Blood pump and oxygenator are given separately below.

3.4.4 Blood pumps

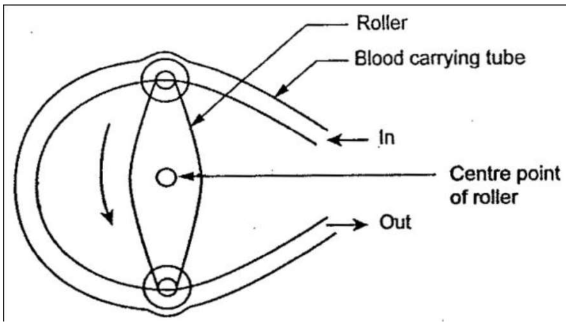
Two types

1.Pulsatile pump
2. non-pulsatile pump

Pulsatile pump:

There are two chambers inner and outer chamber. When the blood is injected inside the outer chamber then the inner chamber is compressed. So the blood is ejected out through the outflow valve. After completely ejecting the blood the inner chamber come to the normal shape. Then once again blood pump is filled blood. The same process is repeated.

Non-Pulsatile pump:



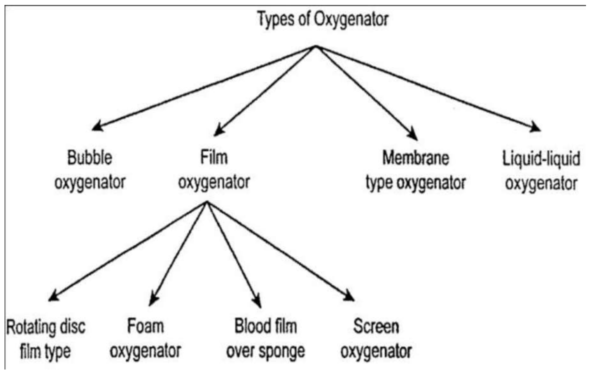
In this pump roller is used . By squeezing action the blood is pumped. Blood carrying tube is positioned with the roller arrangement. When the roller is moving blood in the tube is also moving forward. If the time extended then this pump may produce break down of the red blood cell.

Characteristics of an ideal blood pump

1. It should pump the blood at the rate of 6 litres/minute
2. Pumping action should not produce any damage to blood cells
3. The pump should be operated automaticaklly and manually
4. The calibration of the blood pump should be perfect
5. Blood pump must be cleaned easily

3.4.5 Oxygenators

It does the function of the lungs. The other name of oxygenator is artificial Lung. The oxygen is mixed with small percentage of CO_2(2-5%). Oxygenator should oxygenate 5litres of blood per minute. Priming volume is defined as the amount of blood required to fill the extra corporeal circuit. Various types of oxygenator are given below



(i)Bubble Oxygenator

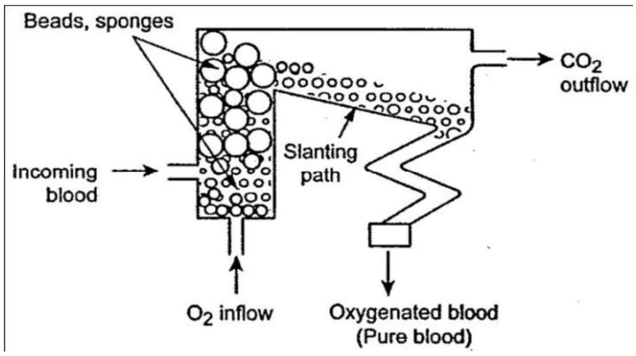


Fig:Bubble Oxygenator

Blood is given to the oxygenator for purification . Oxygen is entered in to the oxygenator. So blood is oxygenated . CO_2 is removed from the blood and removed through CO_2 outflow valva.

Oxygen is bubbled through the blood and blood flows through the slanting path. Beads , sponges, meshes are coated with antifoaming agent (e.g silicon) are used to remove bubbles from the blood. Surface tension of the bubbles is reduced by the silicon .

So bubbles are broken . In this way bubbles are avoided. Finally by using filter blood is taken out. This blood is purified blood.

(ii)Membrane Oxygenator

Blood enters in to the membrane oxygenator one end and the blood is taken out from the other end. Here CO_2 is coming out from the oxygenator. Oxygen is given to the oxygenator blood and oxygen are travelling in the opposite direction. So we can get oxygenation by this method. This type of oxygenator is made up of membrane. Travelling of the oxygen is limited by the thickness of the blood layer.

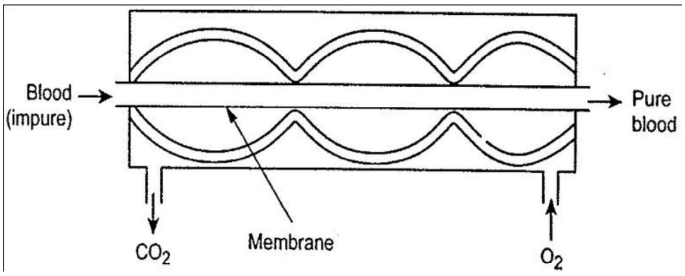


Fig:Membrane Oxygenator

(iii)Liquid-Liquid Oxygenator

Blood and liquid with dissolved oxygen are travelling in the opposite direction. So blood is oxygenated and carbon– dioxide is removed from the blood and sent out. With in the small tube blood and liquid are flowing oppositely. So gaseous exchange takes place. Carbon-dioxide is removed from the blood and oxygen is transferred to the blood.

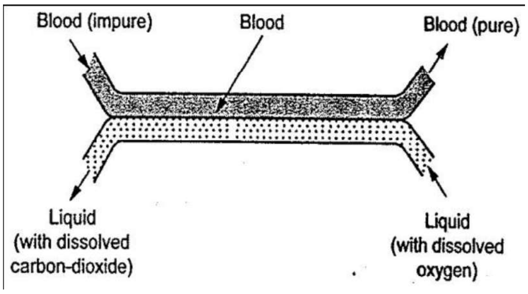


Fig: Liquid-Liquid Oxygenator

(iv)Film oxygenator **:** There are four types

(i)Rotating disc type

It is the shape of horizontal cyclinder. Various rotating discs are fixed in this cyclinder. The horizontal cyclinder is rotated at the speed of 120 rpm. The blood is at the lower level. Thin flim of blood is spread in the rotating disc. Then oxygen is given to the oxygenator. Blood is washed off from the disc and sent out. Then new film is formed and washed off. This procedure is repeated continuously.

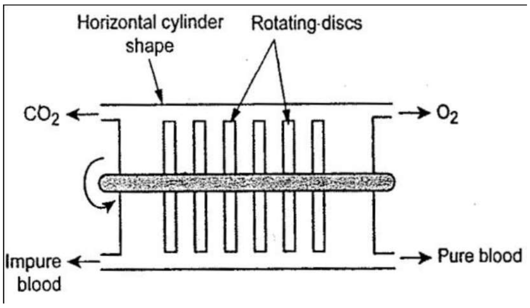


Fig: Rotating disc type

(ii) Foam oxygenator

Blood is poured over the top of the blood foam. The oxygen mioxture is bubbled through the blood in the opposite direction. The blood spreads over the surface of the bubble in a thin film form and effectively it is exposed to oxygen. Then the blood is oxygenated while falling down. Deforming will be done after oxygenation.

(iii) Screen oxygenator

A thin film of blood over a screen is exposed to oxygen for oxygenation. This causes fewer traumas to blood. Disposable units are also available in this type.

(iv) Blood film over sponge type oxygenator

A small volume of sponges saturated with blood provides a large surface area for blood oxygenation if oxygen is simultaneously distributed in the spoge. It is called artificial alveoli.

Advatages and disadvantages of various oxygenators

Name of the oxygenator	Advantages	Disadvantages
Bubble Type	Effective method Simple	Long penetration time Expensive
Membrane type	Possibility of bubble formation is less	Very expensive Difficult to clean
Liquid-Liquid type	Effective method	No trauma is produced
Rotating disc film type	Effective method	Difficult to clean Less trauma produced

3.5 DIALYSER

Dialysis is a process by which the waste products in the blood are removed and restoration of normal P^H value of the blood is obtained by an artificial Kidney machine . It consists of 3 important process

- Diffusion
- Osmosis
- Ultra filtration

Two methods are used to perform dialysis

1.Extra corporeal dialysis(Haemodialysis)

2.Intra corporeal dialysis(Peritoneal cavity dialysis)

3.5.1.EXTRA CORPOREAL DIALYSIS(HAEMODIALYSIS)

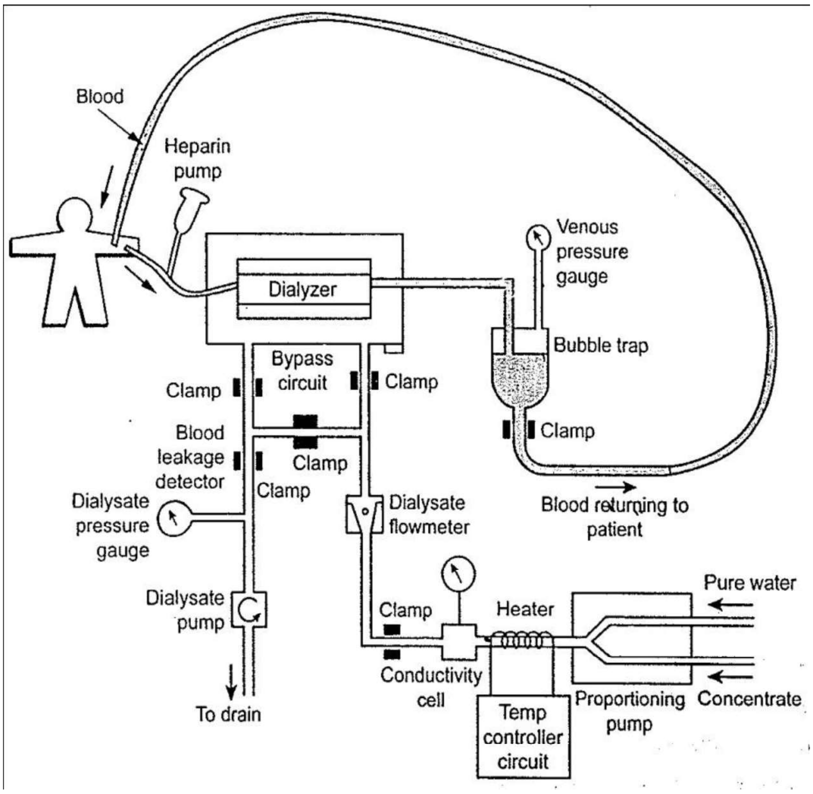


Fig 3.5.1Extra Corporeal Dialysis(Haemodialysis)

Proportioning Pump

It is used to mix the pure water with dialysate. Usually 34:1 ratio of water and concentrate is maintained. The output of the Proportioning pump is given to heater circuit.

There are two types of Proportioning system available

(i)fixed ratio type: In this type fixed ratio is maintained. Generally it is 34:1
(ii)Variable ratio type: In this type variation of ± 5% on the standard ratio 34:1 is possible

Dialysate Temperature control

The dialysis is normally done at specific temperature. The temperature of the dialysate should be monitored and controlled by using temperature control circuit before it is ngiven to the dialyzer. If the temperature exceed 40^0C then the components of blood are damaged. So safety valve is used to turn off the heater if the temperature exceeds 43^0C. In the modern microprocessor based haemodialysis machine temperature control circuit is given to CPU. Temperature of dialysate is displayed.

Conductivity Measurement

The conductivity of the dialysate is continuously monitored by using conducting cell. It is used to verify the accuracy of Proportioning. The result is displayed as a percentage deviation from the standard reading.

Dialysate flow meter

The normal flow rate is 500 ml/minute. It is fixed in the downstream of the dialyzer. If there is any blood leakage occur then it is observed by change of colour in the fluid.

Dialysate pressure control

The dialysate pressure is indicated in the pressure gauge meter. The effective pressure across the membrane is equal to the algebric sum of the dialysate pressure and venous pressuer. If the pressure exceeds certain limit then the effluent pump which creates the negative pressure is switched off automatically and dialysate solution is by passed to the drain.

Blood leakage detector

If there is any blood leakage occur across the dialyzer membrane then it is detected by photo electric transducer. In normal operation blood leakage is 25mg of hemoglobin/litre. If blood leakage is detected then the dialysate is by passed to the drain.

Bubble Trap

Air embolism is serious hazard in dialysis. Now ultra sound method is used for detecting the presence of air in the blood line.

Heparin pump

It is used to deliver heparin from the pump to the blood line.

Ultra filtration circuit

It is used to monitor the amount of fluid removed from the patient

Ultra filteration circuit=total fluid removed in litres/Treatment time in hours.

Dialyzer

Dialyzer is very important part in the artificial kidney. It consists of two circuits one circuit blood is circulated and in another circuit dialysate solution is circulated .Three types of dialyzers can be used.

These are parallel plate dialyzer, coil dialyzer, hollow fiber type of dialyzer. The rate of clearance of waste products from the blood depend upon the rate of blood flow.

The dialyzing surface area of parallel flow dialyzer is 1 square meter. The rate of blood flow is 200ml/minute. The rate of dialysate flow is 500 ml/minute. The rate of clearance of waste product is 64 ml/minute.

The membrane used in the dialyzer is used for ultrafiltration. The dialyzer is not a disposable part. It should be cleaned and reuse.

3.5.2INTRA CORPOREAL DIALYSIS(PERITONEAL CAVITY DIALYSIS)

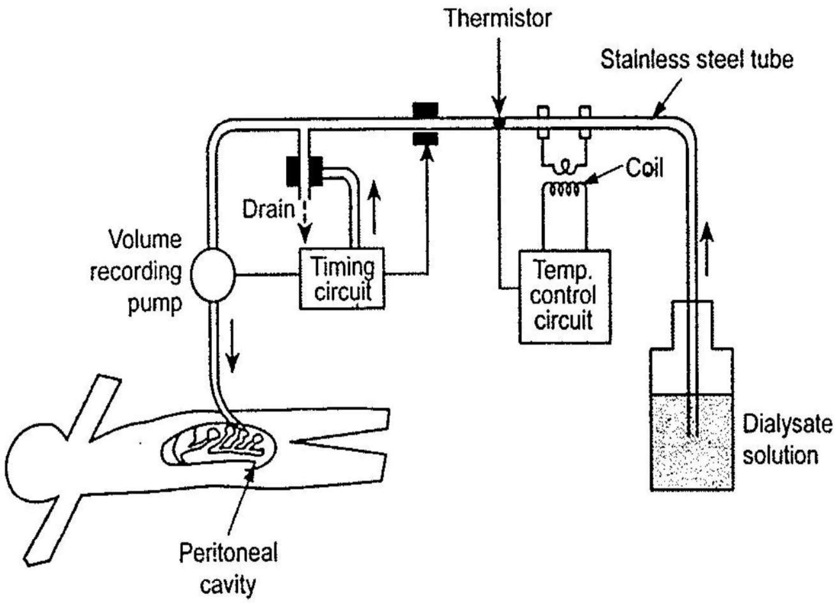


fig3.5.2:intra Corporeal Dialysis(Peritoneal Cavity Dialysis)

In this technique peritoneal cavity in the abdomen is used as semipermeable membrane. Acatheter is inserted in the abdomen. Dialysate solution of 1.5-2 litres is allowed to flow in to the peritoneal cavity . Then diffusion takes place for 30 minutes.

Then the dialysate solution is removed from the cavity. These same procedure is repeated for 20 to 30 times. Finally all waste substances are removed from the blood.

Temperature control circuit is used to maintain the temperature of dialysate solution at 37^0C. In this control circuit thermistor is used.

Here timing circuit is used to monitor the volume of the dialysate solution. If 2 litres of solution is allowed then the circuit deliver the signal to stop the dioalysat6e flow in to the peritoneal cavity.

At the same time timing circuit is used to monitor the diffusion time also. After 30 minutes of diffusion time the timing circuit deliver a signal to stop the diffusion process.

Then the dialysate solution is removed from the abdomen using suction pump. After that the fresh dialysate solution is allowed to enter in to the peritoneal cavity.

If the volume of dialysate solution sucked from the peritoneal cavity is l;ess than 2litres then the alarm circuit is operated. If alarm is operated tyhen sudden action should be taken to take care of the patient.

Difference between Extra corporeal dialysis & Intra corporeal dialysis

Extracorporeal dialysis(Haemodialysis)	Intra corporeal dialysis(Peritoneal cavity dialysis)
Blood is purified by an artificial kidney machine in which blood is taken out from the body and waste products diffuse through a semipermeable membrane which is continuously rised by a dialysing solution	The Peritoneal cavity in our body is used as semipermeable membrane and by passing the dialysate in to it waste products are removed from the blood by diffusion
More effective for seperating the waste products	Less effective
Complex and risk because blood is taken out from the body.	Simple and risk free
Dialysing time is about 3 to 6 hours	Dialysing time is about 9 to 12 hours

TWO MARKS

1 Give two important factors that demand internal pace maker's usage.

The two important factors that demand internal pace maker's usage are

(i). Type and nature of the electrode used

(ii). Nature of the cardiac problems.

(iii). Mode of operation of the pacemaker system.

2) Classify Pacing modes

Based on the modes of operation of the pacemakers, they can be classified into five types. They are:

i) Ventricular asynchronous pacemaker(fixed rate pacemaker)

ii) Ventricular synchronous pacemaker.