ADVANCED BIO MEDICAL INSTRUMENTATION

LECTURE 3: ASSISTIVE DEVICES, CARDIAC SYSTEM AND MONITORS

CARDIAC PACEMAKERS

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. 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. A heartbeat that's too fast is called tachycardia. A heartbeat that's too slow is called bradycardia.

A pacemaker can relieve some arrhythmia symptoms, such as fatigue and fainting. A pacemaker also can help a person who has abnormal heart rhythms resume a more active lifestyle.

A Pacemaker basically consists of two parts

(i) An electronic unit which generates stimulating impulses of controlled rate and amplitude- pulse generator

(ii) The lead which carries the electrical pulses from the pulse generator to the heart.

Pacemakers use low-energy electrical pulses to overcome this faulty electrical signaling. Pacemakers can:

- Speed up a slow heart rhythm.
- Help control an abnormal or fast heart rhythm.
- Make sure the ventricles contract normally if the atria are quivering instead of beating with a normal rhythm (a condition called atrial fibrillation).
- Coordinate electrical signaling between the upper and lower chambers of the heart.
- Coordinate electrical signaling between the ventricles. Pacemakers that do this are called cardiac resynchronization therapy (CRT) devices. CRT devices are used to treat heart failure.
- Prevent dangerous arrhythmias caused by a disorder called long QT syndrome.

Pacemakers also can monitor and record your heart's electrical activity and heart rhythm Pacemakers can be temporary or permanent. Temporary pacemakers are used to treat short-term heart problems, such as a slow heartbeat that's caused by a heart attack, heart surgery, or an overdose of medicine. Temporary pacemakers also are used during emergencies. They might be used until your doctor can implant a permanent pacemaker or until a temporary condition goes away. Permanent pacemakers are used to control long-term heart rhythm problems.

Types of Pacemakers

(i) External Pacemakers

The external pacemaker is a device that uses electrical impulses to stimulate the heartbeat of patients with conditions such as an abnormally slow heart rhythm. It is a small device worn outside of the body that delivers electric current impulses via a lead taped to the chest. This type

of pacemaker is used on a temporary basis until the heart rate returns to normal or a permanent device can be inserted.

The device operates by delivering an electrical impulse to the patient's heart muscles. These impulses stimulate the muscles to contract, thereby normalizing the heartbeat. The most common use of external pacemakers is as an emergency measure to restore and regulate abnormal heart rhythms.

An external pacemaker can apply upto 80 mA pulses through 50 cm^2. The pulses may be delivered

a) Continuously- when the heart rate goes below a preset value.
b) On demand R wave- when R-R interval between two beats exceeds the preset value. Normally used to support an implanted unit.

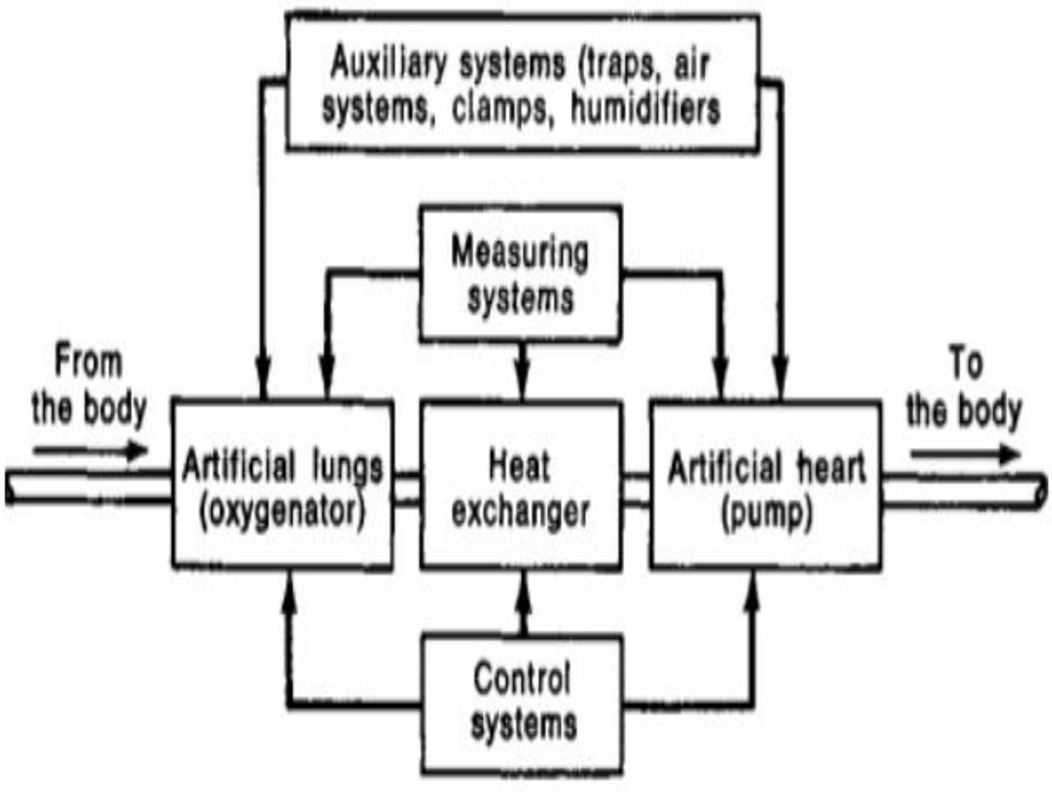
(ii)Implantable pacemakers

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. The pacemaker consists of two parts. The leads are wires with electrodes at the tip that transmit electrical signals to the heart muscle from the pulse generator. These electrical signals cause the heart muscle to contract (pump). The pulse generator (often referred to as the pacemaker) is a small unit with a computer that generates the electrical signal.

Commonly used types are – fixed rate, demand type, R wave triggered pacemaker.

HEART LUNG MACHINE

A device used in open heart surgery to support the body during the surgical procedure while the heart is stopped. The heart-lung machine is often referred to as the "pump", and does the work of the heart and lungs during the operation. 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 CO_2 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.



DIFFERENT TYPES OF OXYGENATORS

An oxygenator is a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures.

There are two main types of oxygenator.

Bubble oxygenators expose the passing blood to a stream of gaseous bubbles composed of 95% oxygen and 5% carbon dioxide. Gas exchange with the blood occurs on the surface of the bubbles and results in reasonably normal levels of oxygenation of the blood and maintains carbon dioxide in the normal physiological range. The bubble oxygenator has a sponge-like filter and reservoir to enable gaseous bubbles to be removed from the oxygenated blood before it is pumped back to the body.

Membrane oxygenators consist of a series of fine tubes which allow diffusion of oxygen and carbon dioxide between the blood flowing through them and the ventilating gas surrounding them (or vice versa).

Other types are foam, film, liquid-liquid oxygenators.

PUMPS

These pump blood at the rate of 6 l/min. There are 2 types of pumps.

Roller pump

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.

Centrifugal pump

Blood flow is produced by centrifugal force by altering the speed of revolution. 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

MONITORING PROCESS

Heat exchangers allow body and organ temperatures to be adjusted. Other fluids such as blood products and medications are also added into the reservoir for filtration of particulate. It is necessary to monitor the patient's blood chemical makeup. Chemical sensors placed in the blood path are able to detect the amount of oxygen bound to hemoglobin. Other, more elaborate sensors can constantly trend the blood pH, partial pressure of oxygen and carbon dioxide, and electrolytes. This constant trending can quickly analyze the metabolic demands of the body. Sensors that communicate system pressures are also a necessity. These transducers are placed in areas where pressure is high, after the pump. Constant scanning of all components and monitoring devices is required. Normal values can quickly change due to device failure or sudden mechanical constrictions.

HEMODIALYSER

It is a machine that uses dialysis to remove impurities and waste products from the bloodstream before returning the blood to the patient's body

PRINCIPLE OF HEMODIALYSER

In hemodialysis, the machine filters wastes, salts and fluid from the blood when the kidneys are no longer healthy enough to do this work adequately.

The principle of hemodialysis involves diffusion of solutes across a semipermeable membrane. Hemodialysis uses counter current flow, where the dialysate is flowing in the opposite direction to blood flow in the extracorporeal circuit. Counter-current flow maintains the concentration gradient across the membrane at a maximum and increases the efficiency of the dialysis. Fluid removal (ultrafiltration) is achieved by altering the hydrostatic pressure of the dialysate compartment, causing free water and some dissolved solutes to move across the membrane along a created pressure gradient.

The dialysis solution that is used is a sterilized solution of mineral ions. Urea and other waste products, potassium, and phosphate diffuse into the dialysis solution.

MEMBRANES

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.

Cupraphan is the most commonly used membrane. It is made up of natural cellulose and is puncture proof and highly elastic. It is a moisture sensitive cellulose hydrate membrane whose function depends on the water content. The number of fibers will be as high as 16000.

DIALYSATE

The fluid and solutes in a dialysis process that simply flow through the dialyzer and do not pass through the semipermeable membrane, being discarded along with removed toxic substances after they flow back out of the dialyzer.

Dialyzer

The dialyser filters the blood. Commonly used one is the hollow-fiber. A cylindrical bundle of hollow fibers, whose walls are composed of semi-permeable membrane, is anchored at each end into potting compound . This assembly is then put into a clear plastic cylindrical shell with four openings. One opening or blood port at each end of the cylinder communicates with each end of the bundle of hollow fibers. This forms the "blood compartment" of the dialyzer. Two other ports are cut into the side of the cylinder. These communicate with the space around the hollow fibers, the "dialysate compartment." Blood is pumped via the blood ports through this bundle of very thin capillary-like tubes, and the dialysate is pumped through the space surrounding the fibers. Pressure gradients are applied when necessary to move fluid from the blood to the dialysate compartment.

DIFFERENT TYPES OF HEMODIALYSER

WEARABLE ARTIFICIAL KIDNEY

The Wearable Artificial Kidney (WAK, looks like a disassembled traditional dialysis machine whose parts have been fit into to a large belt for carrying around the torso. Few modifications have been done from the regular dialysis machine. It is battery powered,(12 V Ni Cd battery) but more importantly the device doesn't require an external source of pure water, instead continuously filtering the water that was used and reintroducing it back into the device. The entire package weighs about 4.5kgs. It uses a 20 L dialysate tank.

IMPLANTABLE TYPE

UCSF researchers today unveiled a prototype model of the first implantable artificial kidney, known as the implantable renal assist device (iRAD), in a development that one day could eliminate the need for dialysis.

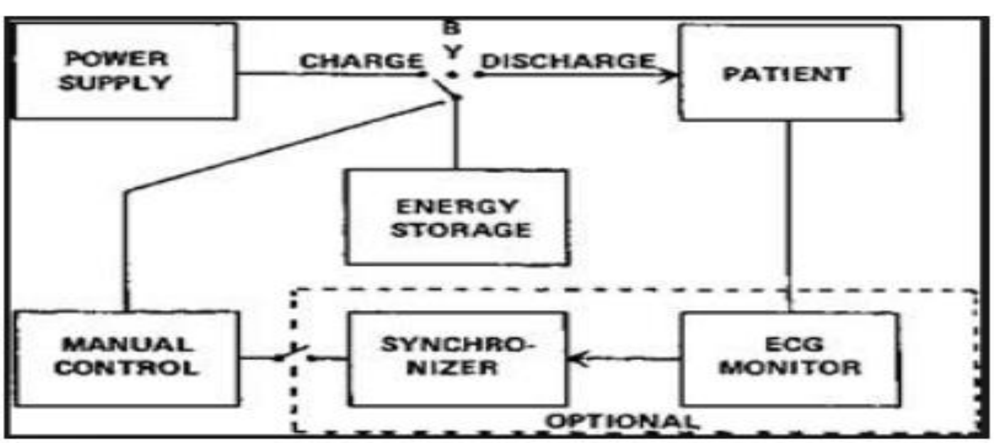
The device, which would include thousands of microscopic filters as well as a bioreactor to mimic the metabolic and water-balancing roles of a real kidney, is being developed in a collaborative effort by engineers, biologists and physicians nationwide,. Research still on.

DEFIBRILLATORS

Defibrillation is a procedure used to treat life threatening conditions that affect the rhythm of the heart such as cardiac arrhythmia, ventricular fibrillation and pulse less ventricular tachycardia.

The procedure involves the delivery of an electric shock to the heart which causes depolarisation of the heart muscles and re-establishes normal conduction of the heart's electrical impulse. The machine used to deliver this therapeutic shock to the heart is called a defibrillator.

Most defibrillators are energy-based, meaning that the devices charge a capacitor to a selected voltage and then deliver a prespecified amount of energy in joules. The connection between the defibrillator and the patient consists of a pair of electrodes, each provided with electrically conductive gel in order to ensure a good connection and to minimize electrical resistance. The paddle electrodes are places at the sternum and apex of the person.



The different types of defibrillators used include external defibrillators, transvenous defibrillators and implanted defibrillators.

IMPLANTABLE DEFIBRILLATORS

These devices are implants, similar to pacemakers. They constantly monitor the patient's heart rhythm, and automatically administer shocks for various life-threatening arrhythmias, according to the device's programming. If the AICD senses that the rhythm is abnormal, it will deliver an "internal" shock(s) to the heart to correct the problem. The unit then resets itself. The AICD is a pulse generator about the size and shape of a deck of cards and weighs about 350 grams. The pulse generator is placed in the abdomen just underneath the skin and is connected to the heart by leads. The lead system sends electrical signals from the heart to the pulse generator, which continuously monitors the heart rhythm. The shock duration is 4-8ms and 4-5 high energy shocks are given at a time. Batteries used are Lithium Silver Vanadium oxide batteries. Programmable recorder monitor acts like a telemetry system.

FUNCTIONAL ELECTRICAL SIMULATOR (FES)

Functional electrical stimulation (FES) delivers a shock to the survivor's muscle. The shock activates nerves and makes the muscle move. FES is commonly used for exercise, but also to assist with breathing, grasping, transferring, standing and walking. FES can help some to improve bladder and bowel function.

Spinal cord Injury

Injuries to the spinal cord interfere with electrical signals between the brain and the muscles, resulting in paralysis below the level of injury. Restoration of limb function as well as regulation of organ function are the main application of FES, although FES is also used for treatment of pain, pressure, sore prevention, etc.

Stroke

FES is commonly used in foot drop neuroprosthetic devices.

In the acute stage of stroke recovery, the use of cyclic electrical stimulation has been seen to increase the isometric strength of wrist extensors.