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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I – DIAGNOSTIC INSTRUMENTATION – SBM1301

BIOMEDICAL RECORDERS

1.1 Basic Measurement system

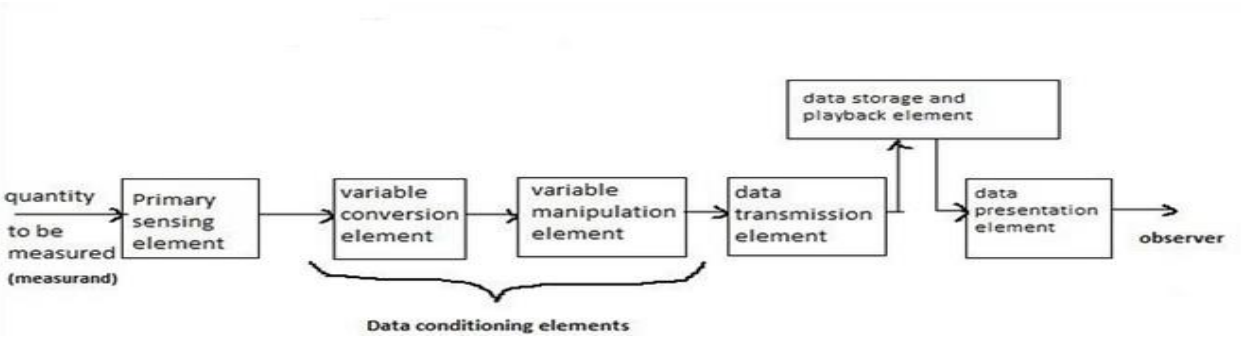


Fig 1.1: Measurement system

A measurement system is used to quantify the physical variables. Generalized measurement system is a system that is comprised of the typical elements of a measurement system. It helps to understand how a measurement system works.

A generalized measurement system consists of the following components:

1.Primary Sensing Element

2.Variable Conversion Element

3.Variable Manipulation Element

4.Data Processing Element

5.Data Transmission System

6.Data Presentation Element

1. Primary Sensing Element

The Element (Part) of an instrument which makes first contact with the measurand is called the primary sensing element. The primary sensing element receives signal of the physical quantity to be measured as input. It converts the signal to a suitable form (electrical, mechanical or other form), so that it becomes easier for other elements of the measurement system, to either convert or manipulate it.

2. Variable conversion Element

The output of the Primary sensing element may not be suitable for the actual measurement system. Variable conversion element converts the output of the primary sensing element to a more suitable form. It is used only if necessary.

3. Variable Manipulation Element

The level of the output from the Variable conversion element may not be enough for the next stage. This element manipulates and amplifies the output of the variable conversion element. It also removes noise (if present) in the signal.The Variable conversion element and the variable manipulation element are together called as Data conditioning element since they help to obtain the signal in pure and acceptable form from highly distorted form.

4. Data Transmission Element

If the elements of the system are physically separated, it is necessary to transmit the data from one stage to the other. It processes the data signal received from the variable manipulation element and produces suitable output. Data processing element may also be used to compare the measured value with a standard value to produce required output.

The data conditioning and the Data transmission are together called as the intermediate stage of an Instrument.

5. Data Transmission System:

Data Transmission System is simply used for transmitting data from one element to another. It acts as a communication link between different elements of the measurement system. Some of the data transmission elements used are cables, wireless antennae, transducers, telemetry systems etc.

6. Data Presentation Element:

It is used to present the measured physical quantity in a human readable form to the observer. It receives processed signal from data processing element and presents the data in a human readable form. LED displays are most commonly used as data presentation elements in many measurement systems.

7. Data storage Element:

A measurement system may also have a data storage element to store measured data for future use.

1.2 Electrocardiography/ ECG

The electrocardiogram (ECG) is the recording on the body surface of the electrical activity generated by heart.

It was originally observed by Waller in 1889.

Potentials originated at individual fibers of heart muscles are added to produce waveform.

The ECG gives the rhythmic depolarization and repolarisation of the heart muscles associated with contraction and relaxation of atria and ventricles.

Any diseased condition is recognized by the shape, time interval and amplitude of the ECG.

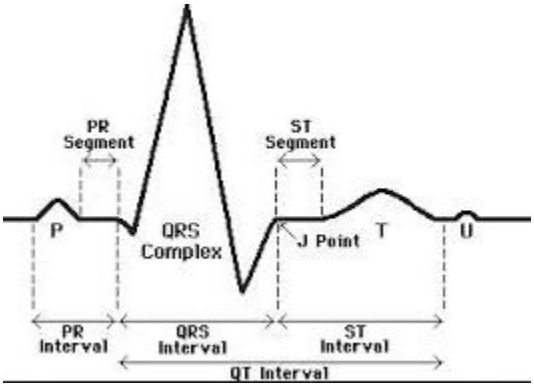


Fig 1.2: PQRS waveform

Table 1.1 Wave form generation

Wave	Origin	Amplitude(mV)	Duration(sec)
P	Atrial contraction or depolarization	0.25	0.12-0.20
R(QRS complex)	Repolarisation of atia and depolarization of ventricles	1.60	0.07-0.1
T	Ventricular repolarisation(relaxation of myocardium)	0.1-0.5	0.05-0.15

1.2.1 Lead configuration

Electrical activity going through the heart can be measured by external (skin)electrodes. The electrocardiogram (ECG) registers these activities from electrodes which have been attached onto different places on the body.

Standard electrode positions are required for recording ECG.

There are three types of electrode systems-

1. Bipolar limb leads/ standard lead system
2. Augmented unipolar limb leads
3. Precordial leads/chest leads

Bipolar limb leads

In bipolar, ECG is recorded with two electrodes, Positive and negative. The Positive looks toward negative.

The final output is the potential difference between the two electrodes kept at different positions of the body.

Table 1.2 – Bipolar Leads

Lead I	Right Arm (RA)	Left Arm (LA)
Lead II	Right Arm (RA)	Left Leg (LL)
Lead III	Left Arm (LA)	Left Leg (LL)

Right leg (RL) is used as the reference electrode.

These three bipolar limb leads roughly form an equilateral triangle (with the heart at the center) that is called Einthoven's triangle.

Einthoven postulated that at any given instant of the cardiac cycle, the frontal plane representation of the electrical axis is a 2D vector.

Also assumed that heart is near the centre of an equilateral triangle,the apexes of which are the right and left shoulder and crotch.

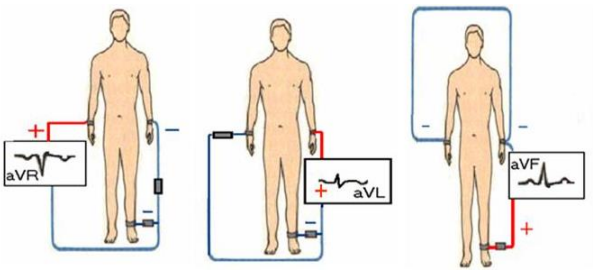


Fig 1.3: Bipolar lead configuration

Lead II produces greatest R wave amplitude and is commonly used.

Augmented unipolar leads

It was introduced by Wilson in 1944.

ECG is recorded between single measuring electrode and a central reference electrode.

It is termed Unipolar leads because there is a single positive electrode that is referenced against a combination of the other limb electrodes.

The positive electrodes for these augmented leads are located on the left arm (aVL), the right arm (aVR), and the left leg (aVF).

Two equal and large resistors are connected to a pair of limb electrodes and the centre of this resistive network acts as central terminal and remaining limb electrode acts as the exploratory electrode.

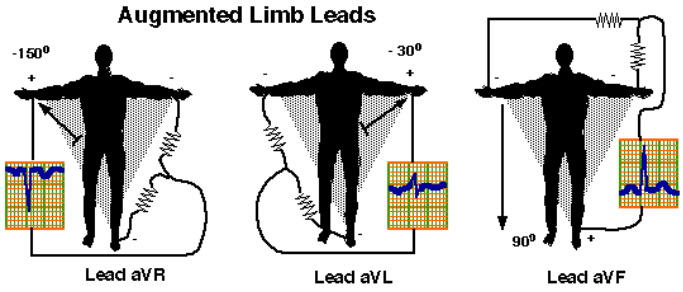


Fig 1.4: Unipolar lead configuration

Unipolar chest leads/12 lead system

In addition to the three standard limb leads and the three augmented limb leads that view the electrical activity of the heart from the frontal plane, there are six precordial, unipolar chest leads. This configuration places six positive electrodes on the surface of the chest over different

regions of the heart in order to record electrical activity in a plane perpendicular to the frontal plane (see figure at right). These six leads are named V1 - V6.

The chest leads provide a different view of the electrical activity within the heart. Therefore, the waveform recorded is different for each lead compared to the limb leads. These leads measure electrical activity in the traverse plane instead of the frontal plane. Similar to the unipolar limb leads, a neutral reference lead is created, this time using all 3 limb leads connected to the negative ECG lead, which basically puts it in the center of the chest. These chest leads are also known as the precordial leads.

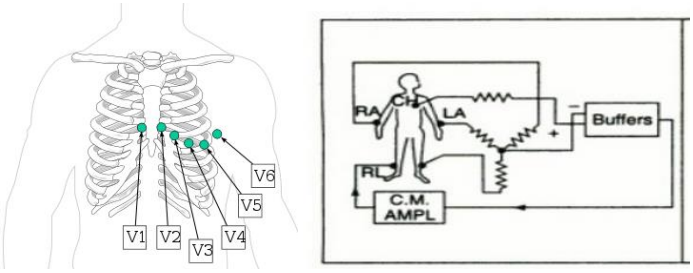


Fig 1.5: Chest lead configuration

1.2.2 Instrumentation set-up

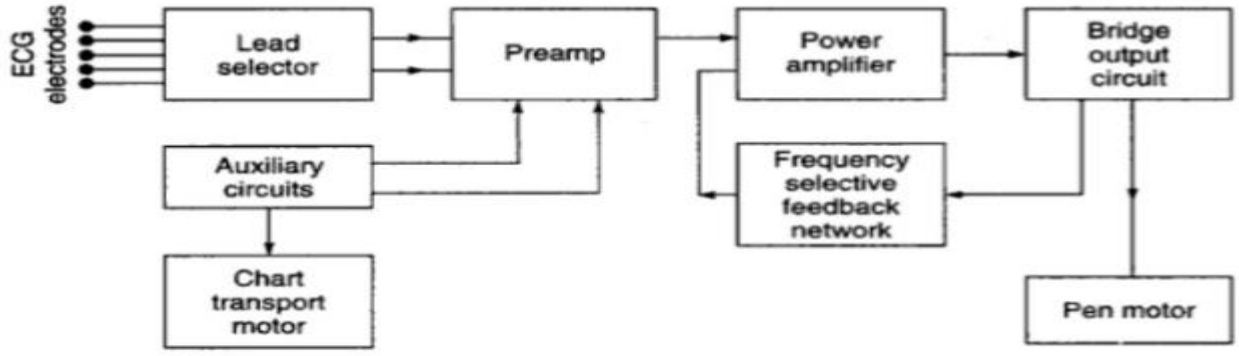


Fig 1.6 ECG block diagram

The ECG signals are characterized by high source impedances, very small signal voltage, significant interference and noise, and a modest frequency range.

Patient cables originating from patient electrdes plug into the ECG recorder.

Lead selector switch is used to feed the input voltage from the appropriate electrode to the preamplifier.

The calibrator is a push button which has a standardization voltage of 1mV.

From lead selector, the ECG signals goes to the preamplifier,a differential amplifier with high CMRR, high gain factor, high input impedance and low output impedance.

A pen amplifier is used to provide power to the pen motor.

Recordings can be viewed on a CRO or a paper chart recorder.

1.2.3 Effects of artifacts

Artifacts are the disturbances that occur when ECG recording are done.

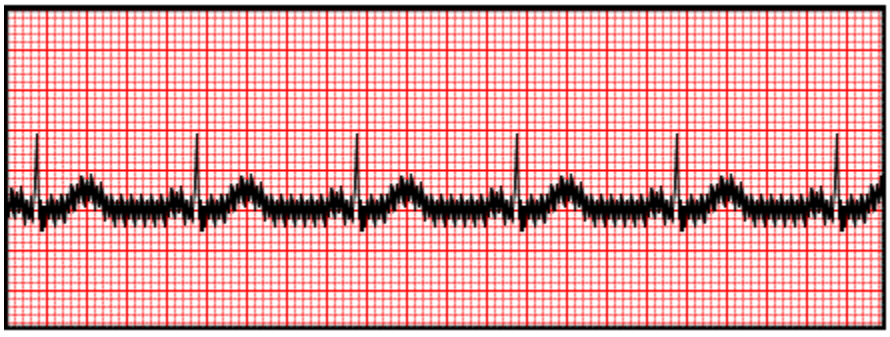
Artifacts are due to

- Interference from power line
- Shifting of base line
- Solid base line

Interference from baseline

Alternating current (AC) describes the type of electricity that we get from the wall.

When an ECG machine is poorly grounded or not equipped to filter out this interference, a thick looking ECG line is obtained.

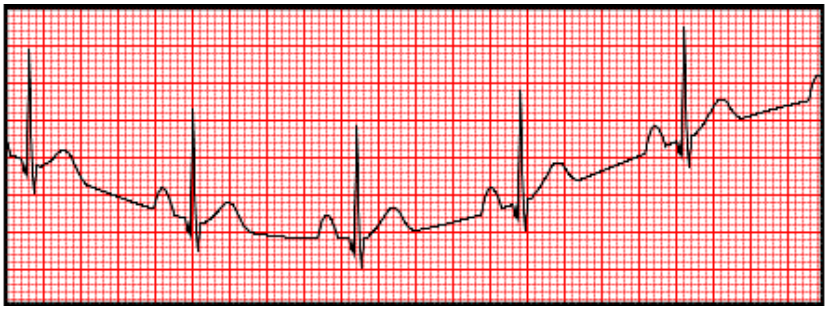


This can be reduced by using high CMRR bioamplifier. Patients can be isolated from other electrical appliances.

Shifting of baseline

Improper attachment of electrodes, movement of electrodes or patient, less electrode paste.

Avoided by selecting proper electrode paste and also strapping of the electrodes.



Solid baseline

Improper heating of stylus

1.3 Electroencephalography/EEG

Electroencephalograms (EEGs) are recordings of the minute (generally less that 300μV) electrical potentials produced by the brain.

The brain's electrical activity is picked up by electrodes attached on the patient's scalp and amplified on the EEG machine to be viewed as brain waves.

Brain waves are the summation of neural depolarization in the brain due to the stimuli from the five senses as well as from thought processes.

Electrodes used are peel and stick electrodes, silver plated cup electrodes, needle electrodes.

These electrodes are very small. They maybe directly applied to the scalp or maybe mounted on special bands or caps that are placed on the patients head.

Signals are picked up either by unipolar recordings or bipolar recordings. In the first method the potential difference between a pair of electrodes is measured. In the latter method the potential of each electrode is compared either to a neutral electrode or to the average of all electrodes

Brain waves

EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The EEG waveform are alpha, beta, theta, delta and gamma waves.

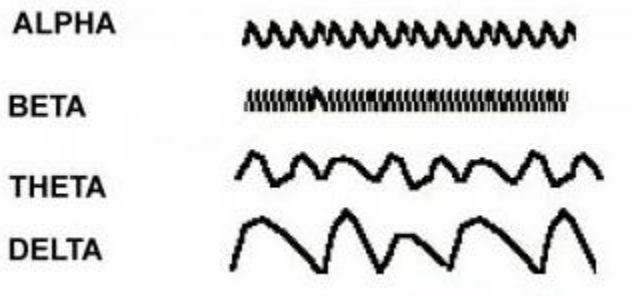


Fig 1.7 EEG waves

Table 1.3: Waveforms and frequencies

Wave	Frequency	Region obtained	Occurence
Delta	0.5- 4Hz	Cortex	deep sleep stages of normal adults
Theta	4-8Hz	Parietal and temporal region	normal infants and children as well as during drowsiness and sleep in adults
Alpha	8-13 Hz	Occipital	relaxed and mentally inactive awakeness
Beta	13-30Hz	Parietal and frontal	Tension
Gamma	>30 Hz		No significance

Principle

The EEG signal is closely related to the level of consciousness of the person. As the activity increases, the EEG shifts to higher dominating frequency and lower amplitude. When the eyes are closed, the alpha waves begin to dominate the EEG. When the person falls asleep, the dominant EEG frequency decreases. In a certain phase of sleep, rapid eye movement called (REM) sleep, the person dreams and has active movements of the eyes, which can be seen as a characteristic EEG signal. In deep sleep, the EEG has large and slow deflections called delta waves. No cerebral activity can be detected from a patient with complete cerebral death.

1.3.1 10-20 Electrodes configuration

The 10/20 system or International 10/20 system is an internationally recognized method to describe the location of scalp electrodes. In this system 21 electrodes are located on the surface of the scalp.

A pattern of electrodes on the head and the channel they are connected is called a montage. They are always symmetrical.

The system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. The numbers ‘10’ and ‘20’ refer to the fact that the distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.

Four anatomical landmarks are used for the essential positioning of the electrodes: first, the nasion which is the point between the forehead and the nose; second, the inion which is the lowest point of the skull from the back of the head and is normally indicated by a prominent bump; the pre auricular points anterior to the ear. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. Three other electrodes are placed on each side equidistant from the neighboring points.

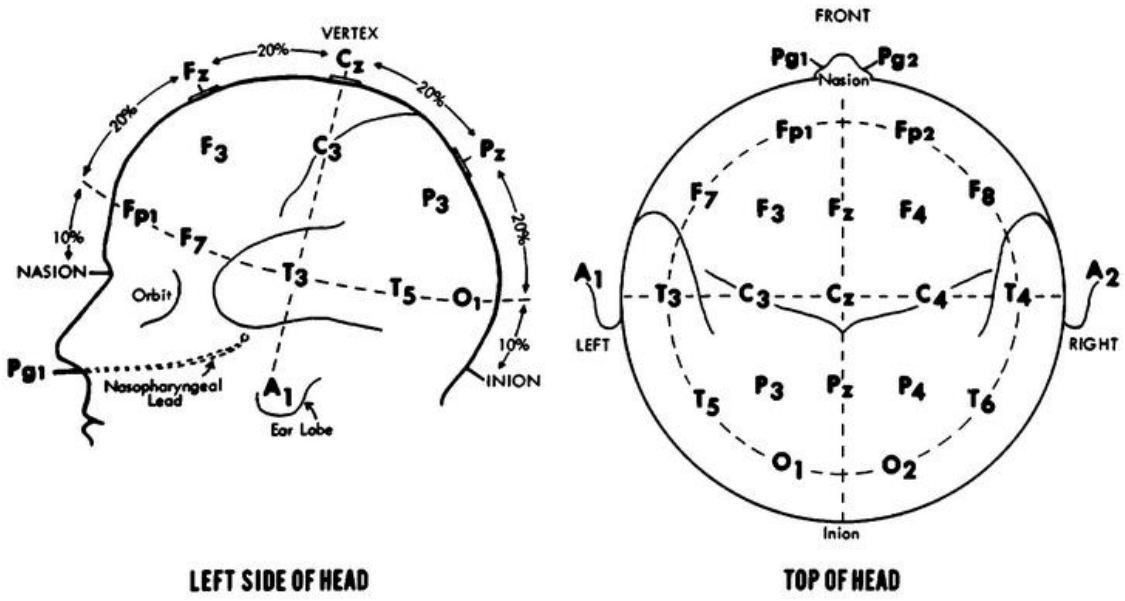


Fig 1.9 10-20 Electrode System

- Fp(frontopolar), F (frontal), C (central), P (parietal), O (occipital) and T (temporal)
- Odd numbers (left), even (right), A (ear)

1.3.2 Instrumentation

Encephalographic measurements employ recording system consisting of

- electrodes with conductive media
- amplifiers with filters
- A/D converter
- recording device.

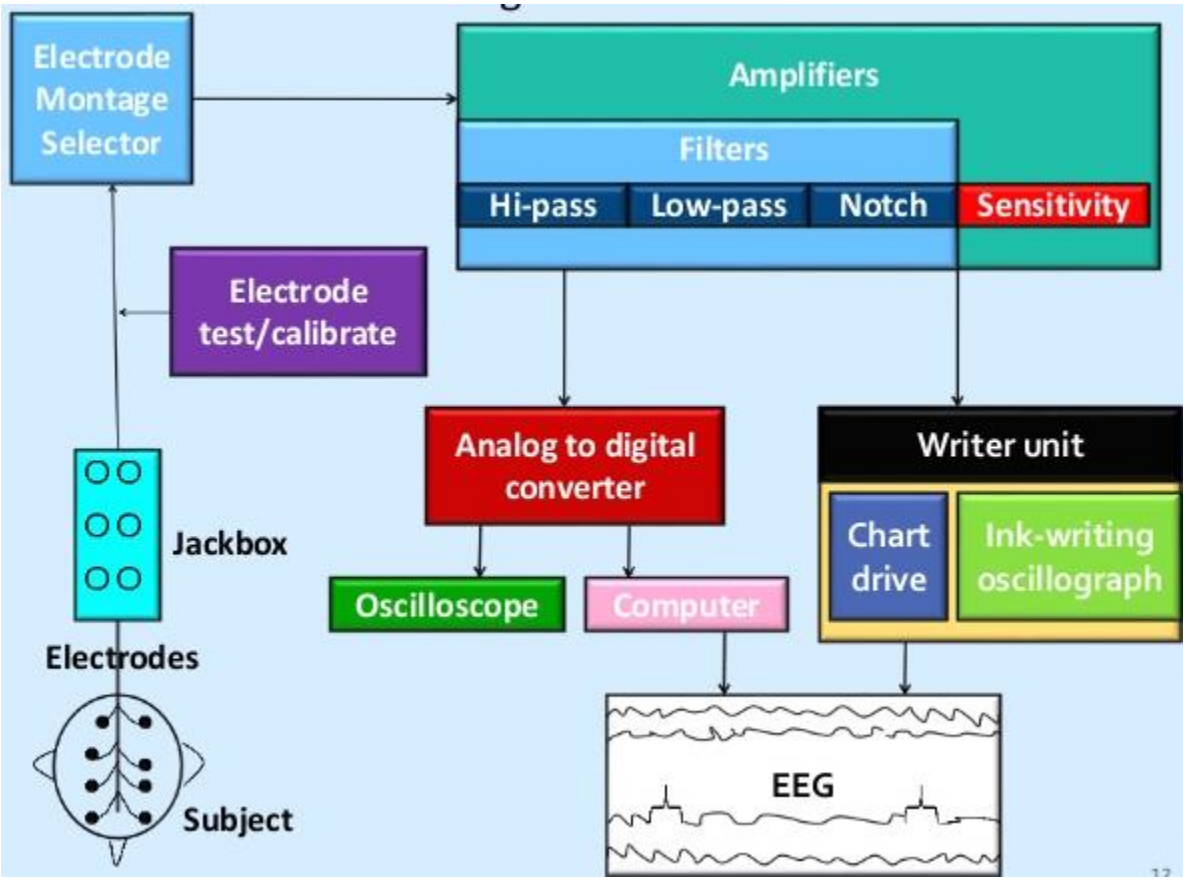


Fig 1.10 Block Diagram

Electrodes read the signal from the head surface, amplifiers bring the microvolt signals into the range where they can be digitalized accurately, converter changes signals from analog to digital form, and personal computer (or other relevant device) stores and displays obtained data.

Electrodes

The EEG recording electrodes and their proper function are critical for acquiring appropriately high quality data for interpretation.

The types of electrodes used are disposable (gel-less, and pre-gelled types), reusable disc electrodes (gold, silver, stainless steel or tin) , headbands and electrode caps , needle electrodes.

Commonly used scalp electrodes consist of Ag-AgCl disks, 1 to 3 mm in diameter, with long flexible leads that can be plugged into an amplifier. AgCl electrodes can accurately record also very slow changes in potential. Needle electrodes are used for long recordings and are invasively inserted under the scalp.

Using the silver-silver chloride electrodes, the space between the electrode and skin should be filled with conductive paste also helping to stick. With the cap systems, there is a small hole to inject conductive jelly. Conductive paste and conductive jelly serve as media to ensure lowering of contact impedance at electrode-skin interface.

Amplifiers and filters

The signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters.

The input signal to the amplifier consists of five components: The desired biopotential, undesired biopotentials, a power line interference signal of 50/60 Hz

and its harmonics, interference signals generated by the tissue/electrode interface, and noise. Proper design of the amplifier provides rejection of a large portion of the signal interferences. The desired biopotential appears as the differential signal between the two input terminals of the differential amplifier.

In order to provide optimum signal quality and adequate voltage level for further signal processing, the amplifier has to provide a gain of 100-100,000 and should have good signal-to-noise ratio. In order to decrease an impact of electrically noisy environment differential amplifiers must have high common-mode rejection ratios (at least 100 dB) and high input impedance (at least 100 MOhms).

When computers are used as recording devices, channels of analog signal are repeatedly sampled at a fixed time interval (sampling interval), and each sample is converted into a digital representation by an analog- to-digital (A/D) converter. The A/D converter is interfaced to a computer system so that each sample can be saved in the computer's memory.

A high-pass filter is needed for reducing low frequencies coming from bioelectric flowing potentials (breathing, etc.), that remain in the signal after subtracting voltages toward ground electrode. Its cut-off frequency lies in the range of 0.1-0.7 Hz.

To ensure that the signal is band limited, a low-pass filter is used. Analog low-pass filters prevent distortion of the signal by interference effects with sampling rate.

Digital filtering is achieved by using finite impulse response (FIR) filters.

Applications

Clinical Use

- Distinguish epileptic seizures from non epileptic ones,fainting.
- To test brain death
- To determine whether to use anti epileptic medications.

Research use

- Cognitive science, cognitive psychology, neuro linguistics, psycho physiological research

1.3.3 Recording of Evoked potentials

Evoked potentials studies measure electrical activity in the brain in response to stimulation of sight, sound, or touch. Stimuli delivered to the brain through each of these senses evoke minute electrical signals. These signals travel along the nerves and through the spinal cord to specific regions of the brain and are picked up by electrodes, amplified, and displayed for a doctor to interpret.

ERPs are suitable methodology for studying the aspects of cognitive processes of both normal and abnormal nature (neurological or psychiatric disorders. Mental operations, such as those involved in perception, selective attention, language processing, and memory , proceed over time ranges in the order of tens of milliseconds.

Evoked potentials studies involve three major tests that measure response to visual, auditory, and electrical stimuli.

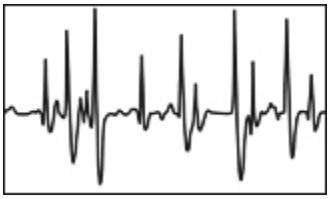
- Visual evoked response (VER) test - This test can diagnose problems with the optic nerves that affect sight. Electrodes are placed along the scalp and the electrical signals are recorded as the person watch a checkerboard pattern flash for several minutes on a screen.
- Brainstem auditory evoked response (BAER) test- This test can diagnose hearing ability and can point to possible brainstem tumors or multiple sclerosis. Electrodes are placed on the scalp and earlobes and auditory stimuli, such as clicking noises and tones, are delivered to one ear.

- Somatosensory evoked response (SSER) test - This test can detect problems with the spinal cord as well as numbness and weakness of the extremities. For this test, electrodes are attached to the wrist, the back of the knee, or other locations. A mild electrical stimulus is applied through the electrodes. Electrodes on thescalp then determine the amount of time it takes for the current to travel along the nerves to the brain.

Amplitudes of ERP components are often much smaller than spontaneous EEG components, so they are not to be recognised from raw EEG trace. They are extracted from set of single recordings by digital averaging of epochs (recording periods) of EEG time-locked to repeated occurrences of sensory, cognitive, or motor events. The spontaneous background EEG fluctuations, which are random relatively to time point when the stimuli occurred, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only that activity which is consistently associated with the stimulus processing in a time-locked way. The ERP thus reflects, with high temporal resolution, the patterns of neuronal activity evoked by a stimulus.

1.4 Electromyography/EMG

Electromyography (EMG) is a diagnostic medicine technique for interpreting and recording the electrical activity produced by skeletal muscles. Motor neurons transmit electrical signals that cause muscles to contract. An EMG translates these signals into graphs, sounds or numerical values.



Electrical activity of the muscles can be measured using surface electrodes or needle electrodes.

1.4.1 Recording set up

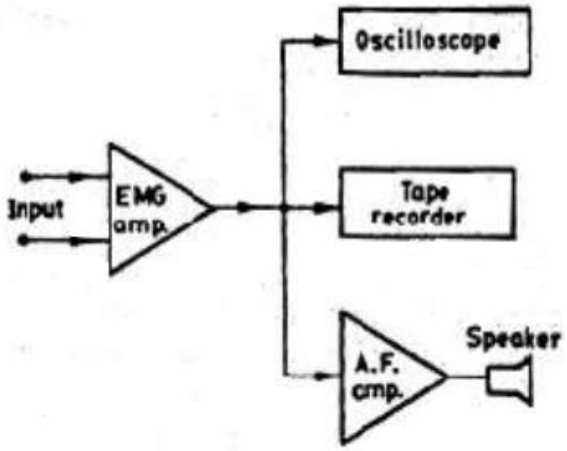


Fig 1.11 Block Diagram

The surface electrodes are Ag-AgCl electrodes and disc shaped.

For basic preparation, The skin is cleaned and electrode paste is applied. Electrodes are kept in place by elastic bands so that contact impedance is reduced.

Both unipolar and bipolar electrodes are used. In unipolar electrodes, reference electrodes are placed on the skin and active electrode(needle electrode) is inserted into the skin.

In coaxial electrode,surrounding steel jacket acts as the reference and metallic wire as active electrode.

Amplitude of EMG signals depends on the type and placement of electrodes and degree of muscular exertion.

EMG signals range from 0.1- 0.5 mV and frequency range is 20Hz-200 Hz. Normal frequncy is 60Hz.

The amplitude of the motor unit action potential depends on many factors which include: diameter of the muscle fiber, distance between active muscle fiber and the detection site and filtering properties of the electrodes themselves. The objective is to obtain a signal free of noise (i.e.,movement artifact, 60 Hz artifact, etc.). Therefore, the electrode type and amplifier characteristics play a crucial role in obtaining a noise-free signal.

Signals are displayed on CRO's and photographic recordings are made.

Applications

To analyse neuromuscular functions

To understand reflex response

To diagnose muscular diseases

1.4.2 Measurement of nerve conduction velocity

A nerve conduction study (NCS), also called a nerve conduction velocity (NCV) test--is a measurement of the speed of conduction of an electrical impulse through a nerve. NCS can determine nerve damage and destruction.

The NCV test allows the physician to tell the difference between an injury to the nerve axon (the nerve fiber) and an injury to the myelin sheath—the protective covering surrounding the nerve. It is also useful for telling the difference between a nerve disorder and a condition where nerve injury has affected the muscles.

Procedure

Two flat surface electrodes are used for the purpose- stimulating electrode and measuring electrode. The electrodes are usually attached to the fingers or toes with another electrode either at the ankle or wrist.

When the electrical pulse is applied to the fingers or toes the sensory nerve carries the electrical signal away from the arm or leg.

The pulse duration is 0.1-0.2ms.The electrode at the wrist or ankle detects the wave of electricity (electrical impulse) when it reaches that point.

The electrodes are connected to a machine which generates the impulses and detects them. It can measure the time taken for the impulse to travel in the nerve from the first electrode to the second.

This information, plus the distance between the two electrodes, can be used to work out the speed at which the impulse is travelling along the nerve. This is referred to as the conduction velocity. The velocity or speed of the propagated (conducted) nerve impulse is directly related to the diameter of the nerve fibre and the presence of a myelin sheath. It is quite fast - usually, 50-60 metres per second.

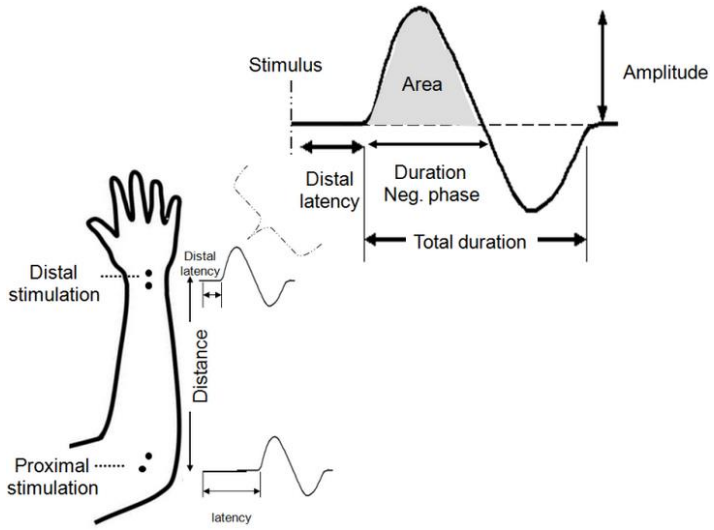


Fig 1.12 Nerve COnduction

Calculation

The electrodes are placed at 2 points on the skin separated by a known distance L1 and L2. (L2 < L1)

The time between the stimulation and excitation is taken as T1.

The latency refers to the elapsed time between the start of the stimulus and the onset of the response. It represents the propagation of the impulse along the nerve, the transmission across the end -plate, and the depolarization of the muscle fibers.

Conduction velocity V = L1 – L2 / T1 –T2.

1.5 Electroretinogram/ ERG

The electroretinogram (ERG) is a diagnostic test that measures the electrical activity generated by neural and non-neuronal cells in the retina in response to a light stimulus. The light-sensitive cells of the eye, the rods and cones, and their connecting ganglion cells in the retina are examined.

Recording

The basic method of recording the electrical response known as the global or full-field ERG is by stimulating the eye with a bright light source such as a flash produced by LEDs or a strobe lamp.

The flash of light elicits a biphasic waveform recordable at the cornea. The two components that are most often measured are the a- and b-waves. The a-wave is the first large negative component, followed by the b-wave which is corneal positive and usually larger in amplitude.

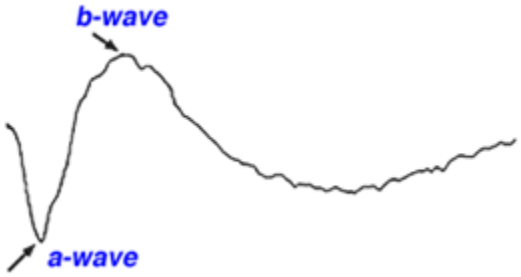


Fig 1.13 ERG waveform

The a-wave, sometimes called the "late receptor potential," reflects the general physiological health of the photoreceptors in the outer retina. In contrast, the b-wave reflects the health of the inner layers of the retina, including the ON bipolar cells and the Muller cells. Two other waveforms that are sometimes recorded in the clinic are the c-wave originating in the pigment epithelium and the d-wave indicating activity of the OFF bipolar cells. Most disorders of the retina are detected by an attenuation of amplitude.

Electrodes

Burian-Allen Electrode- (commonly used electrode for flash ERG) variable lens sizes consisting of an annular ring of stainless steel surrounding the central polymethylmethacrylate (PMMA) contact-lens core with a lid speculum

ERG-Jet Electrode- a disposable plastic lens with a gold-plated peripheral circumference

Mylar Electrode- aluminized or gold-coated Mylar

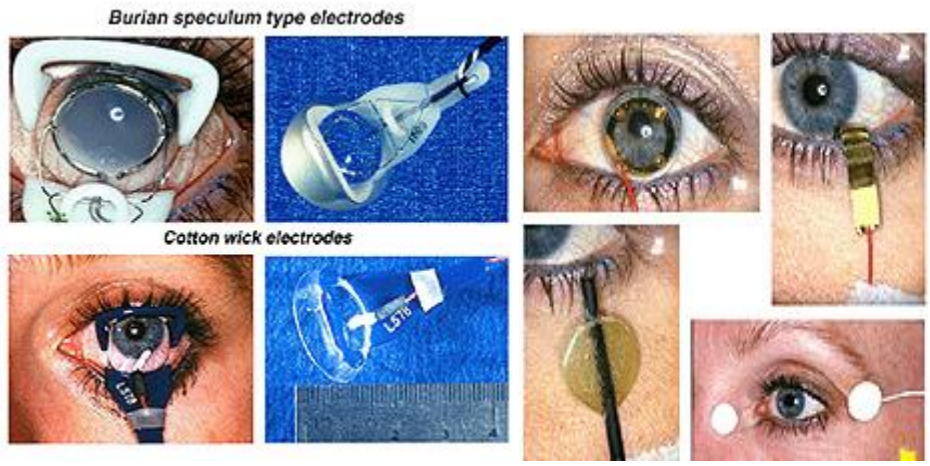


Fig 1.14: Electrodes

Skin Electrode- may be used as a replacement for corneal electrodes by placing an electrode on the skin over the infraorbital ridge near lower eyelid; due to decreased amplitudes and variable responses, the skin electrode is primarily used for screening purposes only

Cotton-Wick Electrode- Burian-Allen electrode shell fitted with a cotton wick which is useful for minimizing light-induced artifact.

If electrodes are to be reused, they should be sterilized with a solution that neutralizes prion-transmitted diseases.

Types

The focal ERG (fERG; also known as the foveal ERG) is used primarily to measure the functional integrity of the fovea and is therefore useful in providing information in diseases limited to the macula. Focal ERG is useful for assessing macular function in conditions such as age-related macular degeneration, however requires good fixation from the subject.

The full-field ERG (ffERG) measures the stimulation of the entire retina with a flashlight source under dark-adapted (scotopic) and light-adapted (photopic) types of retinal adaptation.This is useful in detecting disease with widespread generalized retinal dysfunction i.e. cancer associated retinopathy, toxic retinopathies, and cone-rod dysfunction. Due to the massed retinal electrical response, small retinal lesions may not be revealed in ffERG recordings.

The multifocal ERG (mfERG) simultaneously measures local retinal responses from up to 250 retinal locations within the central 30 degrees mapped topographically.

The pattern ERG (PERG) uses pattern-reversal stimuli similar to VEP testing and captures retinal ganglion cell activity predominantly in the N95 waveform component. The PERG is used to detect subtle optic neuropathies. In demyelinating optic neuropathy, the PERG is relatively normal, while it may be abnormal in ischemic optic neuropathies.

1.6 Electrooculogram/ EOG

Electrooculography (EOG) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is called the electrooculogram.

Principle

The eye acts as a dipole in which the anterior pole is positive and the posterior pole is negative.

1. Left gaze: the cornea approaches the electrode near the outer canthus of the left eye, resulting in a negative-trending change in the recorded potential difference.
2. Right gaze: the cornea approaches the electrode near the inner canthus of the left eye, resulting in a positive-trending change in the recorded potential difference.

Electrodes

Measurement of eye movements is done by placing pairs of electrodes either above and below the eye or to the left and right of the eye.

If the eye moves from the centre position towards one of the two electrodes, this electrode sees the positive side of the retina and the opposite electrode sees the negative side of the retina. Potential difference occurs between the electrodes. The recorded potential is the measure of the eye position.

The EOG ranges from 0.05 to 3.5 mV and is linearly proportional to eye displacement.

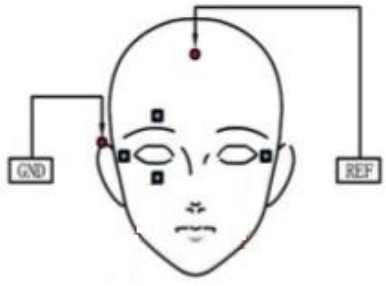
F 

Fig 1.15 Electrode Placement

The EOG makes an indirect measurement of the minimum amplitude of the standing potential in the dark and then again at its peak after the light rise. This is expressed as Arden ratio which is the light to dark peak trough.

Advantages

Application of surface electrodes is easy, noninvasive, without discomfort for the patient, and does not limit the field of view. In contrast to most other methods, EOG can be used with the subject wearing glasses and is applicable to children, poorly cooperative patients, or patients with ophthalmic disease. Further, it is possible to record eye movements with eyes closed.

Disadvantages

The amplitude of the corneo- retinal potential changes with the amount of ambient light, so illumination has to be kept constant as much as possible. Further EOG and ENG is often contaminated by electrical, electroen- cephalographic, and electromyographic artifacts, by lid and blink artifacts, and by slow baseline drifts, caused by changes of skin resistance.

1.7 Phonocardiography/PCG

The technique of listening to sounds produced by the organs and vessels of the body is called auscultation. The areas at which the heart sounds are heard better are called auscultation area.

The graphic recording of the sounds connected with the pumping action of the heart is called phonocardiogram. These sounds are produced by vibrations set up in the blood inside the heart by the sudden closure of valves, movement of heart wall, closure of walls and turbulence and leakage of blood flow.

Phonocardiography is a diagnostic technique that creates a graphic record of the heart sounds. The phonocardiogram is obtained either with a chest microphone or with a miniature sensor in the tip of a small tubular instrument that is introduced via the blood vessels into one of the heart chambers.

Heart sounds

Heart sounds are vibrations or sounds due to the acceleration or deceleration of blood during heart muscle contractions, whereas murmurs (a type of heart sounds) are considered vibrations or sounds due to blood turbulence.

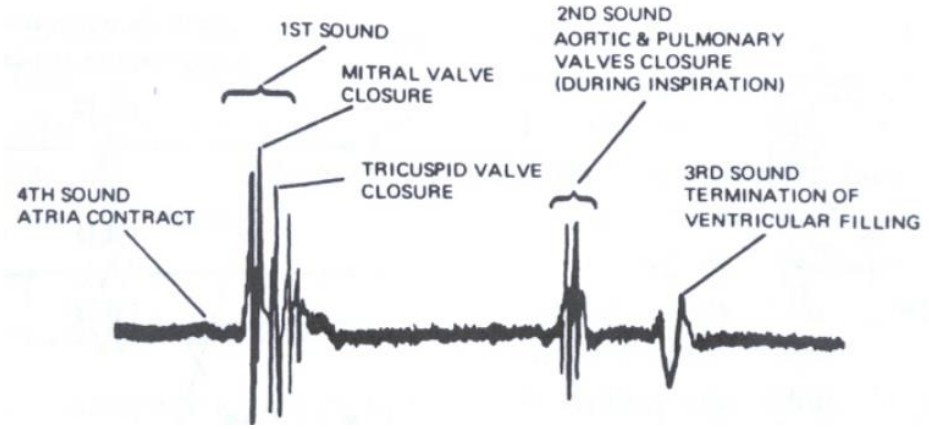


Fig 1.16 PCG Waveform

S. No	Heart sound	Occurence	Frequency	Time duration	Ausculatory area
1	First heart sound (Lub)	Occur at the end of the atrial contraction and at beginning of the ventricular contraction. Due to closure of	30-45Hz(loud deep pitch and is booming in character)(longer in duration, lower in frequency and greater in intensity	50 to 100msec	Occurs approximately 0.05 second after the onset of QRS complex and just before ventricular systole. Best heard at the apex of mid pericardium.

		mitral and tricuspid valves	than the second sound)		
2	Second heart sound(Dub)	Occurs at the end of ventricular systole due to closure of semilunar valves (aortic and pulmonary aortic valves)in the arteries leading out of the ventricles	50 -70 Hz (higher pitch than the first sound)	25 to 50msec	occurs at 0.03-0.05 second after the end of T wave. Best heard in the aortic and pulmonary areas.
3	Third heart sound	Cessation of ventricular filling. heard in children and patient with left ventricular failure due to rapid inflow of blood from the atria into the ventricles	below 30Hz.	0.1to 0.2sec	Starts 0.12 – 0.18 second after the onset of second heart sound. The asculatory area is at the apex

4	Fourth heart sound or atrial heart sound	contraction of the atria	10-50Hz	0.03 to 0.06 second	Occurs immediately before the first heart sound. It starts 0.12 –0.18 second after the onset of P wave

The third and fourth sounds are called diastolic sounds and are generally inaudible in the normal adult but are commonly heard among children.

Murmurs.

It occurs in abnormal hearts between normal heart sounds. They are higher pitched sounds in 100-600Hz range and are longer in duration compared to normal heart sounds.

The causes of murmurs are

1. High velocity blood flow that occurs through small opening when there is improper opening of valves.
2. Regurgitation which results when the valves do not close completely and allow some backward flow of blood.
3. Small opening in the septum that separates the left and right sides of the heart. This forces the blood through the opening from the left ventricle into right ventricle by passing the systemic circulation.

Block Diagram

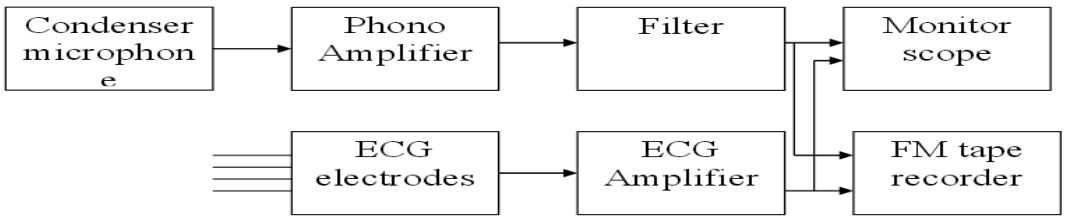


Fig 1.17 Block DIagram

Microphone:

It has a microphone e.g. piezoelectric crystal microphone , condenser, moving coil, carbon and dynamic microphones with frequency response from below 5Hz to above 1000Hz , fastened to the chest wall by an adhesive strip, converts the heart sounds into electrical signals.

The microphones commonly used in PCG are air coupled microphone and contact microphone. In the former, the movement of chest is transferred

through an air cushion and presents low mechanical impedance to the chest. But the second one is directly coupled to the chest wall and presents a higher impedance, high sensitivity, low noise and light weight. Sometimes special microphones are placed at the tips of catheters to pick up heart sounds from within the chambers of the heart or from the major blood vessels near the heart.

Preamplifier:

The electrical signals from the microphone are amplified by a phonocardiographic preamplifier.

Filter:

The high pass filters are used to separate the louder low frequency components from the medically interesting soft high frequency murmurs. For heart sounds, high pass filters with gradual slope are required and for murmurs, high pass filters with sharper slopes are required.

Recorders

Galvanometer recorders and direct writing recordes(ink jet, theral) are used.

Applications

1. Detection of Rheumatic valvular lesions:

Occurs due to Rheumatic fever which is an autoimmune or allergic disease in which the heart valves are likely to be damaged or destroyed.

2. Murmur of Aortic stenosis:

The blood is ejected from the left ventricle through a small opening of the aortic valve. Because of the resistance to the ejection, the pressure in the left ventricle rises sometimes to as high as 350mm of Hg. This causes turbulent blood flow. This turbulent blood impinging the

aortic valve causes intense vibration it produces loud murmur. This sound can be heard several feet away from the patient.

3. Murmur of Mitral regurgitation:

The blood flows backward through the mitral valve during systole.

4. Murmur of Aortic regurgitation:

In aortic regurgitation, the blood flows backward from the aorta into the left ventricle causing “blowing murmur”, during diastole.

5. Murmur of mitral stenosis:

The blood passes with difficulty from the left atrium into the left ventricle due to the pressure difference.

1.8 Echocardiography

Echocardiography or Echo, is a non-invasive diagnostic test that uses high frequency ultra sound waves to create moving pictures of your heart. The images show the size and shape of the heart. It also tells on how the heart's chambers and valves are working.

Echo also can pinpoint areas of heart muscle that aren't contracting well because of poor blood flow or injury from a previous heart attack. A type of echo called Doppler ultrasound shows how well blood flows through the heart's chambers and valves.

Echo can detect possible blood clots inside the heart, fluid buildup in the pericardium (the sac around the heart), and problems with the aorta.

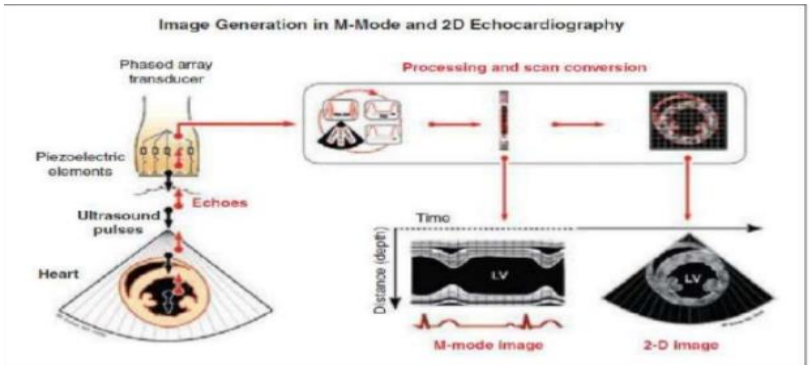


Fig 1.18 Block Diagram

1.8.1Types of Echocardiography

There are several types of echocardiography (echo)—all use sound waves to create moving pictures of your heart.

a. Transthoracic Echocardiography

Transthoracic echo is the most common type of echocardiogram test. It's painless and noninvasive. This type of echo involves placing a device called a transducer on your chest. The device sends sound waves, called ultrasound, through your chest wall to your heart. As the ultrasound waves bounce off the structures of your heart, a computer in the echo machine converts them into pictures on a screen.

b. Stress Echocardiography

Stress echo is done as part of a stress test. During a stress test, a person exercises or takes medicine to make the heart work hard and beat fast. A technician will use echo to create pictures of the heart before exercise and as soon as he finishes. Some heart problems, such as coronary heart disease, are easier to diagnose when the heart is working hard and beating fast.

c. Transesophageal Echocardiography(TEE)

The doctor may have a hard time seeing the aorta and other parts of the heart using a standard transthoracic echo. During this test, the transducer is attached to the end of a flexible tube. The tube is guided down the throat and into the.

d. Fetal Echocardiography

Fetal echo is used to look at an unborn baby's heart. A doctor may recommend this test to check a baby for heart problems. When recommended, the test is commonly done at about 18 to 22 weeks of pregnancy. For this test, the transducer is moved over the pregnant woman's belly.

e. Three-Dimensional Echocardiography

A three-dimensional (3D) echo creates 3D images of your heart. These detailed images show how your heart looks and works. During transthoracic echo or TEE, 3D images can be taken as part of the process used to do these types of echo. Doctors may use 3D echo to diagnose heart problems in children. They also may use 3D echo for planning and overseeing heart valve surgery.

REFERENCES

1.R. S. Khandpur, Hand Book of Biomedical instrumentation, Tata McGraw Hill Publication, 2019.

2. R. AnandaNatarajan, Biomedical Instrumentation & Measurements, PHI Publication, 2015.

3.Cromwell, Biomedical Instrumentation & Measurements Prentice-hall of India private limited, 2011.

4. Carr & Brown, Introduction to Biomedical Equipment Technology, 2010.

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DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – II – DIAGNOSTIC INSTRUMENTATION – SBM1301

IMAGING EQUIPMENTS

2.1 X-Ray machine

X-rays are a form of electromagnetic radiation, similar to visible light. X-rays have higher energy and can pass through most objects, including the body.

Medical x-rays are used to generate images of tissues and structures inside the body. Photographic films are used to visualize the output. X ray picture is called a radiograph.

2.1.1 Generation of X rays

X-rays are produced when the electrons are suddenly decelerated upon collision with the metal target. They are generated inside high vacuum X ray tube. The tube has an electrode pair- cathode and anode. The cathode is a heated filament. The machine passes current through the filament, heating it up. The heat releases electrons off of the filament surface. The positively-charged anode, a flat disc made of tungsten, draws the electrons across the tube. X rays arise from the anode and are focused using collimators.

The high-impact collisions involved in X-ray production generate a lot of heat. A motor rotates the anode to keep it from melting. A cool oil bath surrounding the envelope also absorbs heat.

The entire mechanism is surrounded by a thick lead shield. This keeps the X-rays from escaping in all directions. A small window in the shield lets some of the X-ray photons escape in a narrow beam. The beam passes through a series of filters on its way to the patient.

2.1.2 Block Diagram

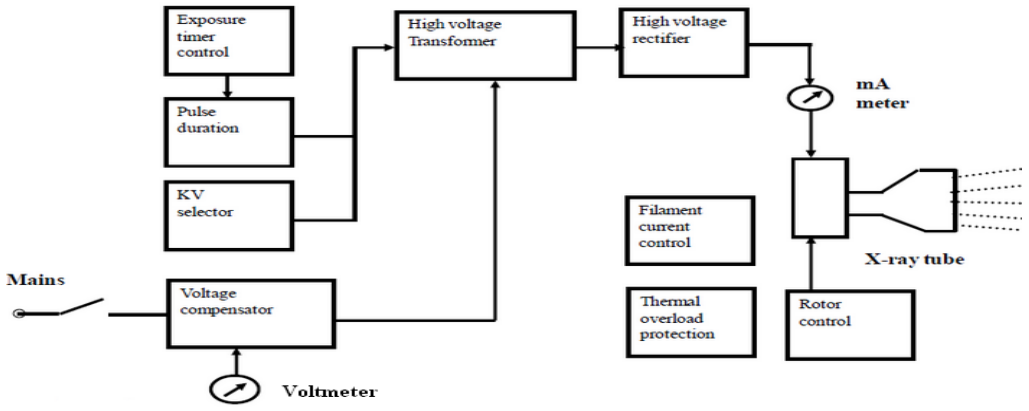

Fig 2.1 X- Ray Machine

The system has two parts- One to produce high voltage and the other to control the heating of X ray tube filament.

High Voltage Generator

These produce high voltages to the HV transformers for a specified time. The transformers produce 20KV – 200 KV at the output. High ratio step up transformers are used. The voltage produced determines the contrast of the image. Higher the voltage, higher the contrast.

High Voltage Rectifier

This rectifies the HV produced by HVT and supplies to the anode of the X ray tube. Usually either a bridge or solid state rectifier is used.

Thermal overload protection

The heat of the X ray tube should not exceed a specified range. If it does exceed, the protection system turns off the machine.

High tension Cable

Highly insulated cables are used as connection to generators. These cables have 3 conductors individually insulated for low filament voltages. They are surrounded by semi conducting and non conducting rubber.

Collimators and Grids

These limit the X -ray beams to a specified area of interest. They are placed between X ray tube and patient. It is made of lead with circular r rectangular holes.

Grids are inserted between patient and film cassette to reduce the loss of contrast due to scattered radiation.

Kilovoltage selector

It allows precise selection of desired kV.

Voltmeter and voltage compensator control

Most X-ray machines are designed to operate on a 220 voltage power source. A voltmeter measures the voltage of electric current and voltage compensator allows adjustment of voltage.

Timer and exposure button

The quantity of X-rays reaching the film is directly related to the X-ray tube current and the time for which the tube is energized i.e. the exposure time.

The range of exposure time in available machines is large with minimum setting being as short as 0,001 second. An exposure device mostly consists of a two-stage exposure button of which first half depression rotates the anode and a complete depression, after a short pause, causes actual radiographic exposure.

2.2 Computed Tomography/ CT

Computed tomography (CT) is a diagnostic imaging test used to create detailed images of internal organs, bones, soft tissue and blood vessels.

The term tomography comes from the Greek words tomos (a cut, a slice, or a section) and graphein (to write or record).

In CT, the picture is made by viewing the patient via X ray imaging from numerous angles, by mathematically reconstructing the detailed structures and displaying the reconstructed images on a video monitor.

Principle

It involves the determination of attenuation characteristics for each small volume of tissue in the patient slice which constitute the transmitted radiation intensity recorded from various irradiation directions.

These calculated tissue attenuation characteristics compose the CT image

$I_t = I_o\, e^{-\mu x}$

I_t – Transmitted intensity

I_o – Incident radiation intensity

x – thickness of tissue

μ - Attenuation coefficient of tissue

2.2.1 Block Diagram

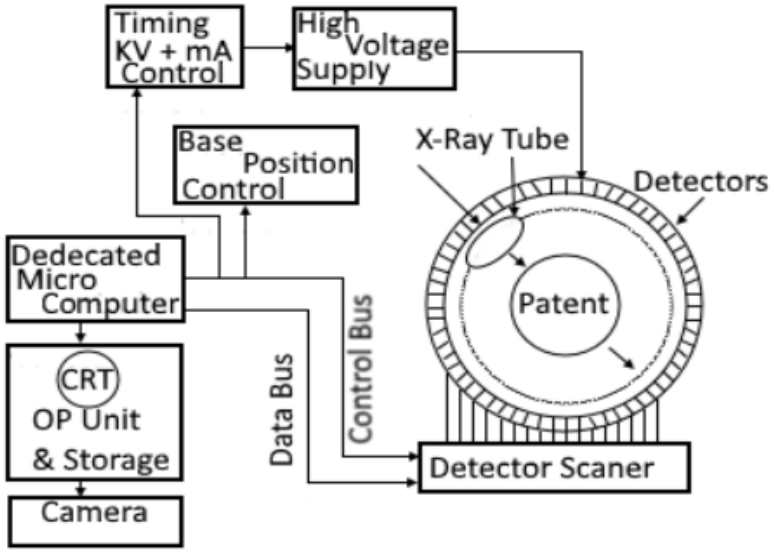

Fig 2.2 CT Machine

The basic three components of a CT scanner are an X-ray tube, an object (patient) and a detection system.

Computer controls the timing, anode voltage and beam current supply.

High voltage DC supply drives the X ray tube which can be rotated around the patient in gantry.

X ray passes through the patient get absorbed and remaining transmitted photons fall on the 1000 radiation detectors fixed around the gantry.

When the photons strike the detector, they are converted into scintillations.

The computer samples the output of the detector parallel to the X ray tube. Calculations are also done by the computer.

Output unit produces a visual image on the CRT.

2.2.2 Scanning system

First generation

Detectors: one

Type of beam: pencil-like X-ray beam

Tube-detector movements: translate-rotate/transverse and index arrangement

Duration of scan (average): 25-30 mins

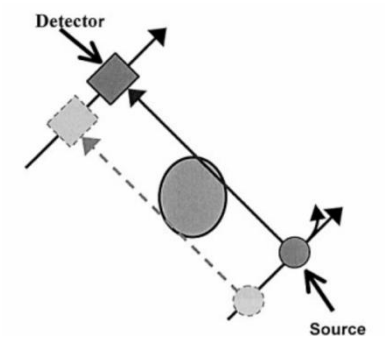

Fig 2.3 First generation

Second generation

Detectors: multiple (up to 30)

Type of beam: fan shaped x-ray beam

Ttube-detector movements: translate-rotate

Duration of scan (average): less than 90 sec

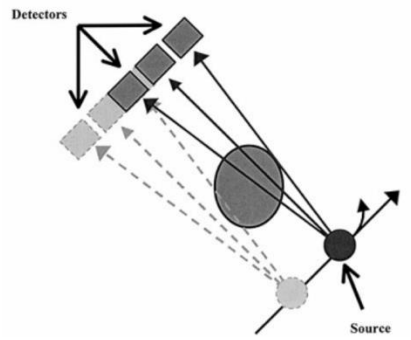

Fig 2.4 Second generation

Third generation

Detectors: multiple, originally 288; newer ones use over 700 arranged in an arc

Type of beam: fan shaped x-ray beam

Tube-detector movements: rotate-rotate

Duration of scan (average): approximately 5 sec

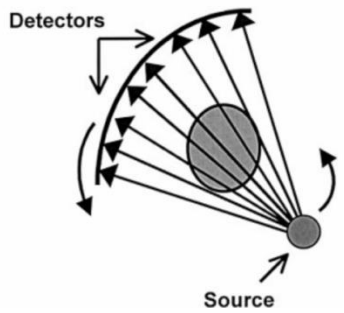

Fig 2.5 Third Generation

Fourth generation

Detectors: multiple (more than 2000) arranged in an outer ring which is fixed

Type of beam: fan shaped x-ray beam

Tube-detector movements: rotate-fixed

Duration of scan (average): few seconds

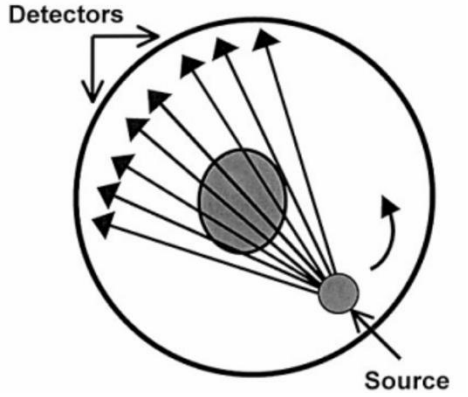

Fig 2.6 Fourth Generation

Fifth Generation

X-ray tube is a large ring that circles patient, opposed to detector ring.

X - rays produced = high - energy electron beam

No moving parts to this scanner gantry

It is capable of 50 - millisecond scan times and can produce 17 CT slices/second

Stationary/stationary geometry

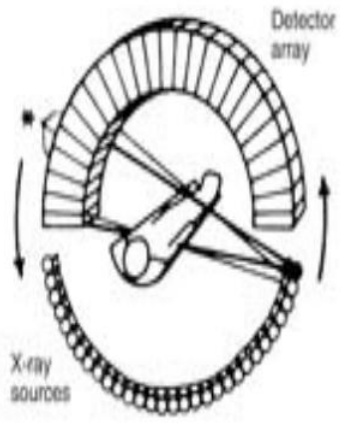

Fig 2.7 Fifth Generation

Sixth Generation

Slip-ring gantry designs

Very high power x-ray tubes

Interpolation algorithms to handle projection data

2.2.3 Processing unit

Processing unit performs image reconstruction. They are algorithms for reconstruction of the images from the information obtained by detectors.

The image of the section of the object irradiated by the X-ray, is reconstructed from a large number of measurements of attenuation coefficient. It gathers together all the data coming from the elementary volumes of material through the detectors.

The typical CT image is composed of 512 rows, each of 512 pixels, i.e., a square matric of 512 x 512 = 262144 pixels (one for each voxel). In the process of image, the value of attenuated coefficient for each voxel corresponding to these pixel needs to be calculated.

Back Propagation: Each image point is surrounded by a halo-shaped star that degrades the contrast and blurs the boundary of the object. To avoid this, the method of filtered back projection is used. The action of the filter function is such that the negative value created is the filtered projection, when projected backwards, is removed and an image is produced, which is the accurate representation of the original object.

Fourier Reconstruction: In the spatial domain, CT reconstruction involves the relationship between a two-dimensional image and its set of one-dimensional views. By taking the two-dimensional Fourier transform of the image and the one-dimensional Fourier transform of each

of its views, the problem can be examined in the frequency domain. As it turns out, the relationship between an image and its views is far simpler in the frequency domain than in the spatial domain.

Iterative Technique: all the pixels in the image array are set to some arbitrary value. An iterative procedure is then used to gradually change the image array to correspond to the profiles. An iteration cycle consists of looping through each of the measured data points. The measured sample is compared with the sum of the image pixels along the ray pointing to the sample. If the ray sum is lower than the measured sample, all the pixels along the ray are increased in value. Likewise, if the ray sum is higher than the measured sample, all of the pixel values along the ray are decreased. After the first complete iteration cycle, there will still be an error between the ray sums and the measured values. Iterative techniques are generally slow, but they are useful when better algorithms are not available

2.2.4 Viewing System

Display subsystems consist of a display controller, image memory, digital-to-analog convertor (DAC), and monitor (CRT). As described elsewhere, CT image data consist of numbers among -1000 to 3000. The human eye, however, cannot distinguish between more than 256 gray levels. The digital numbers are converted to analog signals using an eight-bit DAC, and a window level control is used to control the mapping of CT numbers into gray levels. Software for calculating the mean and standard deviation within a region and for image manipulations such as filtering and magnification is often included as part of the display program.

2.2.5 Storage unit

Picture are stored in digital form and are stored in disks, CD's, etc. Hard copy print outs can also be made in gray scale or color shades.

2.3 Magnetic Resonance Imaging/MRI

Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body.

MRI is based on the principles of nuclear magnetic resonance (NMR).

The technique uses a very powerful magnet to align the nuclei of atoms inside the body, and a variable magnetic field that causes the atoms to resonate, a phenomenon called nuclear magnetic

resonance. The nuclei produce their own rotating magnetic fields that a scanner detects and uses to create an image.

Principle

The human body is mostly water. Water molecules (H20) contain hydrogen nuclei (protons), which become aligned in a magnetic field. An MRI scanner applies a very strong magnetic field (about 0.2 to 3 teslas), which aligns the proton "spins."

The scanner also produces a radio frequency current that creates a varying magnetic field. The protons absorb the energy from the variable field and flip their spins. When the field is turned off, the protons gradually return to their normal spin, a process called precession. The return process produces a radio signal(NMR signals) that can be measured by receivers in the scanner and made into an image.

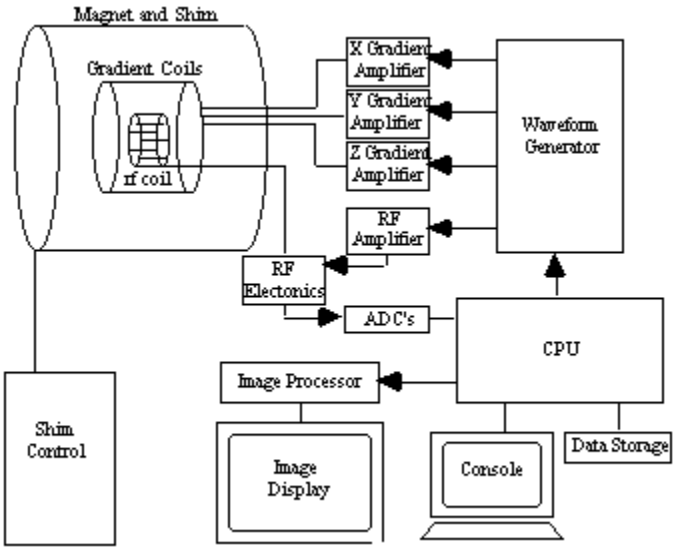

Fig 2.8: MRI machine

2.3.1 The magnet

The various magnets used are permanent magnets(C-Fe alloys), electromagnets, resistive magnets(Al strips) and superconducting magnets(NbTi).

2.3.2 RF transmitter /detector system

The RF transmitter system activates the nuclei so that they emit the NMR signals. The system consists of a RF generator, RF transmitter, RF power amplifier and RF transmitting coils. He RF pulses from coils fall on the patient.

The Detection system detects the nuclear magnetization and generates an output signal for processing by the computer. The system consists of receiving coils, matching networks, amplifiers, filters and ADC.

The receiver coil surrounds the areas of interest, picks NMR signals and converts to output voltage.

2.3.3 Gradient system

It is used to obtain spatial distribution information. The strength of the field is proportional to the density of hydrogen nuclei in that plane.

2.3.4 Imager system

It consists of the computer, display system and control console.

Computer does image processing, timing and control of RF and gradient pulse sequences. A high speed mini computer collects the NMR signals, corrects, recomposes, displays and stores it. An array processor does FFT.

The display section ahs high resolution monitor, image memory and panel indicators.

2.3.5 Advantages

The advantages of MRI include:

- the ability to image without the use of ionizing radiation (x-ray) unlike CT scanning
- images may be acquired in multiple planes (Axial, Sagittal, Coronal, or Oblique) without repositioning the patient. CT images have only relatively recently been able to be recontructed in multiple planes with the same spatial resolution
- MRI images demonstrate superior soft tissue contrast than CT scans and plain films making it the ideal examination of the brain, spine, joints and other soft tissue body parts
- some angiographic images can be obtained without the use of contrast material, unlike CT or conventional angiography
- advanced techniques such as diffusion, spectroscopy and perfusion allow for specific tissue characterisation rather than merely 'macroscopic' imaging
- functional MRI allows visualisation of both active parts of the brain during certain activities and understanding of the underlying networks

2.4 Ultrasonic imaging systems

Ultrasound refers to acoustical wave of frequency 20-20000HZ above. They are generated from piezo electric crystals like quartz, Rochelle salt, lead zirconate,etc.

Medical ultrasound imaging consists of using high pitched sound bouncing off tissues to generate images of internal body structures.

The ultrasound waves (pulses of sound) are sent from the transducer, propagate through different tissues, and then return to the transducer as reflected echoes. The returned echoes are converted back into electrical impulses by the transducer crystals and are further processed in order to form the ultrasound image presented on the screen.

2.4.1 Ultrasonic Imaging Instrumentation

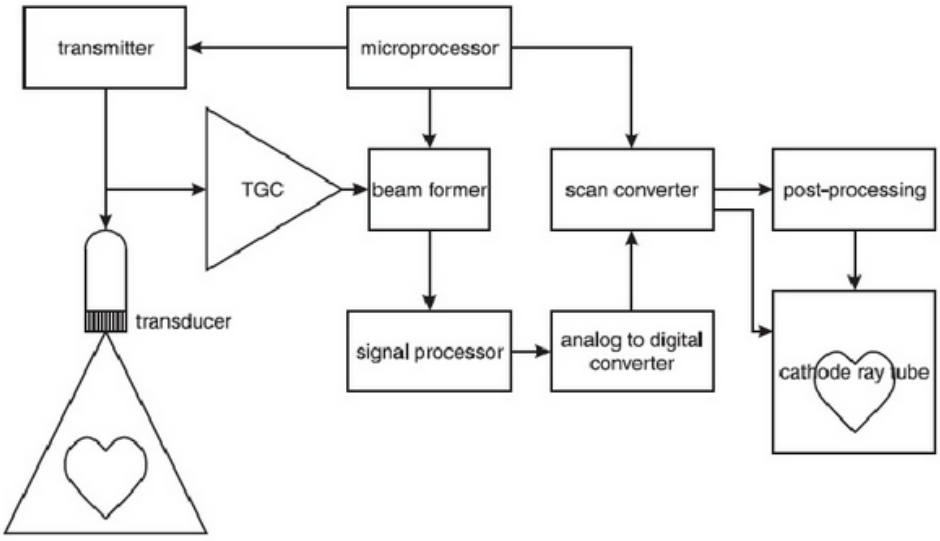

Fig 2.9 Ultrasound Machine set up

Transducer position data is given to computer.

The computer calculates the depth gain compensation and sends the data to signal processing unit. Receiver also sends signals to SPU.

Echoes from body surface are collected by receiver circuit, converted into digital signals and stored in memory. These signals are color coded and converted into analog signals. These signals are fed into video section of TV monitor where it is displayed.

High speed ADC helps in digitization of high frequency signals.

2.4.2 Display Modes

A mode is an operational state that a system has been switched to. A normal mode occurs when all parts of a system oscillate with the same frequency. For ultrasound imaging, different modes are used to examine the arterial/venous system, heart, pancreas, urinary system, ovaries, spinal cord, joints, and more. The different types of modes can be controlled by the operator or tech.

The various display modes are A Mode/Scan, B Mode/Scan, TM Mode Scan**.**

1. A-mode (A=amplitude)

The amplitude of reflected ultrasound is displayed on an oscilloscope screen. A-Mode consists of a x and y axis, where x represents the depth and y represents the Amplitude. The A-mode is now used only in ophtalmology.

2. M-mode (M=motion)

M-Mode, or Motion Mode (also called Time Motion or TM-Mode), is the display of a one-dimensional image that is used for analyzing moving body parts commonly in cardiac and fetal cardiac imaging. This can be accomplished by recording the amplitude and rate of motion in real time by repeatedly measuring the distance of the object from the single transducer at a given moment. The single sound beam is transmitted and the reflected echoes are displayed as dots of varying intensities thus creating lines across the screen. Nowadays, the integration of 2D and M-mode images is possible. Due to its excellent temporal resolution (high sampling rate), M-mode is extremely valuable for accurate evaluation of rapid movements.

3. B-mode (B=brightness)

This is now the essential imaging modality in the diagnostic ultrasound. B-Mode is based on brightness with the absence of vertical spikes. Therefore, the brightness depends upon the amplitude or intensity of the echo. There is no y axis on B-Mode, instead, there is a z axis, which represents the echo intensity or amplitude, and a x axis, which represents depth. B-Mode will display an image of large and small dots, which represent strong and weak echoes, respectively. An amplitude of the reflected ultrasound signals is converted into a gray scale image. Owing to the wide gray scale (most of the ultrasound machines use 256 shades of gray) even very small differences in echogenicity are possible to visualize.

2.5 Thermographic Equipment

Medical Thermography (digital infrared thermal imaging - DITI) is used as a method of research for early pre-clinical diagnosis and control during treatment of homeostatic imbalances.

Thermography is a non-invasive, non-contact tool that uses the heat from your body to aid in making diagnosis of a host of health care conditions. Thermography is completely safe and uses no radiation.

Thermography is used to determine areas of the body that have irregular blood flow. It is commonly used by sports physicians and veterinarians to determine areas of the body that have inflammation.

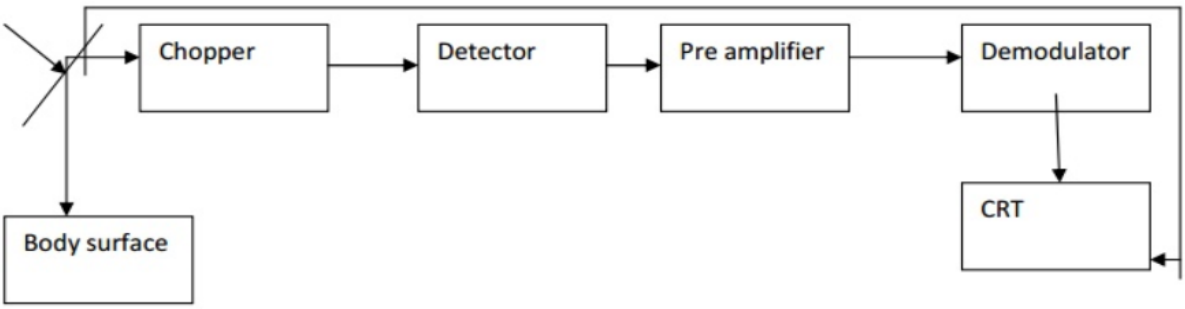

Fig 2.10 Thermographic Equipment

This equipment usually has two parts, the IR camera and a standard PC or laptop computer. These systems have only a few controls and relatively easy to use.

Monitors are high-resolution full color, isotherm or grey scale, and usually include image manipulation, isothermal temperature mapping, and point-by-point temperature measurement with a cursor or statistical region of interest. The systems measure temperatures ranging from 10° C - 55° C to an accuracy of 0.1° C. Focus adjustment should cover small areas down to 75 x 75mm.

Utilising high-speed computers and very accurate thermal imaging cameras, the heat from your body is processed and recorded in the computer into an image map which can then be analyzed on screen, printed or sent via email.

- Minimum temperature resolution, i.e., the temperature differential between two adjacent elements in the scene that will give a signal equal to the system noise.
- Smaller the NETD, better the sensitivity.
- Thus, the Also called noise equivalent temperature difference (NETD).

2.5.1 Application

- Breast pathologies

- Extra-Cranial Vessel Disease
- Neuro-Musculo-Skeletal
- Vertebrae (nerve problems/arthritis)
- Lower Extremity Vessel Disease

Advantages

- Non-invasive
- No contact between the patient and system
- No radiation hazard.
- Real-time system.
- Large surface area can be scanned in no time.
- Presented in visual & digital form.
- Software back-up for image processing and analysis.

REFERENCES

1.R. S. Khandpur, Hand Book of Biomedical instrumentation, Tata McGraw Hill Publication, 2019.

2. R. AnandaNatarajan, Biomedical Instrumentation & Measurements, PHI Publication, 2015.

3.Cromwell, Biomedical Instrumentation & Measurements Prentice-hall of India private limited, 2011.

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DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – III – DIAGNOSTIC INSTRUMENTATION – SBM1301

UNIT III

FLOW METERS

3.1 Flow meters

A flow meter is an instrument used to measure linear, nonlinear, mass or volumetric flow rate of a liquid (blood) or a gas.

3.1.1 Electromagnetic flow meters

These are commonly used to measure blood flow. The two factors that determine the flow of blood through blood vessels are the pressure gradient between two points in the blood vessels and the resistance because of friction.

Noninvasive electromagnetic flow meter was introduced by Fabre where as Kolin and Wetterer found the invasive measurement. Blood can be measured in intact blood vessels without cannulation but the blood vessel should be exposed so that flow head/measuring probe can be put across it. Electromagnetic blood can measure a cardiac output of 4l/min to 25l/min with a frequency range of dc to 20 Hz

Principle

The operation principle behind the electromagnetic blood flow meters is Faraday's law of electromagnetic induction which states that if electrical current carrying conductor moves at right angle through a magnetic field, an electromotive force is induced in the conductor.

In the case of electromagnetic blood flow meters, while the blood flows between forces of magnetic field, which are provided by the electromagnetic blood flow meters, voltage is induced in the blood stream. The induced voltage is perpendicular to the magnetic field and the direction of the flow of blood. Then this voltage is picked up by the blood flow transducer probes placed 90 degree to the direction of the blood flow.

Working

A circular probe with a gap to fit the vessel is fitted around the vessel. This probe applies an alternating magnetic field across the vessel and detects the voltage induced by the flow via small electrodes in contact with the vessel.

The magnitude of the voltage is proportional to the strength of the magnetic files,diameter of blood vessel and velocity of blood flow.

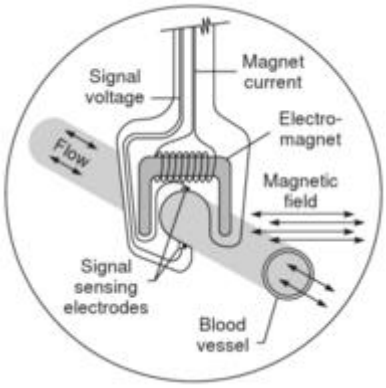

Fig 3.1 EM Assembly

Alternating magnetic fields (typically at 400 Hz) are used since the induced voltages are in the microvolt region and d.c. electrode potentials may cause significant errors with unchanging magnetic fields.

$$e = CHVd$$

where e = induced voltage

C = constant

H = strength of magnetic field

V = velocity of the blood flow

d = diameter of the blood flow

Since H and d are constants, e is directly proportional to V.

$$e = C_1 V \ (C_1 = CHd)$$

Flow rate Q = VA ; V = Q/A A = area of c.s of tube

$$e = C_1 \times Q/A$$

$$= C_2 Q \ (C2 = C_1/A)$$

Therefore the induced voltage is proportional to the flow rate through blood vessel.

The tube is made of a non magnetic conducting material and is insulated. The electrodes are made of Stainless steel or Platinum. A number of probes are required to fit the various diameters of blood vessel. The size varies between 1-24 mm.

An alternative design carries the sensing device on the tip of a special catheter which passes inside the vessel and generates a magnetic field in the space around it and has the electrodes on its surface.

Average flow velocity in arteries = 20-25 cm/s and veins = 10-12 cm/s.

Types

A flowmeter consists of a generator of AC, a robe assembly, series of capacitance coupled amplifiers, demodulator, a dc amplifier and a recording device.

Sine wave electromagnetic blood flow meters

The sine wave electromagnetic blood flow meter uses wave alternating current to generate the required magnetic field. The induced voltage is also sinusoidal.

The main drawback of the sine wave electromagnetic blood flow meter is the induction of transformer voltage. The blood vessel and the blood that flows through it act as the secondary winding of the transformer which in turn generates the transformer voltage. Hence it requires complex circuitry but has a good signal to noise ratio.

Square wave electromagnetic blood flow meters

In the square wave electromagnetic blood flow meter, the excitation is square wave alternating current, and the induced voltage is square wave too.

In the square wave electromagnetic blood flow meter, the transformer voltage appears as a spike at the beginning of the square wave induced voltage which can be easily removed by using gated amplifier.

Applications

The electromagnetic blood flowmeter is sometimes used during vascular surgery to measure the quantity of blood passing through a vessel or graft, before during or after surgery.

3.1.2 Ultrasonic Blood flow meters

An ultrasonic blood flow meter is a type of flow meter that measures the velocity of a blood with ultrasound to calculate volume flow.

There are two types of US flow meters- Transit time velocity meter and Doppler shift meter.

Transit time velocity meters

It measures the difference in travel time between pulses transmitted in the direction of, and against, the flow. This type of meter is also called time of flight and time of travel.

A cuff is placed around an artery, and it incorporates 2 crystals diagonally placed on either sides of the vessel. Both the crystals act as transmitter and receiver. Transit time is measured by starting a ramp voltage rising with each burst emitted and which is stopped by the reception of the pulse.

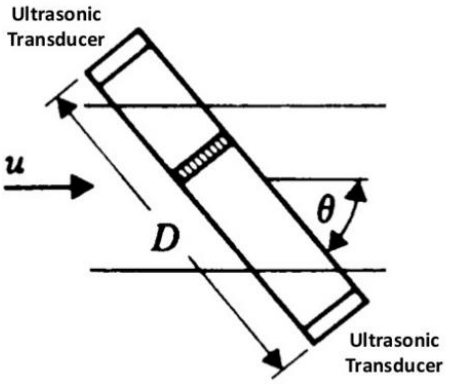

Fig 3.2 Transit US flowmeter

The transit time is shortened when the blood flows in the same direction as the transmitted energy.

t = distance / conduction velocity

$t = D / c +\_ u \cos \theta$

where t – transit time

D – distance between the transducers

c – sound velocity

u – blood flow velocity

Doppler shift US flowmeters

These are used for routine clinical measurements. They are used for the measurement of blood velocity, volume flow, flow direction and flow profile.

The apparent difference between the frequency at which sound or light waves leave a source and that at which they reach an observer, caused by relative motion of the observer and the wave source.

It is a measure of the size and direction of flow velocity.

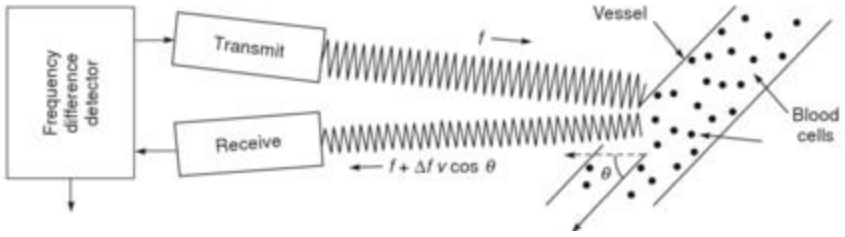

Fig 3.3 Doppler US Flowmeter

Principle

Incident US is scattered by blood cells and the scattered wave is received by the receiver.

The frequency shift due to the scattering is proportional to the velocity of the scatterer. There is a change in frequency as the US arrives at the receiver after it is scattered by the blood cells.

$$f_d = \frac{2f_0 u \cos\theta}{c}$$

Where,

fd = Doppler frequency shift

fo = source frequency

u = target velocity / velocity of blood cells

c = velocity of sound in blood

This forms the basis of measuring blood velocity. Velocity is directly proportional to difference in frequency.

3.1.3Laser Doppler Blood flow meters

Laser Doppler is a standard technique for the non-invasive blood flow monitoring and measurement of blood flow in the microcirculation.

Principle

The laser Doppler technique measures blood flow in the very small blood vessels of the microvasculature, such as the low-speed flows associated with nutritional blood flow in capillaries close to the skin surface and flow in the underlying arterioles and venules involved in regulation of skin temperature.

The technique depends on the Doppler principle whereby low power light from a monochromatic stable laser (a), e.g. a Helium Neon gas laser at a power of 5mW and 632.8nm or a single mode laser diode, incident on tissue is scattered by moving red blood cells and as a consequence is frequency broadened (b). The frequency broadened light, together with laser light scattered from static tissue, is photo detected and the resulting photocurrent processed to provide a blood flow measurement.

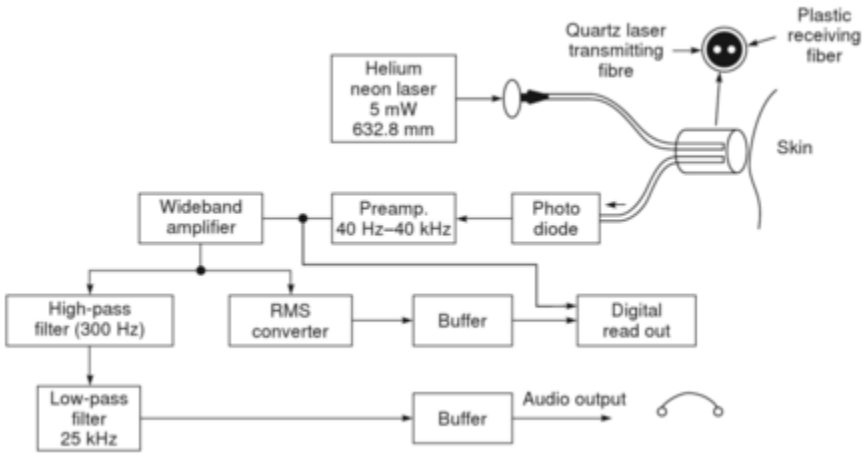

Fig 3.4 Laser doppler flowmeter

Laser light can be directed to the tissue surface either via an optic fibre or as a light beam. In some cases optic fibre terminates in an optic probe which can be attached to the tissue surface. One or more light collecting fibres also terminate in the probe head and these fibres transmit a proportion of the scattered light to a photodetector and the signal processing electronics.

Lasers scattered by moving blood particles undergo change in frequency (Doppler Shift) and these beams are received by a plastic fibre at the skin and are transmitted to photo diode.

Heterodyned optical signal is proportional to the Doppler shift frequency and signal is amplified.

The RMS value of output signal is calculated and the total zero light noise is filtered from it.

The output voltage gives the output flow velocity on a display device.

An audio output can also be added to hear the flow pattern.

3.1.4 NMR Blood flow meters

A non invasive method for measurement of peripheral blood flow or blood flow in organs.

The principle behind NMR is that many nuclei have spin and all nuclei are electrically charged. If an external magnetic field is applied, an energy transfer is possible between the base energy to a higher energy level . The energy transfer takes place at a wavelength that corresponds to radio frequencies and when the spin returns to its base level, energy is emitted at the same frequency.

The signal that matches this transfer is measured in many ways and processed in order to yield an NMR spectrum for the nucleus concerned.

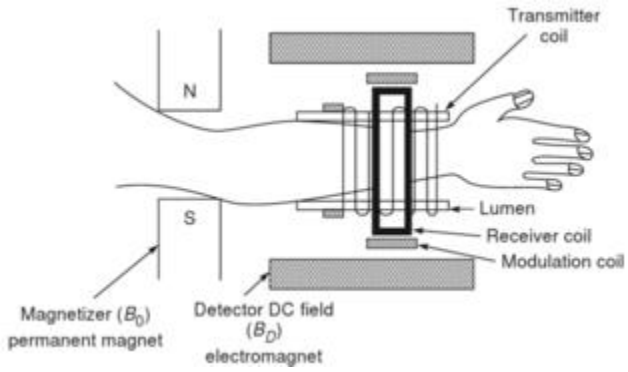

Fig 3.5 NMR blood flowmeter

The NMR signals help in the detection of presence of hydrogen atoms in blood and hence magnitude of magnetization is found. The magnitude of magnetization can be related to the flow rate or flow velocity.

3.2 Cardiac Output Measurement

Cardiac output is the volume of blood pumped by the heart per minute (mL blood/min).

Cardiac output is a function of heart rate and stroke volume. The heart rate is simply the number of heart beats per minute. The stroke volume is the volume of blood, in milliliters (mL), pumped out of the heart with each beat. Increasing either heart rate or stroke volume increases cardiac output.

Cardiac Output in mL/min = heart rate (beats/min) X stroke volume (mL/beat)

An average person has a resting heart rate of 70 beats/minute and a resting stroke volume of 70 mL/beat.

The cardiac output for this person at rest is:

Cardiac Output = 70 (beats/min) X 70 (mL/beat) = 4900 mL/minute.

The total volume of blood in the circulatory system of an average person is about 5 liters (5000 mL).

There are 3 measurement techniques. They are

Indicator Dilution method,

Dye dilution method,

Thermal dilution method

3.2.1 Indicator Dilution method

The principle behind the method states that the volume flow of blood from the heart can be estimated by introducing a known amount of indicator and measuring the concentration difference upstream and downstream of the injection site.

An indicator is a substance that permits observations of some element of volume of the fluid under study. The indicator shows the position of the element of volume in space and with respect to time, and distinguishes the indicated element from all other elements of volume.

In the method, a known quantity of indicator is introduced into a fluid flowing at unknown rate through a system of unknown volume. Fluid is sampled or monitored at one or more points downstream from the plane of introduction and the concentration of indicator, diluted by the parent fluid, is measured as a function of time. Indicator may be introduced at a constant rate in the form of injections or as a bolus. The presence of an indicator is detected by a photoelectric transducer and is displayed on the chart recorder and the dilution curve is obtained.

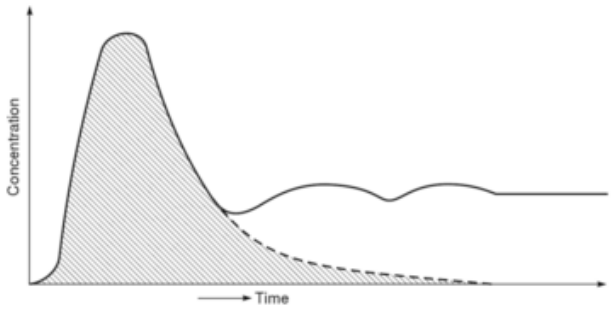

Fig 3.6 Dilution curve

Amplitude of curve depends on the quantity of injected indicator and total quantity of circulating blood.

3.2.2 Dye dilution method

The Dye dilution method is based on the measuring of the light absorbance of the dye injected into the blood.

A known quantity of a dye is rapidly injected into one site of the circulatory system, and withdrawing blood at a distal site for determination of a concentration curve of the dye.

The dye (Indo-Cyanine Green) is injected by special pulmonary catheter. Dyed blood is continuously sucked into the absorption photometer or IR photo cell transducer. Its absorption is maximum in the infrared part of the spectrum (at 805 μm) – where oxyhaemoglobin and reduced haemoglobin transmit light equally.

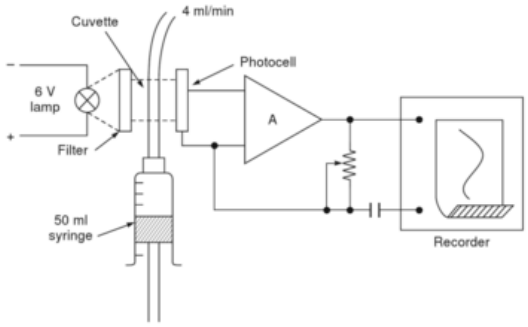

Fig 3.7 Dye dilution setup

Cardiac output = Quantity of dye injected x 60 / Avg. conc of dye in each ml of blood for the duration of the curve x duration of curve in Sec.

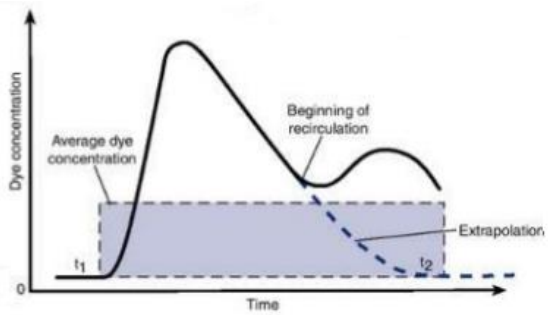

Fig 3.8 Dye Dilution curve

After output is measured, saline is injected to flush the dye out of the circulating blood.

3.2.3 Thermal dilution method

Thermodilution is an indicator-dilution method of measuring blood flow. This method is based on the fact that when an indicator substance is added to circulating blood, the rate of blood flow is inversely proportional to the change in concentration of the indicator over time.

The indicator substance can be a dye (dye-dilution method) or a fluid with a different temperature than blood (thermodilution method).

A 5% dextrose or saline solution that is colder than blood is injected through the proximal port of the catheter in the right atrium. The cold fluid mixes with blood in the right heart chambers, and the cooled blood is ejected into the pulmonary artery and flows past the thermistor on the distal end of the catheter. The thermistor records the change in blood temperature with time and sends this information to an electronic instrument that records and displays a temperature-time curve. The area under this curve is inversely proportional to the rate of blood flow in the pulmonary artery. In the absence of intracardiac shunts, this flow rate is equivalent to the (average) cardiac output.

Blood temperature is measured over a range of 30-40^{o}C.

Cardiac Output = constant x (blood temp-injectate temp) / area under dilution curve

REFERENCES

1.R. S. Khandpur, Hand Book of Biomedical instrumentation, Tata McGraw Hill Publication, 2019.

2. R. AnandaNatarajan, Biomedical Instrumentation & Measurements, PHI Publication, 2015.

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PATIENT MONITORING SYSTEMS

4.1 BP measurement

Blood pressure (BP) is the pressure exerted by circulating blood upon the walls of blood vessels. Blood pressure usually refers to the arterial pressure in the systemic circulation. It is usually measured at a person's upper arm. Blood pressure is usually expressed in terms of the systolic (maximum) pressure over diastolic (minimum) pressure and is measured in millimeters of mercury (mm Hg). It is one of the vital signs along with respiratory rate, heart rate, oxygen saturation, and body temperature. Normal resting blood pressure in an adult is approximately 120/80 mm Hg.

The highest pressure in the arteries, produced as a result of ventricular contraction is known as the systolic blood pressure. The lowest pressure in the arteries, produced as a result of ventricular relaxation is known as the diastolic blood pressure. The difference between the systolic and the diastolic pressure is known as the pulse pressure. The average effective arterial pressure forcing blood through the organs is known as the mean arterial blood pressure. This is determined by adding one-third of the pulse pressure to the diastolic pressure.

4.1.1 Direct and indirect method

Two methods for measuring a blood pressure exist, the direct and indirect method.

Direct BP measurement

In the direct method, a fluid-filled cannula is inserted into an artery and the direct, head-on pressure of the blood is measured with a pressure transducer.

The direct method is the criterion standard and consists of using an intra-arterial catheter to obtain a measurement.

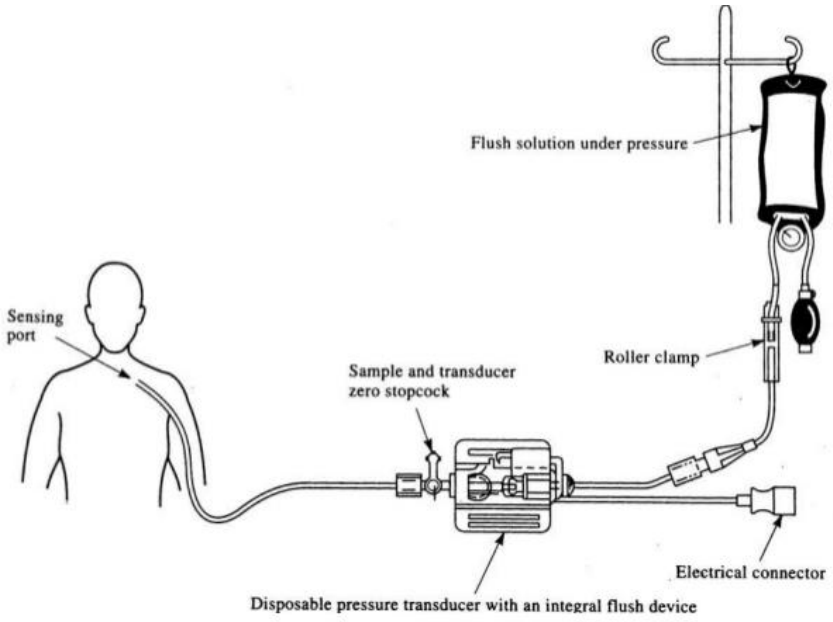

Fig 4.1 Direct BP Measuring Setup

Indirect BP measurement

Sphygmomanometer/Ausculatory method

Pressure is applied externally to an artery occluding it and stopping blood flow. Then the blood pressure is determined by listening to various arterial sounds (korotkoff sounds) that result when the external pressure is reduced and the blood begins to flow again. This is called the Auscultatory Method since the detection of sound is called "auscultation".

In both indirect methods pressure is applied externally to an artery using an instrument called a sphygmomanometer. It consists of an inflatable rubber bag (cuff), a rubber bulb for introducing air into the cuff, and a mercury or aneroid manometer for measuring the pressure in the cuff. The cuff size used varies depending on the circumference of the arm.

Human blood pressure is most commonly measured in the brachial artery of the upper arm. In addition to being a convenient position for taking measurements, it has the added advantage of being at approximately the same level as the heart so that pressures obtained closely approximate the pressures in the aorta leaving the heart. This allows the blood pressure to be correlated with heart activity.

Oscillometric Method

Oscillometric measurement devices use an electronic pressure sensor with a numerical readout of blood pressure. In most cases the cuff is inflated and released by an electrically operated pump and valve, which may be fitted on the the upper arm. Initially the cuff is inflated to a pressure in excess of the systolic arterial pressure, and then the pressure reduces to below diastolic pressure. Once the blood flow is present, but restricted, the cuff pressure will vary periodically in synchrony with the cyclic expansion and contraction of the brachial artery. The values of systolic and diastolic pressure are computed from the raw data, using an algorithm.

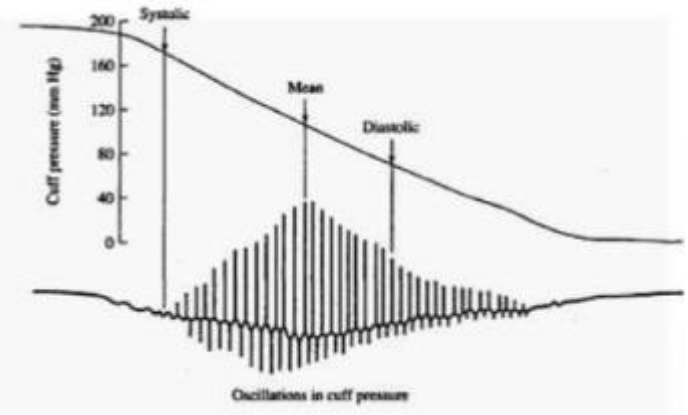

Fig 4.2: Oscillometric Curve

It evaluates the oscillations of the arteries. Those oscillations have a very typical curve. The oscillations occur when the blood flow first is interrupted and than starts flowing again. They become stronger, than diminish until they disappear when the blood starts flowing normally.

Both the systolic and diastolic value is calculated with the help of an algorithm. The calculated values are than visualized on the display.

4.2 Pulse Rate Analysis

Pulse rate is the rate at which the heart beats. The pulse is usually called heart rate, which is the number of times the heart beats each minute.

As the heart pumps blood through your body, you can feel a pulsing in some of the blood vessels close to the skin's surface, such as in your wrist, neck, or upper arm.

When the heart muscle contracts, blood is ejected from the ventricles and a pressure pulse is transmitted through the circulatory system. This pressure pulse displaces the vessel wall when

traveling through the vessels. The pulse wave travels at 5 to 15m/s depending on the size and rigidity of the arterial walls. The velocity is high for large and more rigid artery walls. The velocity is 10 to 15 times faster than blood flow and is relatively independent of it. The pulse can be felt by placing the finger tip over the radial artery in the wrist or wherever an artery is just below the skin. The pulse pressure, timing and waveform are indicators for blood pressure and flow. Instruments used to detect the arterial pulse and pulse pressure waveforms in the extremities are called plethysmographs.

Three methods to measure pulse rate are

1. Electrical impedance method
2. Strain gauge method or microphone
3. Photoelectric method/Optical method

1. Electrical impedance method: The impedance change occurring between two electrodes attached to the body, due to change in the blood volume between them is measured. This is done by applying an alternating current (10 - 100 kHz) between the electrodes. The alternating current is used instead of dc in order to prevent polarization of the electrodes. The change in impedance (0.1 ohm) is very small compared to the total impedance (several hundred ohms).

2. Mechanical Method: A strain gauge is connected to a rubber band placed around a limb or a finger. The resistance of the strain gauge changes when the band expands due to change in blood volume. A semiconductor strain gauge can also be used. In another technique, a sensitive crystal microphone is placed on the skin's surface to pick up the pulsation.

3. Optical method (Photoelectric Plethysmography): The most commonly used method to measure the blood volume changes is by photoelectric method. Two methods are common: Reflectance method and transmittance method.

a) Transmittance method: A LED and a photoresistor connected as part of a voltage divider circuit are mounted in an enclosure that fits over the tip of the patient's finger. Light is transmitted through the finger tip and falls on the photoresistor. With each contraction of the heart, the blood is forced into the finger and the amount of blood in the finger increases. Hence the light transmitted by the finger reduces and hence the resistance of the photoresistor increases. Thus the voltage drop across the photoresistor varies according to the amount of blood in the

finger. This voltage displayed on an oscilloscope or recorded on a strip-chart recorder, closely follows the wave shape of the pressure pulse.

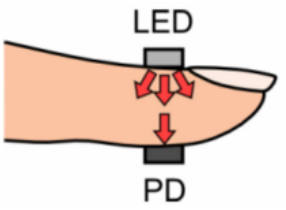

Fig 4.3: Transmittance Method

b) Reflectance method: The photoresistor is placed adjacent to an LED. Part of the light rays emitted by the LED is reflected and scattered from the skin and tissues, based on the amount of blood in the finger, and falls on the photoresistor. Hence the voltage drop across the photoresistor varies according to the amount of blood in the finger. Change in voltage is proportional to pulse rate.

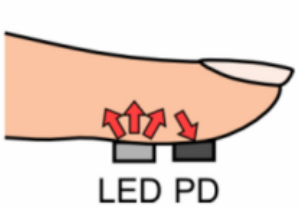

Fig 4.4: Reflectance Method

The LED's used are Ga-As(Gallium Arsenide) IR emitting diode.

Advantages of measuring pulse:

1. The monitoring of pulse is more useful and dependable that monitoring the heart rate derived from ECG in the case of a heart block because it immediately indicates the cessation of blood circulation in the limb terminals.
2. Photoelectric transducer is much easier to apply than three ECG electrodes.
3. The amplitude of plethysmographic signal is large compared to ECG signal and therefore gives better signal to noise ratio.

Disadvantages: However, the technique is severely subject to motion artifacts.

4.3 Temperature measurement

A central monitoring system makes use of a thermistor for measurement of temperature. Change in resistance of thermistor with corresponding change in temperature unbalances a bridge circuit. The unbalanced signal is indicated on a meter calibrate in terms of temperature.

The range of temperature measured is 30^{o}-42^{o}C.

A thermistor is a resistance thermometer, or a resistor whose resistance is dependent on temperature. Thermistors are easy to use, inexpensive, sturdy, and respond predictably to changes in temperature.

4.4 Respiration Rate

Human respiration rate is measured when a person is at rest and involves counting the number of breaths for one minute by counting how many times the chest rises. Or the rate at which the rhythmic activity of inhalation and exhalation takes place under normal circumstances is called respiration rate. T

The typical respiratory rate for a healthy adult at rest is 12–20 breaths per minute.

The different methods for measuring respiration rate are –

1. Displacement method
2. Thermistor method
3. Impedance pneumography method
4. CO_2 method.

Displacement method

Respiratory cycle is accompanied by changes in thoracic volume. Thorax expands and come back to normal during respiration.

Transducers like strain gauges are held by an elastic band around the chest. During respiration, there is a resistance change in the strain gauge element connected as one arm of the Wheatstone's bridge. The output signals correspond to the respiratory activity.

Thermistor Method

Air is warmed during its passage through the respiratory system. There is a detectable difference between the temperature of inspired air and expired air. The difference in temperature can be sensed by placing a thermistor in front of the nostrils using a holding device. The thermistor is a part of the voltage divider circuit whose unbalanced signal can be amplified to obtain the respiration activity.

Impedance pneumography method

Impedance pneumography is a technique to measure respiration rate.

Impedance pneumography employs low amplitude, high frequency (50 to 500

kHz) alternating current (AC) between two surface electrodes to record thoracic movements or volume changes at the rib cage (RC) during a respiratory cycle. Based on Ohm's Law, the voltage drop across the electrodes is computed as impedance, which increases during inspiration and decreases during expiration.

A high-frequency ac current is injected into the tissue through the drive electrodes. The ac current causes a potential difference to develop across any two points

between the drive electrodes. This potential difference is related to the resistivity of the tissue between the voltage-sensing or receive electrodes. The equivalent resistance is defined as the ratio of the voltage difference between the two receive electrodes and the current that flows through the tissue.

When measuring respiration, the thorax presents an electrical impedance to the electrode that consists of two impedance components: a relatively constant value and a varying value. The relatively constant value of thoracic impedance is referred to in this document as the baseline impedance, or RB (typically 500 Ω;). The varying value, on the other hand, is known as respirative impedance, or ΔR.

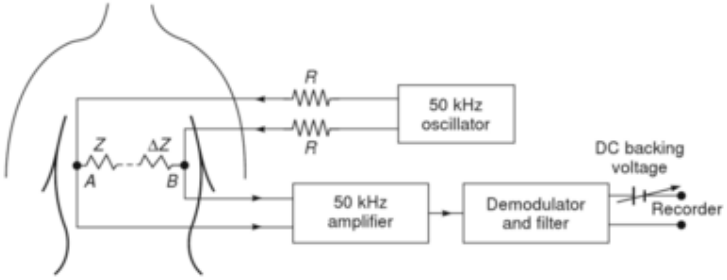

Fig 4.5: Impedance Pnuemography Setup

Changes in the electrical resistance of the lungs are mainly a result of the following two effects:

1. During inspiration, there is an increase in the gas volume of the chest in relation to the fluid volume; this increase causes conductivity to decrease.
2. During inspiration, the length of the conductance paths increases because of expansion.

Taken together, both of these effects cause the electrical impedance to increase. There is a good correlation between this impedance change and the volume of respirated air. This relationship is approximately linear. The varying component of impedance (that is, respirative impedance), generates a varying voltage component (ΔV) when current is injected. This varying voltage component is the parameter of interest because this component can then be used to determine the person's breathing rate.

Typically, ΔR is in the range of 0.1 Ω to 1 Ω. ΔV, in turn, depends on the magnitude of the current injected.

4.5 Central Monitoring System

Continuous monitoring is a valuable tool that helps provide additional information to the medical and nursing staff about the physiologic condition of the patient.

Depending on their configuration, central monitors include modules to measure various parameters, including ECG, respiratory rate, NIBP and IBP, body temperature, SpO2, cardiac output, intracranial pressure, and airway gas concentrations. They include computing capabilities and additional displays to observe trend information. They do not replace bedside monitors.

Central Station is a powerful computer with one or two color displays, with a sound alarm system, laser and thermal printers.

Central Station provides:

Comprehensive review

Remote control access

Reception, analysis and documentation of real-time information

Continuous monitoring of basic parameters of patient’s condition

Patients databases maintenance

Data exchange within a local hospital or the global information network

Central Station enables bed-to-bed viewing of alarms, waveforms, numerical values and trends between network monitors.

It performs the following functions:

Real-time patients information input received from bedside patient monitors (up to 32 bedside patient monitor selection of the necessary quantity of patient monitors to be visualized from connected monitors list)

Simultaneous visualization of information received from up to 16 monitors on the system display

Real-time visualization of all parameters (depending on monitor configuration) received from patient monitor and waveforms – not less than 2 waveforms for one monitor during joint observation and up to 9 waveforms for one selected monitor

Details of each monitor are displayed in a separate independent window

Output up to 2 waves for each patient, while monitoring 16 patients (4 waves - for 8 patients, 8 waves - for 4 patients in real time)

Ability to view extended information on each monitor (all ECG leads, trends and parameters of HRV)

Displays the short trend - up to 4 parameters in the last 10 minutes

Freezing of displayed waveforms for selected monitor

Maintenance of current and archive database (patient data are kept after their discharge)

Record of user chosen information into database – 20s of ECG interval and 72h of trends

Automatic recognition of arrhythmia events and its types (with automatic saving of 20s ECG intervals in database)

Entering, editing and saving patient identification data

Three-level alarm system individually for each patient with the priorities for each parameter

Color coding of alarm levels

Documentation of patient data on laser and thermal printers

In case of high priority alarm automatically prints out up to 20 sec. of two ECG-waveforms on the thermal printer

4.6 Endoscope

The basic technology behind the modern endoscope was developed in the early 1950s by English physicist Harold Hopkins.

Endoscope is an instrument used to examine the interior of a hollow organ or cavity of the body. The device uses fiber optics and powerful lens systems to provide lighting and visualization of the interior of a joint. The portion of the endoscope inserted into the body may be rigid or flexible, depending upon the medical procedure.

Endoscopes may be rigid or flexible. The two types differ in appearance, but function in similar ways.

Flexible endoscopes are useful for looking at the digestive and respiratory tracts because they bend in places. They use fibre optics to shine light into the body.

Rigid endoscopes are much shorter than flexible endoscopes. They are used to look at the surface of internal organs, and may be inserted through a small cut in the skin. Rigid endoscopes are commonly used to examine the joints.

Components

An endoscope consists of

- a rigid or flexible tub
- a light delivery system to illuminate the organ or object under inspection. The light source is normally outside the body and the light is typically directed via an optical fiber system.
- a lens system transmitting the image from the objective lens to the viewer, typically a relay lens system in the case of rigid endoscopes or a bundle of fiberoptics in the case of a fiberscope.
- an eyepiece.
- A camera transmits image to a screen for image capture.
- an additional channel to allow entry of medical instrument like foreceps, scissors,etc.

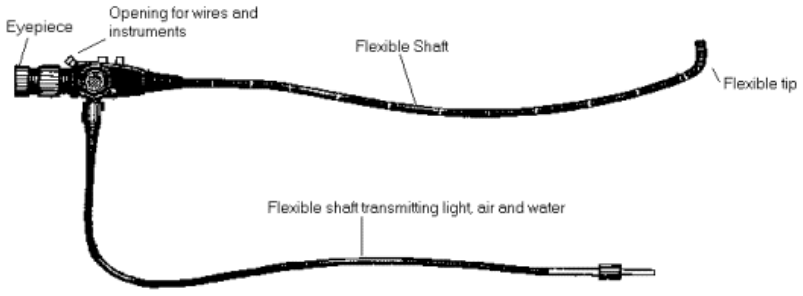

Fig 4.6 Endoscope

Working

Light from a bright lamp outside the patient's body shines into one of the endoscope tubes.

The light bounces along the walls of the fiber-optic endocope tube into the patient's body cavity.

The diseased or injured part of the patient's body is illuminated by the light shining in.

Light reflected off the body part travels back up a second fiber-optic tube, bouncing off the glass walls as it goes.

The light shines up into the physician's eyepiece so, looking down, the physician can see what's happening inside the patient's body

Types of endoscopes

Arthroscope: Joints

Bronchoscope: Esophagus and lung

Colonoscope: Colon and bowel

Cytoscope: Bladder

Duodenoscope: Small intestine

Esophagogastroduodenoscope: Esophagus, stomach and small intestine

Fetoscope: Womb

Gastroscope: Stomach

Hysteroscope: Womb

Laparoscope: Abdomen

Laryngoscope: Larynx

Rhinoscopy - examination of the inside of the nose.

Sigmoidoscope: Large intestine

Thoracoscope: Thorax

Applications

Endoscopy allows doctors to check for irritation, ulcers, inflammation and abnormal tissue growth in the internal organs. It can be used to close off a blood vessel or remove small growths.

4.7 Oximetry

Oximetry is a noninvasive method for monitoring a person's oxygen saturation (SpO2).Oxygen saturation is an indication of the cardio-pulmonary functions.

Types Of Oximetry

Two types of oximetry are there – invitro and invivo oximetry.

in Vivo oximetry

The oxygen saturation of the blood is measured while blood is flowing through the vascular system by means of transducers.

(a) Pulse Oximetry

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band.

Pulse oximetry uses a light emitter with red and infrared LEDs that shines through a reasonably translucent site with good blood flow. Typical adult/pediatric sites are the finger, toe, pinna (top) or lobe of the ear. Infant sites are the foot or palm of the hand and the big toe or thumb. Opposite the emitter is a photodetector that receives the light that passes through the measuring site.

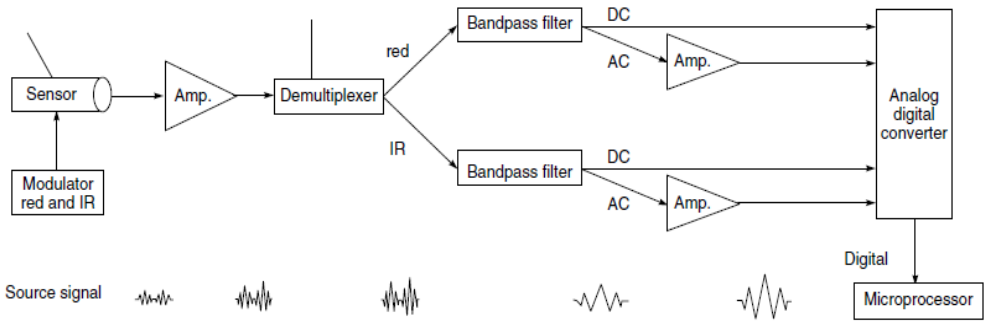

Fig 4.7: Pulse oximeter

There are two methods of sending light through the measuring site: transmission and reflectance. In the transmission method, the emitter and photodetector are opposite of each other with the measuring site in-between. The light can then pass through the site. In the reflectance method, the emitter and photodetector are next to each other on top the measuring site. The light bounces from the emitter to the detector across the site. The transmission method is the most common type used and for this discussion the transmission method will be implied.

After the transmitted red (R) and infrared (IR) signals pass through the measuring site and are received at the photodetector, the R/IR ratio is calculated. The R/IR is compared to a "look-up" table (made up of empirical formulas) that convert the ratio to an SpO2 value. Most manufacturers have their own look-up tables based on calibration curves derived from healthy subjects at various SpO2 levels. Typically a R/IR ratio of 0.5 equates to approximately 100% SpO2, a ratio of 1.0 to approximately 82% SpO2, while a ratio of 2.0 equates to 0% SpO2.

(b) **Ear Oximeter-**

Transmission principle used to measure the arterial oxygen saturation. Pinna of the ear acts as a cuvette. Technique involves measuring the optical transmittance of the ear at 8 wavelengths in the 650 to 1050 nm range. 2.5 m long flexible fibre ear probe connects the patient to the instrument. Resulting light transmissions are processed digitally according to a set of empirically determined constants and the resulting oxygen saturation results are displayed in the digital form. The instrument is based on the Beer-Lambert law.

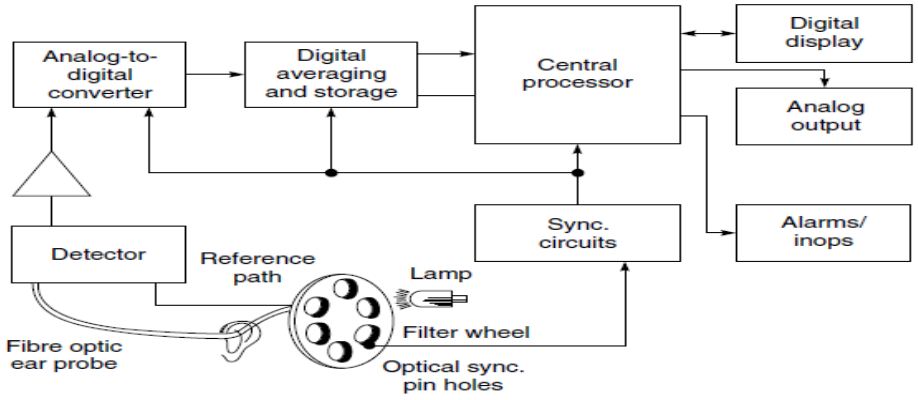

Fig 4.8 Ear Oximeter

Light source is a tungsten-iodine lamp .Lens system collimates the light beam and directs it through thin-film interference filters that provide wavelength selection. Mounted in the periphery of a wheel rotating at 1300 rpm and thus cut the light beam sequentially. Filtered light beam enters a fibre optic bundle that carries it to the ear. Another fibre optic bundle carries the light passing through the ear back to a detector in the instrument. Second light path is developed with a beam splitter in the path of the collimated light beam near the source. This path also passes through the filter wheel and then through a fibre optic bundle directly to the photodetector. Detector receives two light pulses for each wavelength. Processor takes the ratio of two pulses as the measured value; Current developed is less and amplified in a high gain amplifier and converted to a 16-bit digital form by an A-D converter synchronized with the wheel rotation. Given to a digital signal averager that averages out the noise content of the signal with a time constant of 1.6 s and secondly it serves as a buffer to hold information till it is required for computation

In Vitro Oximetry

The oxygen saturation is measured by taking the blood out of the body and measuring in a lab.

2 methods- Transmission and Reflection Oximetry

Transmission Oximetry-

Spectrophotometric method

Concentrations of substances held in solution are measured by determining the relative light attenuations that the light absorbing substances cause at each of several wavelengths. Follows Beer-Lambart's law. Intensity of transmitted light I is related to the incident light

- I_O, *as follows:*
    - $I = I_O^{-kCb}$

where *K absorption coefficient and varies as a function of the substance and the* wavelength of light.

C- concentration of medium

B- thickness of medium

Reflection Oximetry- based on the scattering of light by the erythrocytes.

Light from a tungsten filament lamp (E) is condensed on the plane bottom of a cylindrical cuvette (F). Cuvette -15 mm internal diameter and contains about 2 ml of whole blood.

Portion of light scattered by sample at an angle of about 1350 with respect to the impinging light is condensed on two matched photoconductors (A and B).

Two interference filters (C and C') limit the light reaching each cell to a narrow band centered at l1 = 650 nm and l2 = 805 nm, respectively. The ratio of the resistance of the photocells is measured by means of a conventional Wheatstone bridge.

REFERENCES

1.R. S. Khandpur, Hand Book of Biomedical instrumentation, Tata McGraw Hill Publication, 2019.

2. R. AnandaNatarajan, Biomedical Instrumentation & Measurements, PHI Publication, 2015.

3.Cromwell, Biomedical Instrumentation & Measurements Prentice-hall of India private limited, 2011.

4. Carr & Brown, Introduction to Biomedical Equipment Technology, 2015.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – V – DIAGNOSTIC INSTRUMENTATION – SBM1301

AUDIO AND VISUAL EQUIPMENTS

5.1 AUDIOMETER

Audiometer is an instrument used in measuring the acuity of hearing. They usually consist of an embedded hardware unit connected to a pair of headphones.

They are most commonly used in hospitals, audiology centers and research communities. These audiometers are also used to conduct industrial audiometric testing. It also measures the ability to discriminate between different sound intensities, recognize pitch, or distinguish speech from background noise.

There are three main types of audiometrical procedures:

Pure tone audiometry
Speech audiometry
Screening audiometry

Pure tone audiometry

This procedure uses an audiometer (an instrument for recording the intensity of sound heard by the patient) to determine the extent of hearing loss. The patient is made to hear pure tones (musical or non-musical) of varying frequencies and intensities. There may be high-pitched sounds played at frequent intervals and the patients response to these are noted. The site of hearing loss can also be determined by the readings on the audiogram. They are given by air conduction by an earmuff, and by a probe put on the bone behind the ear. The patient is seated in a quiet testing chamber and made to wear earphones. Each ear is tested separately. The sounds begin with the lowest frequency that is increased till the person is able to hear the sound. The patient indicates as such by raising a hand, and the audiometer reading is noted.

Speech audiometry

The procedure being essentially the same, speech audiometry utilises human speech instead of pure tones for testing. The test measures patient’s ability to hear a sentence (sensitivity) and to distinguish intelligible speech sounds. The examiner asks the patient to repeat whatever is said to

him and then determines the extent and area of hearing loss. Unlike the clinical speech- hearing assessment, a definite number of words, for a set protocol are used, and the percentage of words understood is noted, and the lowest intensity to understand a set percentage is noted. This helps in differentiating between hearing loss caused due to damage in the hearing organ, and the hearing nerve.

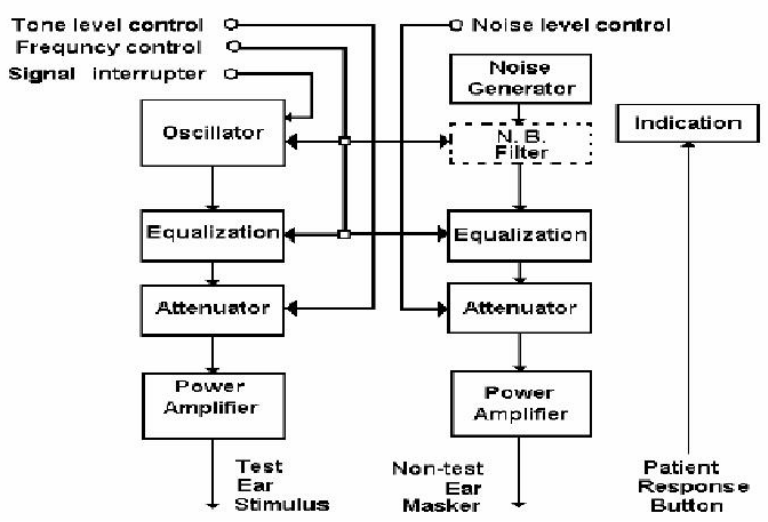

Fig 5.1 Audiometer

5.2 HEARING AIDS

A hearing aid or deaf aid is an electroacoustic device which is designed to amplify sound for the wearer, usually with the aim of making speech more intelligible, and to correct impaired hearing as measured by audiometry.

Parts of Hearing Aids

Hearing aids are fairly simple devices, consisting of four basic parts:

A microphone picks up sound from the environment and converts it into an electrical signal, which it sends to the amplifier. An amplifier increases the volume of the sound and sends it to the receiver. A receiver/speaker changes the electrical signal back into sound and sends it into the ear. Then those impulses are sent to the brain. A battery provides power to the hearing aid.

Types of hearing Aids

In the ear (ITE): This large hearing aid works well for people with mild to severe hearing loss. It fits completely in the bowl of the ear. Because it is so large, the ITE hearing aid is among the most visible of styles, but the battery lasts longer than in smaller aids, and it can accommodate directional microphones.

In the canal (ITC): The ITC hearing aid works only for mild to moderate hearing loss. It is customized to fit the size and shape of the person's ear canal. Although this hearing aid is inconspicuous, its small size makes it difficult to adjust and change the battery.

Behind the ear (BTE): The BTE hearing aid can help with all types of hearing loss, from mild to profound. The electronics are in a case that sits just behind the ear. The case connects by a piece of clear tubing to a plastic piece called an earmold, which sits inside the ear. Sound travels from the earmold into the ear.

Most hearing aids use zinc-air cells, which are powered by oxygen, but a few use mercury batteries.

Analog – This is the original way of transmitting sound. In analog transmission, the signal travels from one media to another without changing shape. The sound waves picked up by the microphone are the same as the signal that is transferred by the hair cells, just electronic and amplified. Analog hearing aids come preprogrammed according to directions provided by your audiologist. In addition, your audiologist can adjust and re-program your analog hearing aid. Because this technology allows for various programs, you can have different programs for different hearing environments. Analog technology is less expensive than digital technology.

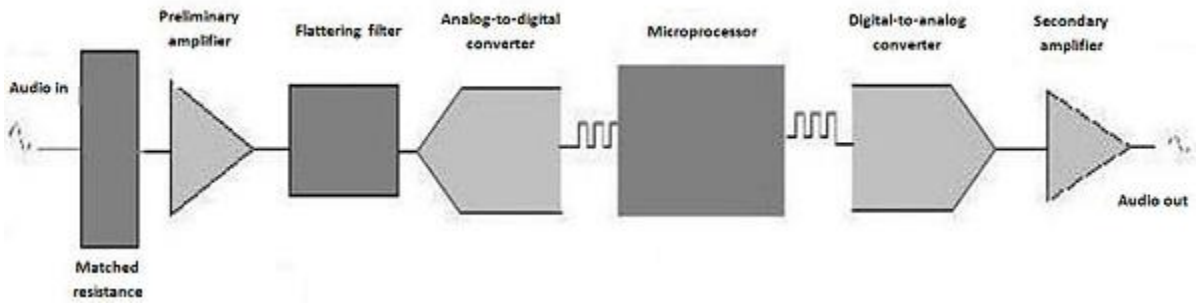

Fig 5.2 Digital Hearing Aid

Digital – The majority of modern hearing aids are digital. Digital devices take the sound signal picked up by the microphone and break it down into binary code before it gets to the amplifier. This binary code is the same series of 1s and 0s that are used in computer communication. What makes digital transmission of data so great is that in addition to transmitting the data, digital can include information about the original transmission. This information helps to detect errors in transmission. Also, the use of digital transmission allows the device to be programmed to act in a specific manner for certain pitches or tones. These devices are also programmable by your audiologist to fit your exact needs, which makes them great when hearing loss is not consistent across all frequencies.

5.3 SPIROMETRY

Spirometry is the most common of the lung function tests. These tests look at how well your lungs work. Spirometry shows how well you breathe in and out. Breathing in and out can be affected by lung diseases such as chronic obstructive pulmonary disease (COPD), asthma, pulmonary fibrosis and cystic fibrosis. Spirometry is the name of the test, whilst a spirometer is the device that is used to make the measurements.

A spirometer measures ventilation, the movement of air into and out of the lungs. The spirogram will identify two different types of abnormal ventilation patterns, obstructive and restrictive. There are various types of spirometers which use a number of different methods for measurement

Procedure

You need to breathe into the spirometer machine. First you breathe in fully and then seal your lips around the mouthpiece of the spirometer. You then blow out as fast and as far as you can until your lungs are completely empty. This can take several seconds. You may also be asked to breathe in fully and then breathe out slowly as far as you can. A clip may be put on to your nose to make sure that no air escapes from your nose. The measurements may be repeated two or three times to check that the readings are much the same each time you blow into the machine.

Spirometry measures the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled. The most common measurements used are:

Forced expiratory volume in one second (FEV1). This is the amount of air you can blow out within one second.

Forced vital capacity (FVC). The total amount of air that you blow out in one breath.

FEV1 divided by FVC (FEV1/FVC). Of the total amount of air that you can blow out in one breath, this is the proportion that you can blow out in one second.

A spirometry reading usually shows one of four main patterns:

Normal.

An obstructive pattern- This is typical of diseases that cause narrowed airways. The main conditions that cause narrowing of the airways and an obstructive pattern of spirometry are asthma and COPD.

A restrictive pattern - This is caused by various conditions that affect the lung tissue itself, or affect the capacity of the lungs to expand and hold a normal amount of air. Conditions that cause fibrosis or scarring of the lungs give restrictive patterns on spirometry.

A combined obstructive/restrictive pattern- asthma plus another lung disorder. Also, some lung conditions have features of both an obstructive and restrictive pattern. An example is cystic fibrosis where there is a lot of mucus in the airways, which causes narrowed airways (the obstructive part of the spirometry results), and damage to the lung tissue may also occur.

Water sealed spirometer

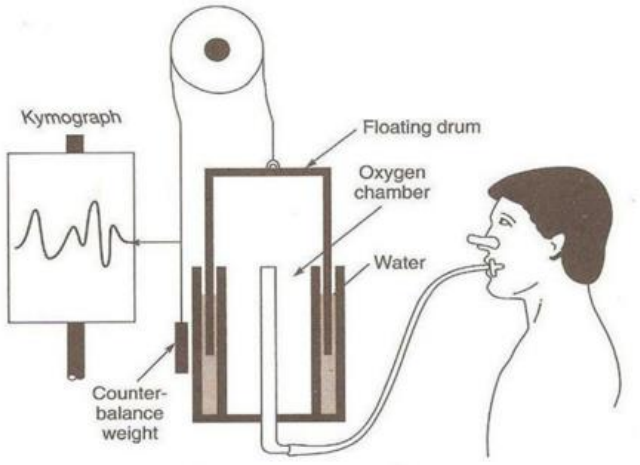

Fig 5.3 Spirometer

The water-seal spirometer is a counterweighted bell inverted into a water reservoir; the bell rises and falls as the patient breathes. Its motion moves either a transducer or a pen that records volume data on calibrated chart paper mounted on a rotating drum (kymograph). The low-friction water seal and counterweight limit resistance and back pressure so that the measurement itself does not adversely affect the patient's response.

Wedge Spirometer

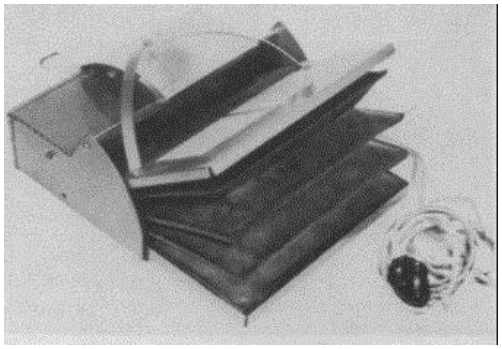

Fig 5.4 Wedge Spirometer

A waterless spirometer constructed of two large rectangular plates with edges connected by accordion-pleated rubber so that large changes in volume are accommodated by small changes in the acute angle of the wedge-shaped interior, sensed by an electrical transducer; designed to record rapid changes in respiratory function.

5.4 AUTO REFRACTOMETER / DIOPTRON

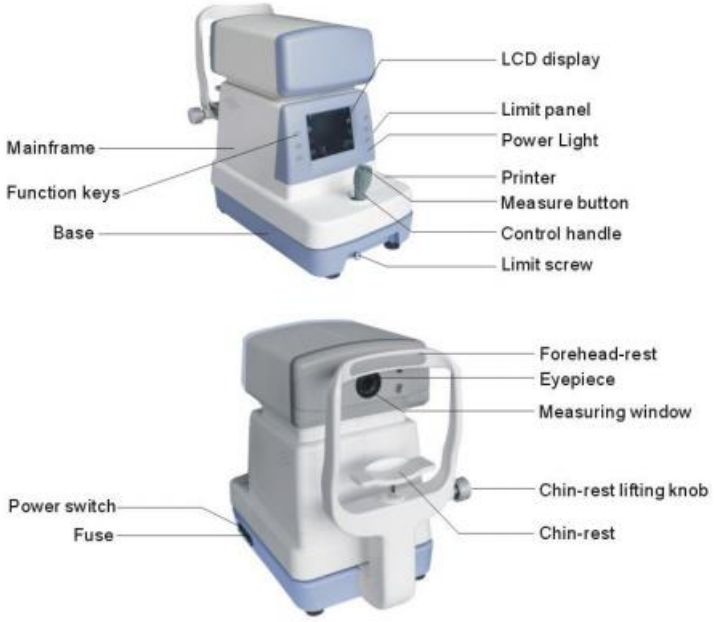

Fig 5.5 Components of Dioptron

An autorefractor or automated refractor is a computer-controlled machine used during an eye examination to provide an objective measurement of a person's refractive error and prescription for glasses or contact lenses. This is achieved by measuring how light is changed as it enters a person's eye.

It is a precision ophthalmic instrument. It is used to measure parameters of farsightedness, near sightedness, astigmatism, axis and pupil distance diagnosis.

Instrument for measuring the refractive state of the eye is an optometer. There are two main types of optometers: subjective and objective. Subjective optometers rely upon the subject's judgment of sharpness or blurredness of a test object while objective ones contain an optical system which determines the vergence of light reflected from the subject's retina. Electronic optometers in which all data appear digitally within a brief period of time after the operator has activated a signal can be of either type. Objective types (also called autorefractors or

autorefractometers) have become very popular and several of these autorefractors are now providing both objective and subjective systems within the same instrument.

Principle

The speed of light in a vacuum is always the same, but when light moves through any other medium it travels more slowly since it is constantly being absorbed and reemitted by the atoms in the material. The ratio of the speed of light in a vacuum to the speed of light in another substance is defined as the index of refraction (aka refractive index or n) for the substance.

The majority of autorefractors calculate the vision correction a patient needs (refraction) by using sensors that detect the reflections from a cone of infrared light. These reflections are used to determine the size and shape of a ring at the back of the eye called the retina. By measuring this zone, the autorefractor can determine when a patient's eye properly focuses an image. The instrument changes its magnification until the image comes into focus. The process is repeated in at least three meridians of the eye and the autorefractor calculates the refraction of the eye, sphere, cylinder and axis.

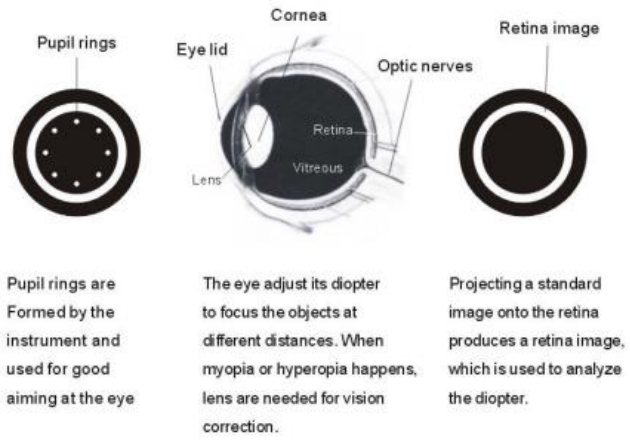

Fig 5.6 Retinal changes during refractometry

The refractometer projects a standard IR image to the retina of the eye. By means of analyzing the image on the retina, it can measure myopia, hyperopia, astigmatism and axis. In order for precision measurement, a good alignment with the eye is essential.

5.5 RETINISCOPY/RETINOSCOPE

Retinoscopy (also called skiascopy) is a technique to objectively determine the refractive error of the eye (farsighted, nearsighted, astigmatism) and the need for glasses. The test can be quick, easy, reliably accurate and requires minimal cooperation from the patient.

The examiner uses a retinoscope to shine light into the patient's eye and observes the reflection (reflex) off the patient's retina. While moving the streak or spot of light across the pupil the examiner observes the relative movement of the reflex or manually places lenses over the eye (using a trial frame and trial lenses) to "neutralize" the reflex. Retinoscope is an instrument which uses refracted light which is send off the pupil, this helps the doctor to determine whether a patient needs corrective lens or not.

Working

When we shine the light of a retinoscope into a person’s eye,we can look at the loght reflected back from the retina.This reflected light is called the retinoscopic relex or ret reflex. It looks like a red light inside the pupil.

Depending on the person’s refractive error,when we move the retinoscope, the ret reflex will move in a particular way inside the pupil.

Types Of Retinoscopy:

There are mainly two types of retinoscopy. They are: Spot and Streak

Spot retiniscope – Has a light globe that gives a patch or spot of light.

Streak retiniscope – Has a special globe that gives a line or streak of light.

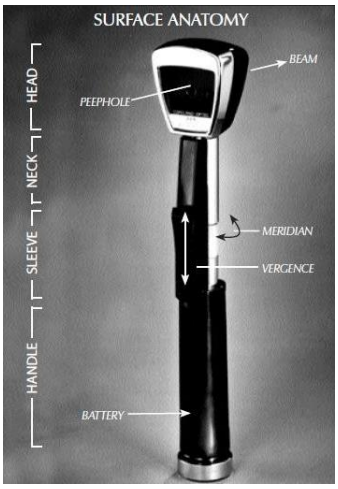

Fig 5.7: Retiniscope

A hand held instrument called a retinoscope projects a beam of light into the eye . When the light is moved vertically and horizontally across the eye, the examiner observes the movement of the reflected light from the back of the eye. This reflection is called red reflex. The examiner then introduces lenses in front of the eye and as the power of the lenses changes, there is a corresponding change in the direction and pattern of the reflection. The examiner keeps changing the lenses until reaching a lens power that indicates the refractive error of the patient.

Parts of a retinoscope

Power switch – Turns the device on and off, controls the brightness of the light

Small globe/Bulb- Provides the light

Electrical Supply – Batteries/Power chord

Mirror- Reflects light from globe to the eye

Sight/Viewing Hole – Allows the ret reflex to be seen.

Sleeve – Rotates the axis of the retinoscope's light and changes the light beam from divergent to convergent.

REFERENCES

1.R. S. Khandpur, Hand Book of Biomedical instrumentation, Tata McGraw Hill Publication, 2019.

2. R. AnandaNatarajan, Biomedical Instrumentation & Measurements, PHI Publication, 2015.

3.Alan. H. Tumadadiffe, Introduction to Visual optics, 2012

4. David. B. Henson, Optometric Instrumentation,2014