UNIT -V

RECENT TRENDS IN MEDICAL INSTRUMENTATION

Thermograph, Endoscopy unit Laser in Medicine, Diathermy unit, Electrical safety in Medical Equipment.

5.1THERMOGRAPH:

Thermography is the process of recording true thermal images of surface of objects under study. In medicine, it displays image representing the thermal radiation of skin areas. Thermogram contains both qualitative and quantitative information relevant to the image and to temperature. Thermography is an important diagnostic aid in many diseases especially in breast cancers and in rheumatic (or) joint diseases. In Breast cancer it is used for early diagnosis. In joint diseases, it is used to record the progress of joint diseases and effect of treatment.

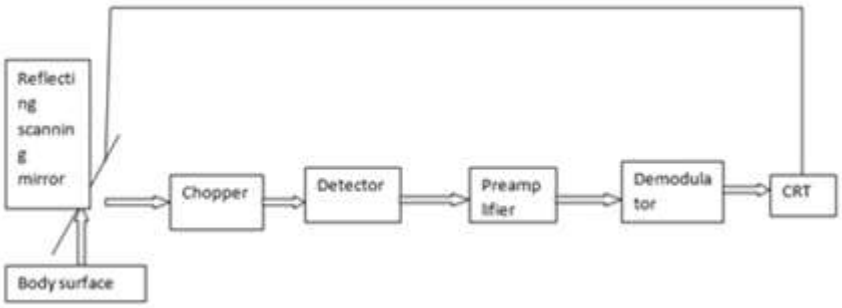

Fig5.1: Simplified block diagram of a thermo graphic equipment

Every thermo graphic equipment is provided with a special Infrared camera that scans the object and Display unit for displaying thermal pictures on screen.

The camera contains an optical system in the form of an oscillating flat plane mirror which scans at a very high speed and focuses the collected infrared radiation onto the chopper.

The chopper disc interrupts the infrared beam so that a.c signals are produced, amplified and demodulated further. The demodulated signals are given to the cathode ray tube in synchronization with scanning mechanism.

The signals are displayed on the screen by intensity modulation which controls brightness and contrast with the strength of signal.

Based on the detection of thermal radiation from skin areas, thermography can be classified into three methods.

1. Infrared Thermography
2. Liquid crystal Thermography
3. Microwave Thermography

5.1.1.Infrared Thermography:

Human skin emits infrared radiation as an exponential function of its absolute temperature and emissive properties of skin temperature. The radiant energy is emitted in a broad band of wavelengths with maximum emission dependent upon surface temperature.

Thermographic examination is carried out in an ambient temperature of 20^0C after a cooling period of about 15 min.Abnormal thermograms have the following:

1. A localized area of temperature increases greater than 1.5^0C.
2. A localized increase in vascularity & its thermal pattem
3. An increase in temperature of one breast

Photovoltaic and Photo- conductive infrared radiation detectors are commonly used. The operation of a thermography apparatus is as follows. A chopper is inserted infront of a Infrared radiation detector.

Infrared radiation from body and from block body enters the detector surface through optical focusing system alternately by chopper to compare the both. The cassegrain optical system is frequently used to collect low energy infrared radiation from skin surface of human body.

The black body is connected with another thermal sensor for compensating. The detected output by detector is amplified and led to phase sensitive detector. The detector output by phase sensitive detector is amplified and given to analog meter or digital meter and the absolute temperature of an object is calibrated and displayed.

For imaging infrared radiation from body is scanned horizontally and vertically with high frequency by a small plane mirror and is focused by a cancer mirror and germanium lens on the detector.

A good thermography equipment must have

- Short frame time
- High resolution
- A small size and light weight optical head
- A wide spectrum band detector
- An easy handling instrument in wards or operation rooms
- Containing interfaces for image processing
- Absolute temperature can be measurable

Solid state electronic circuits can achieve the above said things. There are two types of infrared cameras for medical purpose. a] High speed b] High resolution.

The former type have

i] Shortening picture taking time. ii] Incapable of measuring absolute temperature. Iii] Inferior to latter type with regard to temperature and image resolution.

Infra eye, Thermoscope, Thermoviewer, Thermocamera and Infra vision are of the thermographic equipments.

5.1.2. Liquid Crystal Thermography:

Liquid crystals are a class of compounds which exhibit colour-temperature sensitivity in cholesteric phase. Scattering effects with the material give rise to iridescent colours, dominant wavelength being influenced by very small changes in temperature. The high temperature sensitivity makes cholesteric liquid crystals useful for thermal mapping. In this technique, the temperature sensitive plate consists of a blackened thin film support into which

liquid crystals have been incorporated. Thermal contact between the skin surface and plate produces a colour change in encapsulated liquid crystals.

i] Red for relatively low temperature.

ii] Violet for high temperature.

In Infrared thermograms violet colour is used to identify low temperature regions and the bright colour or red for high temperature regions.

5.1.3. Microwave Thermography:

Microwave emission intensity from skin surface is very small when compared with infrared radiation intensity. Modern microwave radiometer can defect temperature change of 0.1k. Measurement of temperature by this corresponds to radiations from the skin surface to a depth of several cm.

Thermographic system using infrared radiation give a temperature map of skin due to low penetration depth of emitted radiation. Using a microwave receiver a penetration depth of 1 cm in tissue and 8 cm in fat and bone can be obtained.

A severe problem is the unknown emissitivity of the body surface for microwaves, as part of radiation is reflected back into the body. The conventional radiometer causes a measurement error proportional to the temperature difference between body surface and the applied antenna. The error lies in the order of 1-2k.

The problem has been solved by adding artificial microwave noise from the antenna, thus providing a radiation balance between the receiver and body surface. Hence a temperature sensitivity of 0.1k could be obtained. Based on the transducer attachment on the skin surface thermography can be classified into i] Contact Thermography ii] Tele Thermography

To design a thermographs, we must the choice of

- Detector and its response
- Parameters of optical system
- Scanning mechanism
- Time constant of total system
- Method of data presentation

Medical Application Of Thermography

i] Health cases

The distribution of a health person's skin temperature is symmetrical. This is true with regard to head, face & limbs. The location of disease can be easily diagnosed if there is an abnormality in this symmetry. In case of chest, left side tends to show a slightly higher temperature than the right side.

ii] Tumors

In case of benign tumors, difference in temperature with the surrounding tissues is very small, about 1^0C. The benign angioma shows a temperature 2^0C higher than the surrounding tissues temperature due to increased blood flow. In case of superficial malignant

tumors such as breast cancer, cancer of upper jaw, a temperature is 2-3^{0}C higher than that of surrounding tissues.

iii] Inflammation

The area of an acute inflammation shows a high temperature because of active metabolism and increase in local blood flow.

iv] Diseases of peripheral vessels

When the arteries are occluded, blood flow of peripheral vessels either decreases or disappears resulting a low temperature in that part.

v] Burns and perniones:

In the treatment of burns and perniones, the first thing to do is deciding on their degree of serenity. When burns are concerned, first degree burns register a high temperature but third degree show a temperature 2-3^{0}C lower than normal value because of absence of blood flow.

vi] Skin Grafts and organ transplantation

The condition of skin grafts after transplantation can be detected by means of local blood flow. In kidney transplantation the rejection causes a high temperature while malfunction of transplanted organ leads to a low temperature.

vii] Collagen diseases

Collagen diseases are usually attended with peripheral vascular discarders. Patients suffering from Raynaud's syndrome have abnormal low temperature in the fingers patients.

viii] Orthopedic Diseases

Fractures, arthritis, bruises and sprains can be easily diagnosed because the local skin temperature rises in these cases.

ix] Brain and Nervous diseases

Temperature distribution can be quantitatively diagnosed by means of thermogram.

x] Hormone diseases

Thyroid glands normally register high temperature due to their active metabolism. Patients affected with hyper thyrodism have high temperature. Patients suffering from cyst have low temperature.

xi] Examination of placenta attachment

Detection of location of placenta is possible by means of thermogram because increase in local blood flow leads to a high temperature.

Notes:Theremography- 'Heat camera in Medicine' is useful as a screening procedure and can be used to diagnose breast cancer. Thermography is nondestructive, noninvasive and comfortable for the patients. The technique is carefully standardized and possible to achieve faithful reproducible results. In India, thermography equipment is not very common in hospital because of its higher cost.

5.2 ENDOSCOPES

Optical fibers play a vital role in medical field. Endoscopes or fiberoscopes are designed with low quality, large diameter and short silica fibers. Broncho fiberoscopes, Gastrointestinal fiberoscopes and laproscopes are the important endoscopes. Endoscopes are used in hospital for examination, treatment of diseases and surgery.

There are two types

1. Flexible
2. Rigid

In each endoscopes, there are two fiber bundles.

One is used to illuminate the inner structure of object. Other is used to collect the reflected light from that area and from that we can view the inner structure of object.

Endoscope is an optical instrument to view the body cavities which are not visible to naked eye. Endoscope can be inserted to inspect or view the body cavities.

The body is filled with air to improve optical transmission. The light is guided through the glass fibers by total internal reflection.

Atypical glass fiber consists of a central 'core' glass having high refractive index surrounded by a cladding made of glass of slightly lower refractive index.

The numerical aperture (light collection efficiency) of the fiber is equal to $(n_1^2-n_2^2)^{1/2}$ where n_1 & n_2 are refractive index of core and cladding respectively.

For better image quality, a telescope system is added in the internal part of endoscope. In the endoscope, at the object end there is an assembly of objective lens and prism and at the viewing end there is an eye lens.

Endoscopic pictures can be recorded with color film and videotape recorders.

Difference types of commonly available endoscopes

Type	Range of use	Diagnostic Problem or Operation
1. Bronchoscope	Trachea larger airways	Foreign bodies infections aspiration of mucus
2. Cardioscope	Heart cavities	Valvular defects septal defect
3. Cystoscope	Urinary bladder	Tumors, inflammation, stones
4. Gastroscope	stomach	Gastritis, gastric ulcer, tumors
5. Laparoscope	Abdominal cavity	Tumors, family planning operation
6. Ophthalmoscope	Eye fundus	Stateof vessels in high blood pressure, retinol detachment
7. Otoscope	Tympanic membrance	Infections perforation of ear drum pressure conditions in the middle ear
8. Proctoscope	rectum	Hemorrhoids
9. Sigmoidoscope	Rectum and distal part of colon	Bowel lesions, side pockets of the bowel
10. Thoracoscope	Pleural cavity	Tumors, air in the pleural cavity

5.2.1 Endoscopic Laser Coagulator

It uses argon ion laser as high energy optical source and endoscope as the delivery unit. Argon ion lasers are very useful for the coagulation of blood vessels since its green light is highly absorbed by red blood vessels and hemoglobin.

The absorption of green light result in the photocoagulation of blood protein and micro hemostasis. Argon ion laser is useful for the photocoagulation of retina because of their ability to do coagulation without affecting the surrounding healthy issue.

To control gastric haemorrhage photocoagulation technique is adopted. In fiber optic endoscope, output from argon ion laser is delivered to required spot to arrest the gastric bleeding.

We can more the laser beam in any direction with the flexible endoscope. The argon ion laser gives an output of 13w in the form of continuous waves. The diameter of quartz fiber endoscope is about 2mm.

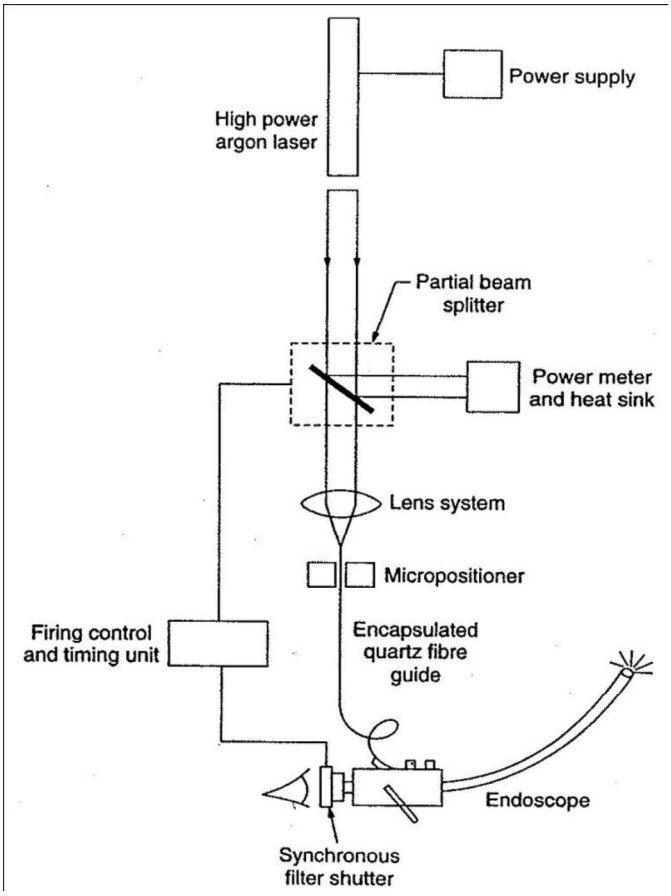

Fig5.2.1: Endoscopic Laser coagulation

5.3 LASER IN MEDICINE

LASER- Light Amplification by Stimulated Emission of Radiation Basic principle of laser action . Laser beam consists of high intense radiation in unique direction without spreading its energy in other direction. It has high monochromaticity and high directionality. Stimulated emission alone produce coherent radiation.

For continuous stimulated emission output, population inversion of atoms should be maintained. This can be done by optical pumping of atoms of active medium. Population of atoms in higher energy level is smaller than the lower energy level in an atomic system.

During population inversion, the number of atoms in the higher level is more than the number of atoms in the ground level. This can be done by pumping source. Assume that there is population inversion such that the atom in the higher metastable energy level is more.

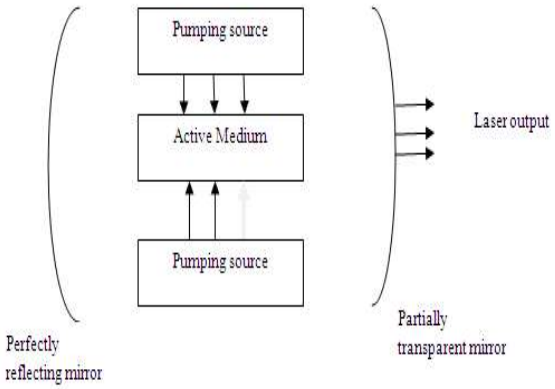

Fig5.3 : Laser Principle

There are two type of emission

1. Spontaneous emission
2. Stimulated emission

In the case of spontaneous emission, the emission takes place without any inducement. (i.e) Transition from high energy state to any lower energy state takes place volunteerly with the emission of polychromatic radiation. A photo emitted by spontaneous emission has an energy equal to energy difference between laser transmission levels.

Then it can stimulate the excited atom in the metastable state to undergo transition with the emission of a photo such that the stimulated photo (emitted wave) falls in phase with stimulating photo (incident wave).

The two photos stimulate other two atoms and finally amplification of light takes place. Hence laser output can be obtained. The biomedical applications of laser are based on the fact that lasers could produce high photon flux on a localized spot

The properties of the laser are

a. Monochromaticity
b. Spatial & Temporal coherence
c. Directionality
d. Brightness

When light photons fall on the tissues, four bask optical processes may occur

1. Direct reflection at the boundaries of the layer due to change in the refractive index
2. Scattering by molecules, particle, fibers, cell organelle and cells within the layer
3. Absorption
4. Direct transmission through the layer

All the above process depend on

a. Wave of laser
b. Energy density
c. Pulse duration
d. Irradiation time
e. Absorption characteristics of target molecule

The laser photon of wavelength of 600 – 1300 nm can penetrate deep into tissues and that fact is used for phototherapy and selective surgery.

Table Photo biological laser processes

Process	Principle	Power density (W/cm^2)	Interaction time (s)	Type of Laser
Photochemical process	Due to continuous or quasi continuous wave irradiation	1	10^3	He-Ne
Thermal processes	Due to continuous or quasi continuous wave irradiation	10^2 10^2	10 1	CO_2 Nd-YAG
Photoablative processes	Due to high power short pulse wave irradition	10^8	10^{-7}	Excimer lasers (ArE XeCl & XeF)
Electromechanical process	Due to high power short pulse wave irradition	10	10^{-9}	Nd-YAG

Table Physical principles of photothermal processes in tissues

Temperature	Effects of tissue
43-45^{0}C	Conformational changes, Hyperthermia (cell mortality)
50^{0}C	Reduction of enzyme activity
60^{0}C	Protein denaturation Coagulation
80^{0}C	Collagen denaturation
100^{0}C	Membrane permeabilization
300^{0}C	Vaporization Abalation
500^{0}C	Carbonization, Tissue burning

Laser Instrumentation

Laser irradiation of patients with skin tumors is performed in a specially designed operating unit which consists of three sections.

First section :A pulsed ND – YNG laser and a continuous wave CO_2 laser and continuous wave Argon ion laser are installed. The laser irradiation is transmitted as a suitable optical fiber light guide system to scanning device in the second section.

Second section: It contains necessary operation theatre equipment and remote controlled scanning device.

Third section

It is intended for remote control unit. The operation can be absorbed by means of a television arrangement. A radio communication is maintained between the biomedical engineer who is incharge of lasers and surgeon in the operating theatre.

Lasers are equipped with water cooling system. The energy of radiation is indicated by energy meter and the irradiation time is controlled properly by a timer. The rooms are equipped with warning signal circuits and a blocking system that presents the laser system from working unless the doors of that room are closed.

The beam with maximum focusing capability and minimum beam divergence is used for surgery. During laser surgery the patient and surgeon should wear protective goggles to protect the eyes.

The pulsed radiation of ND – YAG laser and unfocussed radiation of CW CO2 laser are used for the destruction of tumors by coagulation. Focussed beam of CO2 laser function as a light knife for performing tissue incisions and tumor nodule excisions.

The partially focussed beam of CW Argon ion laser is used for the treatment of haemangiomas by means of blood vessel coagulation.

Advantages of Laser surgery

a. Highly sterile
b. Highly localized & precise
c. Noncontact surgery
d. Dry field, almost bloodless surgery
e. Clear field of view and easy access in confined areas
f. Prompt heating with minimal post operative swelting and scarring
g. Apparent reduction in post operative pain
h. No electromagnetic interference on monitoring instruments
i. More advantageous for children since it is a painless surgery
j. Short period of surgical time

Medical Application of Laser

a) Photothermal Application

Laser heating of tissues is used for two surgical functions. Cutting and photo coagulation. Cutting was used in ophthalmology. It is used to treat variety of eye problems, including retinal bleeding, excessive growth of blood vessels in the eye caused by diabetes and also for 'spot – welding'. Spot-welding - Reattaching retinas from back surface of eye, chroid. Photocoagulation can also be used for spot-welding. Argon ion lasers are used for photocoagulation of small blood vessels in the eye. Nd-YAG laser are also used for blood vessel and tissue coagulation. Laser photocoagulation is used in conventional surgery on sun organs like spleen, liver and kidneys where excessive bleeding is often a problem. In cutting tissues with CO_2 laser beam is absorbed in a small volume causing a little damage to surrounding tissues. It is a bloodless and precise one. Laser light can be used to remove tumors from brain & spinal cord.

b) Photochemical Application

Laser can be used to diagnose and treat diseases non-surgically. Low power lasers can induce more chemical, enzymatic and metabolic changes in human body. The wavelength, coherency and power of lasting can be controlled to generate photobiological effects for medical treatment. Recently lasers are used to cure skin cancers. Laser fluorescence bronchoscope can be to detect lung tumors in the early stage.

5.4 INTRODUCTION TO TELEMEDICINE

Telemedicine is the application of telecommunication and computer technology to deliver health care from one location to another. In other words telemedicine involves the use of modern information technology to deliver timely health services to those in need by the electronic transmission of the necessary expertise and information among geographically dispersed parties including physicians and patients to result in improved patient care and management resource distribution efficiency and potentially cost effectiveness. The

telemedicine technology includes hardware, software, medical equipment and communication link.

Telemedicine Application

Teleradiology: radiological images such as X-ray, CT or MRI images can be transferred from one location to another location for expert interpretation and consultation

Telepathology : To obtain an expert opinion on the microscopic images of pathology slides and biopsy reports from specialists.

Telecardiology: Telecardiology relates to the transmission of ECG, echocardiography, colour Doppler etc.

Tele-education: delivery of medical education programmes to the physicians and the paramedics located at smaller towns who are professionally isolated from major medical centres.

Tele consultation: Specialist doctors can be consulted either by a patient or by the local medical staff through telemedicine technology.

Telemedecine concepts:

Store and forward:

It involves storing the information relating to audio, video images and clips , ECG etc. The stored information in the digital form is sent to the expert for review, interpretation and advice at his/her convenience. The expert's opinion can be transmitted back without any immediate compulsion on the consultant's time during his/her busy professional schedule.

Real time :

It involves real time exchange of information between the two centres simultaneously and communicating interatively. It may include video conferencing, interviewing, and examing the patients, transmission of images of various anatomic sites, asculation of the heart and lung sounds and a continuous review of various images.

5.4.1Principles and sub system of telemedicine setup:

In this arrangement a computer at a transmitting station and another computer at receiving station are connected through satellite communication link. The computers have software for transfer of video clips, audio messages, moving images and video conferencing facility. At the transmitting end ECG machine , X-ray machine,CT scanner,MRI scanner, patient data bank are interfaced with the transmitting computer. At the receiving end the receiving computer has data avhiving facility, printer, analysis software and application software.

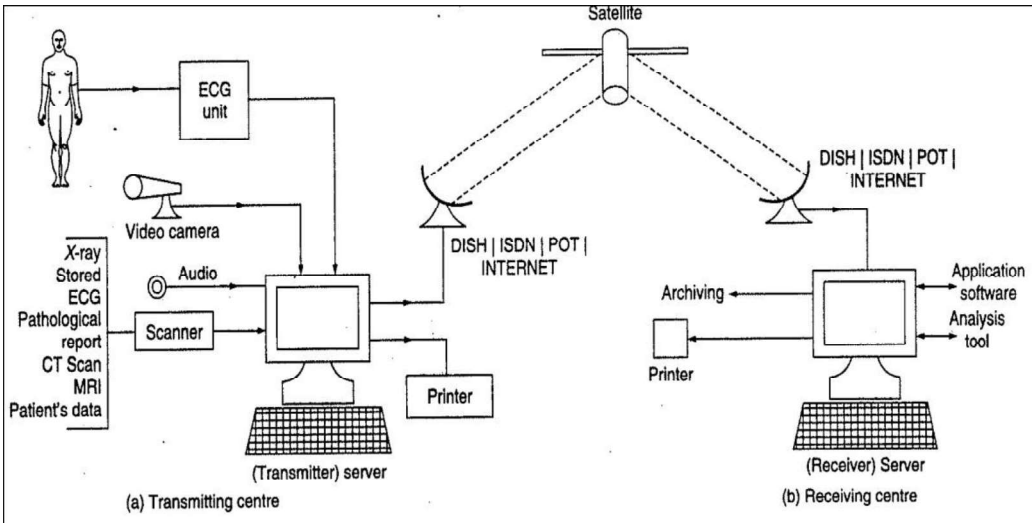

Fig 5.4.1Principles and sub system of telemedicine setup:

5.4.2Telemedicine technology:

5.4.2.1 Transmission of medical images: one of the most important aspect of telemedicine is the acquisition and transmission of medical images such as X-rays, CT, MRI etc. These images are first required to be converted into digital form. The usual types of diagnostic images used in telemedicine include:

(i) images stored on traditional film or print media and converted in to digital format by direct imaging in a raster sequence under controlled lighting condition. Charge coupled device and laser based scanners are commercially available for digitizing the film recorded X-ray images.

(ii) Computer generated images available in standard video format , computer format. In modern digital radiography system the X-ray images is stored in the computer in digital format. Being a filmless system it does not require any further digitization.

5.4.2.2Video conferencing

One of the essential components in a telemedicine system is the video conferencing facility which permits real time transmission of both audio and video information. A number of internationally recognized standards have been established by Telecommunication standardization Sector to assure a high degree of functional compatibility between like equipment supplied by different manufactures and also to standardize the interface protocols which access and control the communications network.

5.4.2.3 Digital communication system

There are various digital communication services available today for this purpose

POTS : Using a modern (modulator/demodulator)the analog telephone systems (plain Old Telephone Service(pots) digital signal at data rates up to about 30kbps can be transmitted. However depending upon the quality of the circuit the maximum reliable data transfer rate may be less than half of this rate.

ISDN: All the digital integrated services digital network is available for the transmission of voice and data. The common form of ISDN,BRI(basic rate interface)consists of 64kbps data channels and 16kbps data control channel (2B+D)multiplexed on two wire pairs.

The data channel can be combined into 128kbps channels. For example a codec used for desktop video conferencing. ISDN dialing and other control functions are handled in the D-channel. In some locations ISDN, PRI(primary rate interface) is available and provides 23 B-channel at 1472kbps and one D-channel at 64kbps.

ATM : ATM(Asynchronous Transfer Mode) is a high capacity communication link between widely dispersed sites, usually connected by fibre communication channels such as OC-3(155Mbps) or OC-12(622Mbps). This network service is well suited for transmitting digital video and audio.

5.4.2.4 Telemedicine using Mobile communication

Mobile communication and satellite communication have opened up new possibilities for mobile telemedicine in emergency situations.

In a moving vehicle, colour images,audio signals and physiological signals such as ECG and blood pressure are obtained from the patient.

These images and signals are multiplexed and transmitted to a fixed station. In the fixed station the signals received are demultiplexed and presented to a medical specialist. Instructions from the specialist are then transmitted back to the mobile station through the communication link.

In mobile communication the capacity of transmission link is generally limited and is typically 10kbps100kbps. These capacities are far below those required for the transmission of medically significant information. By adopting data compression on video, audio, ECG and blood pressure signals the capacity required is about 19kbps which is well within the practical capacity of mobile communication link.

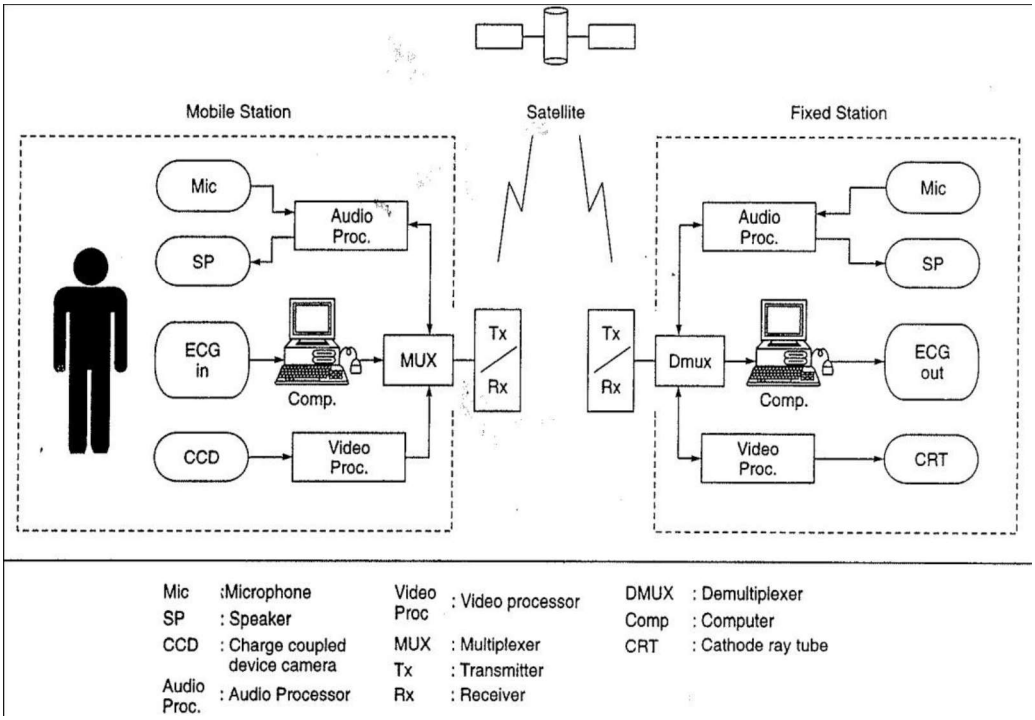

Fig **5.4.2.4 Telemedicine using Mobile communication**

5.5 CRYOGENIC

Cryogenics is the study and use of materials at extremely low temperatures. Such low temperatures cause changes in the physical properties of materials that allow them to be used in medical applications. For example, in the cryogenic temperature range, air becomes a liquid—or even a solid—and living tissue freezes instantly. Matter behaves strangely at the lowest temperatures of the cryogenic range. Electric currents never stop flowing, liquids run uphill, and rubber becomes as brittle as glass. In medicine, cryogenic cooling is used in some diagnostic techniques, such as magnetic resonance imaging (MRI). Cryosurgery uses liquid nitrogen to kill unhealthy tissue by freezing it. Cryogenics is expected to play an important role in the development of better procedures for preserving human organs for transplant.

Types Of Cryogenic Treatment

- Shallow Cryogenics-The objects are cooled down to temperature of approximately -85^{o}C

- Flooding-First the object is taken to -85^{o}C, then the chamber is flooded with liquid nitrogen to reduce the temperature further.
- Deep Cryogenics Treatment-Subjects the objects to the temperature of approximately-185^{o}C

Other applications of cryogenics include fast freezing of some foods and the preservation of some biological materials such as livestock semen as well as human blood, tissue, and embryos. The practice of freezing an entire human body after death in the hope of later restoring life is known as cryonics, but it is not an accepted scientific application of cryogenics. The freezing of portions of the body to destroy unwanted or malfunctioning tissue is known as cryosurgery. It is used to treat cancers and abnormalities of the skin, cervix, uterus, prostate gland, and liver.

The Cooling Process

A substance is normally cooled by placing it next to something colder. To make the substance supercold, however, heat must also be removed and the substance must be insulated (encased). An important method of cryogenic super cooling involves liquefying gases and using these gases to cool other substances. One technique is to convert to liquid form a gas that can be liquefied by pressure alone. Then a gas requiring a lower temperature to become a liquid is placed in a container and immersed (dipped) in the first. The gas that is already liquefied cools the second and converts it to a liquid. After several repetitions of this process, the targeted gas is liquefied. A Dewar flask is normally used to store such very low temperature liquefied gases.