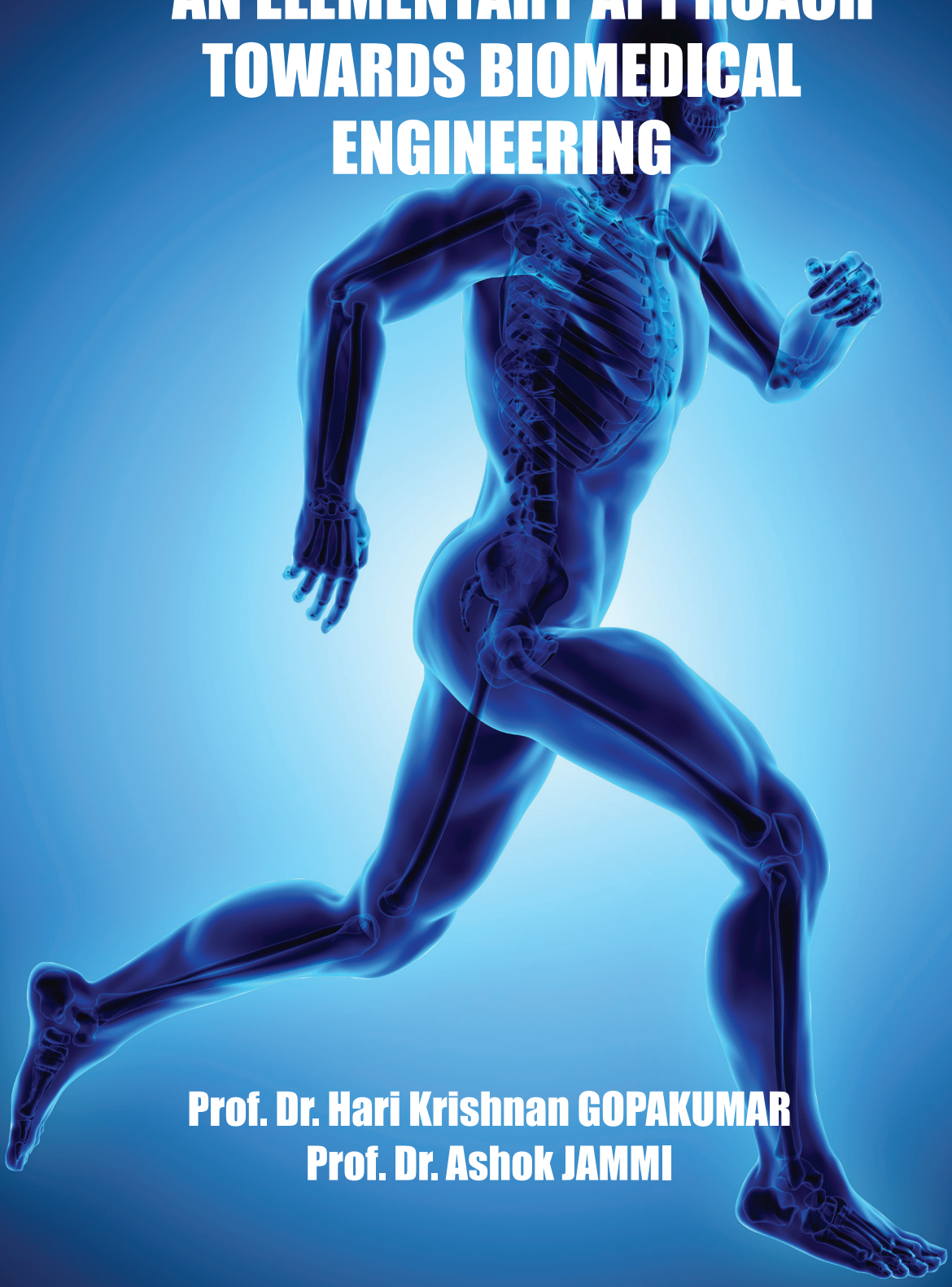
AN ELEMENTARY APPROACH TOWARDS BIOMEDICAL ENGINEERING



Prof. Dr. Hari Krishnan GOPAKUMAR
Prof. Dr. Ashok JAMMI

AN ELEMENTARY APPROACH TOWARDS BIOMEDICAL ENGINEERING

Prof. Dr. Hari Krishnan GOPAKUMAR
Prof. Dr. Ashok JAMMI

AN ELEMENTARY APPROACH TOWARDS BİOMEDİCAL ENGİNEERİNG

WRITERS
Prof. Dr. Hari Krishnan GOPAKUMAR
Prof. Dr. Ashok JAMMI

Güven Plus Group Consultancy Inc. Co. Publications: 06/2021
APRIL-2021

Publisher Certificate No: 36934
E-ISBN: 978-625-7367-11-0
Güven Plus Group Consultancy Inc. Co. Publications

Text, Publication and Language Editor
Assoc. Prof. Gökşen ARAS
Assist. Prof. Senai YALÇINKAYA

Cover Design
Prof. Dr. Pelin AVŞAR KARABAŞ

Page Layout
Burhan MADEN

Print-Binding
GÜVEN PLUS GROUP CONSULTANCY INC. CO. PUBLICATIONS®
Kayaşehir Neighborhood Evliya Çelebi Street Emlakkonut Başakşehir Houses 1/A D Block Floor 4 Number 29 Başakşehir İstanbul - Turkey
Phone: +902128014061- 62 Fax: +902128014063 Mobile: +9053331447861

BOOK / MAGAZINE / CONGRESS LICENSEE
GÜVEN PLUS GROUP CONSULTANCY INC. CO. PUBLICATIONS®
Kayaşehir Neighborhood Evliya Çelebi Street Emlakkonut Başakşehir Houses 1/A D Block Floor 4 Number 29 Başakşehir İstanbul - Turkey Phone: +902128014061-62-63 - +905331447861 info@guvenplus.com.tr, www.guvenplus.com.tr

CONTENTS

FIGURE

PREFACE

This book has been written to provide adequate knowledge on Biomedical Engineering. It is designed as a text for UG level course in ECE branch in the professional colleges affiliated to technical universities. The materials available with the listed reference books have a significant impact on this book.

The book uses plain, lucid language to explain fundamentals. The book provides logical method of explaining various complicated concepts and stepwise methods to explain the important topics. Each chapter is well supported with necessary illustrations, practical examples and solved problems. All the chapters in the book are arranged in a proper sequence that permits each topic to build upon earlier studies. All care has been taken to make students comfortable in understanding the basic concepts of the subject.

The book not only covers the entire scope of the subject but explains the philosophy of the subject. This makes the understanding of this subject more clear and makes it more interesting. The book will be very useful not only to the students but also to the subject teachers.

We would like to express our sincere thanks to our beloved secretary Sri Benny John Ayanikkal, Holy Grace Group of Institutions , for the encouragement in bringing this book.

I gratefully acknowledge our family members, well wishers, students and friends for their moral support in bringing out this book.

Finally I wholeheartedly thank the ALMIGHTY whose blessings made the book to be possible.

Prof. Dr. Hari Krishnan GOPAKUMAR
Prof. Dr. Ashok JAMMI

Prof. Dr. Hari Krishnan GOPAKUMAR

B.E,MTech-PhD,MBA,Msc Applied Psychology*

Dr G Hari Krishnan, Currently working as Principal, Holy Grace Academy of Engineering, Thrissur, kerala. He obtained his PhD in communication and Networking Engineering from SCSVMV University .He has done his MTech in Remote Sensing and Wireless sensor

Networks from Amrita University Coimbatore and B.E.'in Electronics and Communication Engineering from Tamilnadu college Of Engineering (Anna University). He is a recipient of Distinguished Engineer Award form Professional society- Malaysia. He has developed.

Several Student Centric academic development programmes and conducted several training programmes based on effective student centric teaching – learning methodologies .He is involved in career guidance and mind building counseling activities .Currently doing Msc Applied Psychology .He has Several publications to his credits which includes SCI/Scopus journals and books. He is involved in several socio-educational activities in and around south India. His areas of interest include Medical Electronics, Computer Networks, Mobile Computing, Microwave Engineering, Semantic Web, Cryptography and Network Security and Satellite Communication, Deep space image processing, Remote sensing and wireless sensor networks, Applied Psychology. He has organized many Workshops, Symposiums and National Conferences.

Prof. Dr. Ashok JAMMI

Dr. Jammi Ashok, Currently working as a Professor and Principal at Anurag College of Engineering, Hyderabad,Telangana state. He obtained his Ph.D from Anna University, Chennai in the faculty of Information and Communication Engineering. He is having 23+ years of experience in teaching and research. He worked at various capacities like Principal, Professor, Head, PG Coordinator, Vice Principal and Dean at reputed engineering colleges. He also worked as a Professor in the school of Electrical and Computer Engineering of reputed universities in East Africa and Australia.

He is the recipient of 25 international prestigious awards like Bharat Jyothi award, Bharat Ratna Mother Teresa Gold Medal award, Outstanding Scientist Award, Best Citizen's of India award, Mother Teresa Excellence award, Rastriya Shiksha Ratna Award, Bharat Vidya Shiromani award,Vidya Ratan Gold Medal award ,Distinguish Researcher Award, Glory of India award, Best educationist Award, United Writer's Association Excellence Award, International Global Achiever's Award and Best paper Awards in International conferences to name a few. His biography has been included in 2000 Outstanding Intellectuals of 21st century by International Biography Centre, Cambridge, England.

Dr. Jammi Ashok has been stepped into Marquis Who is Who, a renowned and highly sophisticated public profile in the world, very off late just 3%public stalwarts in our country got this tremendous achievement in India. A great achievement takes rest on his intellectuals thought provoking arena is man of the year 2016 by International Biographical Centre of Cambridge , England.

Dr. Jammi Ashok has more than 90 refereed international journal and conference papers to his credit and presented papers national and internationally. He has four text books to his credit which were published internationally. He also has two patents. He has given live interviews on career guidance for some television channels in India. He is an editorial board member of many international peer reviewed journals

and also a regular reviewer for many international peer reviewed scientific journals and conferences. He is a member in board of studies for reputed universities in India. He is a member of many societies like ISTE, CSI, IAENG, TheIRED, UACEE, IAAST and CSTA.

UNIT I.
ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING

INTRODUCTION

Biologic systems frequently have electric activity associated with them. This activity can be a constant dc electric field, a constant flux of charge-carrying particles or current, or a time-varying electric field or current associated with some time-dependent biologic or biochemical phenomenon. Bioelectric phenomena are associated with the distribution of ions or charged molecules in a biologic structure and the changes in this distribution resulting from specific processes. These changes can occur as a result of biochemical reactions, or they can emanate from phenomena that alter local anatomy. One can find bioelectric phenomena associated with just about every organ system in the body. Nevertheless, a large proportion of these signals are associated with phenomena that are at the present time not especially useful in clinical medicine and represent time-invariant, low-level signals that are not easily measured in practice. There are, however, several signals that are of diagnostic significance or that provide a means of electronic assessment to aid in understanding biologic systems.

These signals, their usual abbreviations, and the systems they measure are listed. Of these, the most familiar is the electrocardiogram, a signal derived from the electric activity of the heart. This signal is widely used in diagnosing disturbances in cardiac rhythm, signal conduction through the heart, and damage due to cardiac ischemia and infarction. The electromyogram is used for diagnosing neuromuscular diseases, and the electroencephalogram is important in identifying brain dysfunction and evaluating sleep.

The other signals listed are currently of lesser diagnostic significance but are, nevertheless, used for studies of the associated organ systems. Although the above discussion are concerned with bioelectric phenomena in animals and these techniques are used primarily in studying mammals, bioelectric signals also arise. These signals are generally steady-state or slowly changing, as opposed to the time-varying signals listed.

1.1. ORIGIN OF BIO POTENTIALS

Bioelectric phenomenon is of immense importance to biomedical engineers because these potentials are routinely recorded in modern clinical practice.

1. Cells transport ions across their membrane leading to ion concentration differences and therefore charge differences - hence generating a voltage.

2. Most cell groups in the tissues of the human body do not produce electric voltages synchronously, but more or less randomly. Thus most tissues have a resultant voltage of zero as the various random voltages cancel out.

3. When many cells produce voltages synchronously the resultant voltage is high enough to be measurable e.g., EMG - muscle fibre contraction, most cells of the fibre perform the same electric activity synchronously and a measurable electric voltage appears.

4. Many organs in the human body, such as the heart, brain, muscles, and eyes, manifest their function through electric activity. The heart, for example, produces a signal called the electrocardiogram or **ECG.** The brain produces a signal called an electroencephalogram or **EEG**. The activity of muscles, such as contraction and relaxation, produces an electromyogram or **EMG.** Eye movement results in a signal called an electrooculogram or **EOG** and the retina within the eyes produces the electroretinogram or **ERG**.

5. Measurements of these and other electric signals from the body can provide vital clues as to normal or pathological functions of the organs. For example, abnormal heart beats or arrhythmias can be readily diagnosed from an ECG. Neurologists interpret EEG signals to identify epileptic seizure events. EMG signals can be helpful in assessing muscle

function as well as neuromuscular disorders. EOG signals are used in the diagnosis of disorders of eye movement and balance disorders.

The **origins of these bio potentials** can be traced to the electric activity at the cellular level. The electric potential across a cell membrane is the **result of different ionic concentrations** that exist inside and outside the cell. The electrochemical concentration gradient across a semipermeable membrane results in the **Nernst potential**.

The cell membrane separates high concentrations of potassium ion and low concentrations of sodium ions (along with other ions such as calcium in less significant proportions) inside a cell and just the opposite outside a cell. This difference in ionic concentration across the cell membrane produces the **resting potential**.

Some of the cells in the body are **excitable** and produce what is called an ***action potential,*** which results from a Measurements of these and other electric signals from the body can provide vital clues as to normal or pathological functions of the organs. For example, abnormal heart beats or arrhythmias can be readily diagnosed from an ECG. Neurologists interpret EEG signals to identify epileptic seizure events. EMG signals can be helpful in assessing muscle function as well as neuromuscular disorders. EOG signals are used in the diagnosis of disorders of eye movement and balance disorders.

Some of the cells in the body are **excitable** and produce what is called an ***action potential,*** which results from a **rapid flux of ions across the cell membrane** in response to an electric stimulation or transient change in the electric gradient of the cell. The electric excitation of cells generates currents in the surrounding volume conductor manifesting itself as potentials on the body. Each cell in the heart produces a characteristic action potential. The activity of cells in the **sinoatrial node** of the heart **produces an excitation** that *propagates* from the **atria to the ventricles** through well-defined pathways and eventually throughout the heart; this electric excitation produces a **synchronous contraction** of the heart muscle. The associated biopotential is the ECG.

Electric **excitation** of **a neuron** produces an **action potential** that travels down its **dendrites and axon;** activity of a massive number of

neurons and their interactions within the cortical mantle results in the **EEG** signal.

Excitation of neurons transmitted via a nerve to a neuromuscular junction produces **stimulation of muscle** fibers. Constitutive elements of muscle fibers are the **single motor units**, and their electric activity is called a **single motor unit potential**. The electric activity of large numbers of single motor unit potentials from groups of muscle fibers manifests on the body surface as the **EMG**. Contraction and relaxation of muscles is accompanied by proportionate EMG signals.

The retina of the eye is a multilayered and rather regularly structured organ containing cells called rods and cones, cells that sense light and color. **Motion of the eyeballs inside** the conductive contents of the skull **alters** the **electric potentials**. Placing the electrode in the vicinity of the eyes (on either side of the eyes on the temples or above and below the eyes) picks up the potentials associated with eye movements called **EOGs**. Thus, it is clear that bio potentials at the cellular level play an integral role in the function of various vital organs.

To understand the origin of bio potentials we need to focus on:

1. Bioelectric phenomena at the cellular level,
2. Volume conductor fields of simple bioelectric sources,
3. Volume conductor fields of complex bioelectric sources,
4. Volume conductor fields as a necessary link between cellular activity and gross externally recorded biological signals.

1.1.1. ELECTRICAL ACTIVITY OF EXCITABLE CELLS

1. Bio potentials are produced as a result of electrochemical activity of excitable cells: i.e., nervous, muscular (cardiac and smooth) and glandular cells Factors influencing the flow of ions across the cell membrane are,
2. Diffusion gradients,
3. Inwardly directed electric field (inside negative, outside positive),
4. Membrane structure (availability of pores; K+, Na+ and permeability of membrane to different ions),

5. Active transport of ions across membrane against established electrochemical gradients,
6. When appropriately stimulated, they generate an action potential (flow of ions across the cell membrane and generation of a propagating wave of depolarization along the membrane).

1.1.2. BIOELECTRIC PHENOMENA AT THE CELLULAR LEVEL

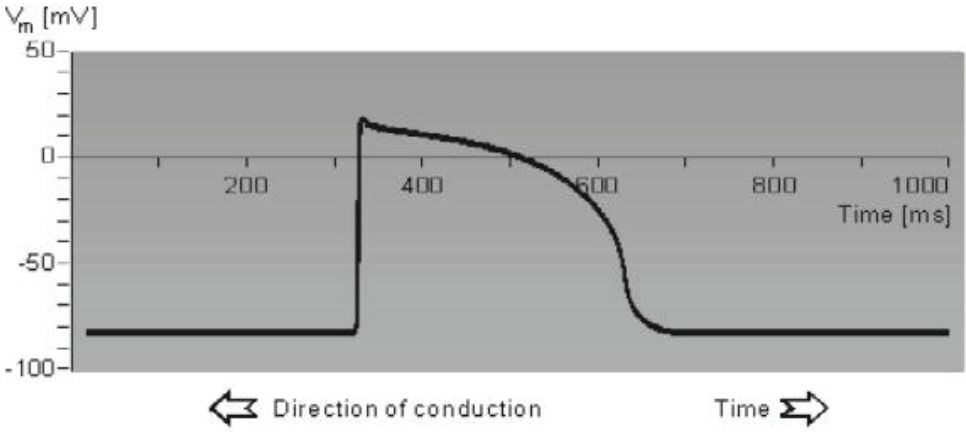


Figure 1.1. Recording of action potential

The Sources of Bioelectric Signals are

- Electrocardiogram ECG Heart—as seen from body surface.
- Cardiac electrogram — Heart—as seen from within
- Electromyogram EMG Muscle
- Electroencephalogram EEG Brain
- Electrooptigram EOG Eye dipole field
- Electroretinogram ERG Eye retina
- Action potential — Nerve or muscle
- Electrogastrogram EGG Stomach
- Galvanic skin reflex GSR Skin

1.2. BIO-POTENTIAL ELECTRODES

The difference between the potential at zero current and the measured potentials while current is passing is known as the *over voltage* and

is the result of an alteration in the charge distribution in the solution in contact with the electrodes or the ion-selective membrane. This effect is known as polarization and can result in diminished electrode performance, especially under conditions of motion.

There are three basic components to the polarization over potential: the ohmic, the concentration, and the activation over potentials. Of these, the activation over potential is of greatest concern in bioelectric measurements. More details on these over potentials can be found in electrochemistry or biomedical instrumentation. Perfectly polarizable electrodes pass a current between the electrode and the electrolytic solution by changing the charge distribution within the solution near the electrode. Thus, no actual current crosses the electrode-electrolyte interface. Non polarized electrodes, however, allow the current to pass freely across the electrode-electrolyte interface without changing the charge distribution in the electrolytic solution adjacent to the electrode. Although these types of electrodes can be described theoretically, neither can be fabricated in practice. It is possible, however, to come up with electrode structures that closely approximate their characteristics.

Electrodes made from noble metals such as platinum are often highly polarizable. A charge distribution different from that of the bulk electrolytic solution is found in the solution close to the electrode surface. Such a distribution can create serious limitations when movement is present and the measurement involves low frequency or even dc signals. If the electrode moves with respect to the electrolytic solution, the charge distribution in the solution adjacent to the electrode surface will change, and this will induce a voltage change in the electrode that will appear as motion artifact in the measurement. Thus, for most biomedical measurements, nonpolarizable electrodes are preferred to those that are polarizable.

The silver–silver chloride electrode is one that has characteristics similar to a perfectly nonpolarizable electrode and is practical for use in many biomedical applications. The electrode consists of a silver base structure that is coated with a layer of the ionic compound silver chloride. Some of the silver chloride when exposed to light is reduced to metallic silver, so a typical silver–silver chloride electrode has finely divided metallic silver within a matrix of silver chloride on its surface.

Since the silver chloride is relatively insoluble in aqueous solutions, this surface remains stable. Because there is minimal polarization associated with this electrode, motion artifact is reduced compared to polarizable electrodes such as the platinum electrode. Furthermore, due to the reduction in polarization, there is also a smaller effect of frequency on electrode impedance, especially at low frequencies. Silver–silver chloride electrodes of this type can be fabricated by starting with a silver base and electrolytic ally growing the silver chloride layer on its surface. Although an electrode produced in this way can be used for most biomedical measurements, it is not a robust structure, and pieces of the silver chloride film can be chipped away after repeated use of the structure. A structure with greater mechanical stability is the sintered silver–silver chloride electrode. This electrode consists of a silver lead wire surrounded by a sintered cylinder made up of finely divided silver and silver-chloride powder pressed together.

In addition to its nonpolarizable behavior, the silver–silver chloride electrode exhibits less electrical noise than the equivalent polarizable electrodes. This is especially true at low frequencies, and so silver–silver chloride electrodes are recommended for measurements involving very low voltages for signals that are made up primarily of low frequencies. A more detailed description of silver–silver chloride electrodes and methods to fabricate these devices can be found in Janz and Ives and biomedical instrumentation

1.2.1. Electric Characteristics of Bio-Potential Electrodes

The electric characteristics of bio potential electrodes are generally nonlinear and a function of the current density at their surface. Thus, having the devices represented by linear models requires that they be operated at low potentials and currents. Under these idealized conditions, electrodes can be represented by an equivalent circuit of the form shown. In this circuit *Rd* and *Cd* are components that represent the impedance associated with the electrode-electrolyte interface and polarization at this interface. *Rs* is the series resistance associated with interfacial effects and the resistance of the electrode materials themselves.

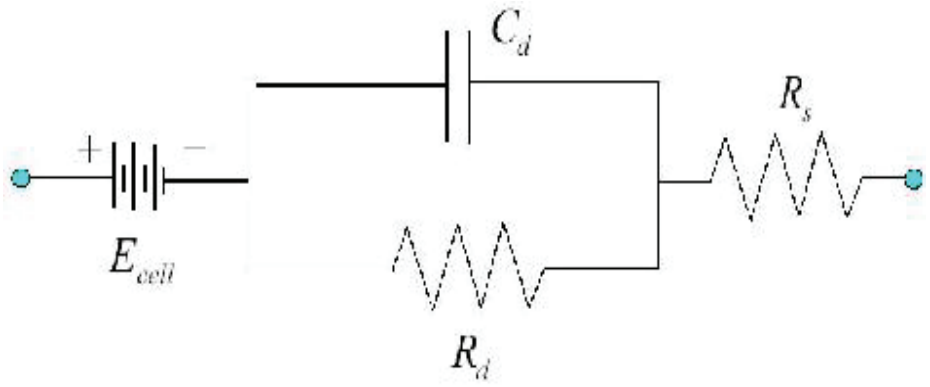


Figure 1.2. Circuit for measurement of bio potential electrodes

Half Cell Potential

A characteristic potential difference established by the electrode and its surrounding electrolyte which depends on the metal, concentration of ions in solution and temperature.

Half-Cell Potential Cannot be Measured Without a Second Electrode

The half-cell potential of the standard hydrogen electrode has been arbitrarily set to zero. Other half cell potentials are expressed as a potential difference with this electrode.

Reason for Half Cell Potential

Charge Separation at Interface Oxidation or reduction reactions at the electrode-electrolyte interface lead to a double charge layer, similar to that which exists along electrically active biological cell membranes.

Polarization

If there is a current between the electrode and electrolyte, the observed half-cell potential is often altered due to polarization.

Nernst Equation

When two aqueous ionic solutions of different concentration are separated by an ion selective semi-permeable membrane, an electric potential exists across the membrane. The Nernst equation for half-cell potential is;

$$E=E0 + RT/n[ac^{y}ad/\ aA^{\alpha}aB^{\beta}]$$

Where E0: Standard Half Cell Potential

E : Half Cell Potential

a : Ionic Activity (generally same as concentration)

n : Number of valence electrons involved.

Perfectly Polarizable Electrodes

These are electrodes in which no actual charge crosses the electrode-electrolyte interface when a current is applied. The current across the interface is a displacement current and the electrode behaves like a capacitor.

Example: Ag/AgCl Electrode.

Perfectly Non-Polarizable Electrode

These are electrodes where current passes freely across the electrode-electrolyte interface, requiring no energy to make the transition. Over potentials.

Example: Platinum electrode

Example: Ag-AgCl is used in recording while Pt is use in stimulation.

1.2.2. Motion Artifact

When the electrode moves with respect to the electrolyte, the distribution of the double layer of charge on polarizable electrode interface changes. This changes the half-cell potential temporarily.

If a pair of electrodes is in an electrolyte and one moves with respect to the other, a potential difference appears across the electrodes known

as the ***motion artifact.*** This is a source of noise and interference in bio potential measurements. Motion artifact is minimal for non-polarizable electrodes.

Body Surface Recording Electrodes

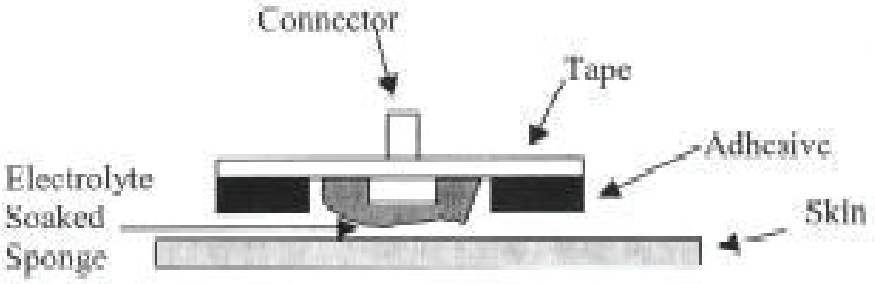


Figure 1.3. Body surface recording electrodes.

1.2.3. Commonly Used Bio potential Electrodes

Metal Plate Electrodes are

1. Suction Electrodes
2. Floating Electrodes
3. Flexible Electrodes.

Metal Plate Electrodes

– Large surface: Ancient, therefore still used, ECG
– Metal disk with stainless steel; platinum or gold coated
– EMG, EEG
– Smaller diameters
– Motion artifacts
– Disposable foam-pad

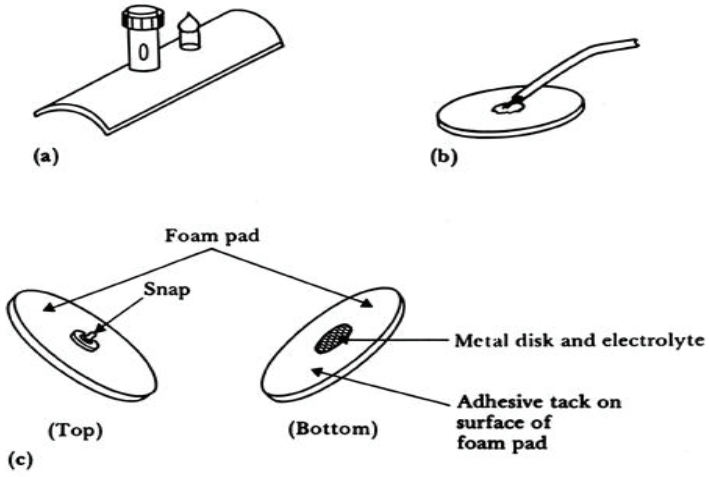


Figure 1.4. Metal plate electrode.

Suction Electrodes

- No straps or adhesives required
- Precordial (chest) ECG
- Can only be used for short periods

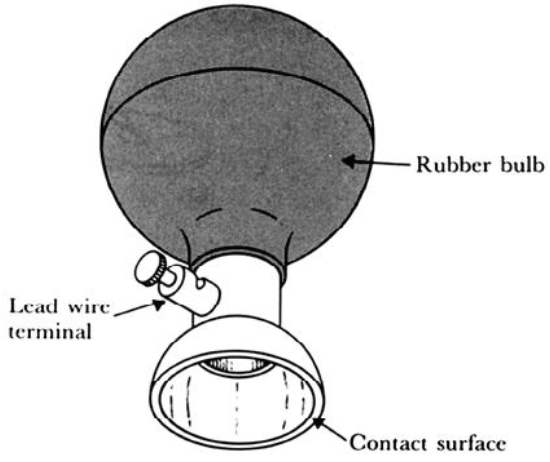


Figure 1.5. Suction electrode.

Flexible Electrodes

- Body contours are often irregular
- Regularly shaped rigid electrodes may not always work.
- Special case: infants
- Material:
- Polymer or nylon with silver
- Carbon filled silicon rubber (Mylar film)

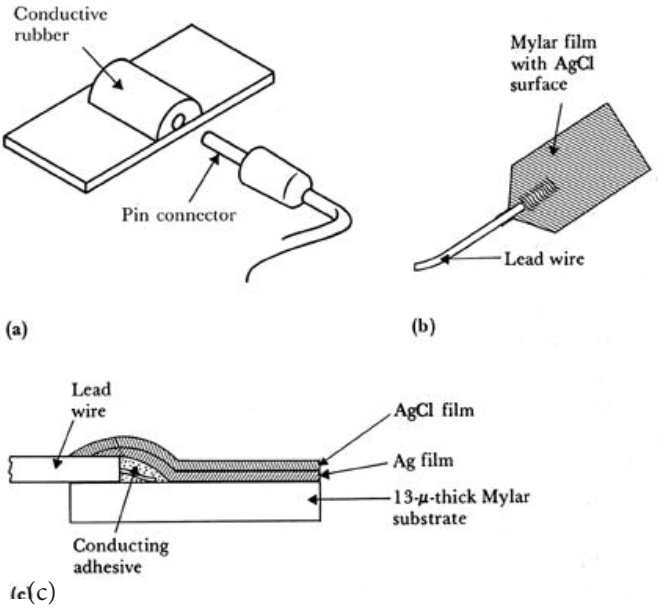


Figure 1.6. Flexible electrodes.

(a). Carbon-filled silicon e rubber electrode.

(b). Flex iblethin-film neonatal electrode.

(c). Cross-sectional view of the thin-film electrode in (b).

Electrodes in Bio potential Measurements

- To make the electrode cheaper
- More suitable for lower noise measurement for EEG
- Circumvent patents that are based on plastic/foam electrode body
- Attractive to consumers for use with their ECG machines at home

• Reduce artifact (minimize the motion of skin/electrode) in ambulatory recording,

Neural Electrodes/Microelectrodes

It is used to measure potential within a single cell. It is small in diameter and during insertion

of microelectrode into cell will not damage to human cell. It is classified into

1. Metallic
2. Nonmetallic (Micropipette),

Metallic Electrode

It is formed by electrolytic ally etching the tip of fine tungsten filament stainless wire into a minute structure. Potential within the cell can be measured by using two electrodes

1. Micro electrode,
2. Reference electrode.

Non Metallic (Micropipette)

It is used to measure the potential within the single cell using nonmetallic material is used.

It is filled within an electrolyte that is compatible with the cellular fluids.

1.3. BIOPOTENTIAL AMPLIFIERS

These are very important part of modern medical instrumentation. We need to amplify bio potentials which are generated in the body at low levels with high source impedance. Bio potentials amplifiers are required to increase signal strength while maintaining fidelity.

Basic Requirements of Bio potential Amplifiers

Essential functions of a bio amplifier are:

• To take a weak bio potential and increase its amplitude so that it can be processed,

Recorded or displayed,

• To amplify voltage, but it could be considered as a power amplifier as well. To amplify current since in some cases a bio potential amplifier is used to isolate the load from the source current gain only,

- All bio potential amplifiers must have high input impedance
- Only the desired signal is to be amplified;
- The signal should not be distorted;
- Any disturbance should be rejected;
- The device should not affect in any way the biological system;
- It should be protected against external discharges (defibrillators, electro surgery); and these requirements are to be taken as the general design criteria of the device.

Examples of biological amplifiers are: Differential Amplifiers Based on a Single Op-Amp, instrumentation amplifiers.

Mode of Operation

• Very frequently bio signals are obtained from bipolar electrodes,

• Electrodes symmetrically located with respect to ground need differential amplification,

High CMRR Required Because

1. Common mode signals much greater than the bio signal appear on bipolar electrodes,

2. Symmetry with respect to ground is not perfect (mismatch between electrode impedances) –more on this later.

Calibration Signal

Medical and clinical equipment require quick calibration. The gain of the bio potential amplifier must be calibrated to provide us with an accurate indication of the signal's amplitude,

Push button to apply standard signal to the input of the biopotential amplifier,

Adjustable gain switch carefully selects calibrated fixed gains.

1.4. 12-LEAD ECG SYSTEM

Augustus D Waller measured the human electrocardiogram in 1887 using Lippmann's capillary electrometer (Waller, 1887). He selected five electrode locations: the four extremities and the mouth (Waller, 1889). In this way, it became possible to achieve a sufficiently low contact impedance and thus to maximize the ECG signal. Furthermore, the electrode location is unmistakably defined and the attachment of electrodes facilitated at the limb positions. The five measurement points produce altogether 10 different leads. From these 10 possibilities he selected five - designated *cardinal leads*. Two of these are identical to the *Einthoven leads I* and *III* described below.

Willem Einthoven also used the capillary electrometer in his first ECG recordings. His essential contribution to ECG-recording technology was the development and application of the *string galvanometer*. Its sensitivity greatly exceeded the previously used capillary electrometer. The string galvanometer itself was invented by Clement Ader (Ader, 1897). In 1908 Willem Einthoven published a description of the first clinically important ECG measuring system (Einthoven, 1908). The Einthoven *limb leads* (standard leads) are defined in the following way:

$$\text{Lead I:} \quad V_{I} = \Phi_{L} - \Phi_{R}$$

$$\text{Lead II:} \quad V_{II} = \Phi_{F} - \Phi_{R}$$

$$\text{Lead III:} \quad V_{III} = \Phi_{F} - \Phi_{L}$$

Where,

V_{I} = the voltage of Lead I

V_{II} = the voltage of Lead II

V_{III} = the voltage of Lead III

Φ_{L} = potential at the left arm

Φ_{R} = potential at the right arm

Φ_{F} = potential at the left foot

(The left arm, right arm, and left leg (foot) are also represented with symbols LA, RA, and LL, respectively.)

According to Kirchhoff's law these lead voltages have the following relationship:

$$V_{\mathrm{I}} + V_{\mathrm{III}} = V_{\mathrm{II}}$$

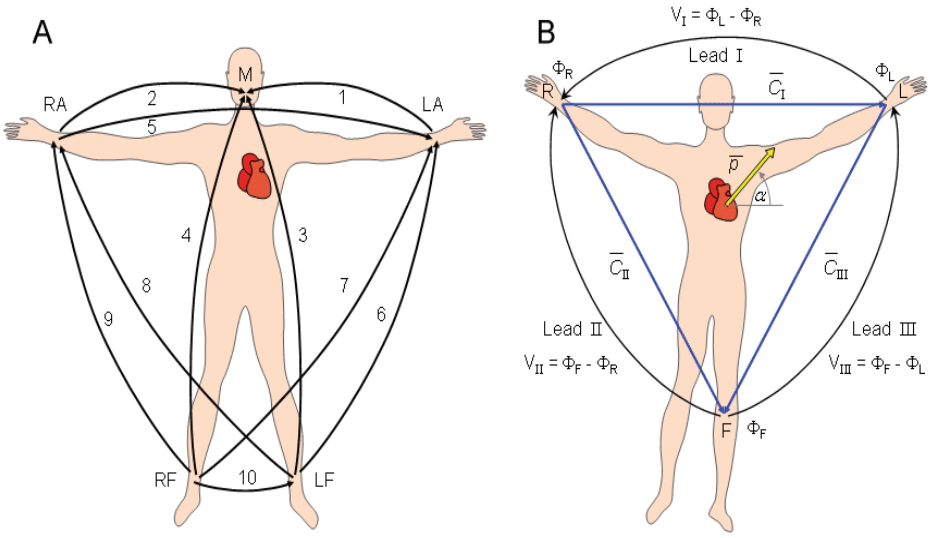


Figure 1.7. (A) The 10 ECG leads of waller. (B) Einthoven limb leads and einthoven triangle

The Einthoven triangle is an approximate description of the lead vectors associated with the limb leads According to Kirchhoff's law these lead voltages have the following relationship:

$$V_{\mathrm{I}} + V_{\mathrm{III}} = V_{\mathrm{II}}$$

hence only two of these three leads are independent.

The lead vectors associated with Einthoven's lead system are conventionally found based on the assumption that the heart is located in an infinite, homogeneous volume conductor (or at the center of a homogeneous sphere representing the torso). One can show that if the position of the right arm, left arm, and left leg are at the vertices of an equilateral triangle, having the heart located at its center, then the lead vectors also form an equilateral triangle.

A simple model results from assuming that the cardiac sources are represented by a dipole located at the center of a sphere representing the torso, hence at the center of the equilateral triangle. With these assumptions, the voltages measured by the three limb leads are proportional to the projections of the electric heart vector on the sides of the lead vector triangle. The voltages of the limb leads are obtained from Equation below.

$$\begin{aligned} V_I &= p\cos\alpha = p_y \\ V_{II} &= \frac{p}{2}\cos\alpha - \frac{\sqrt{3}}{2}p\sin\alpha = \frac{1}{2}p_y - \frac{\sqrt{3}}{2}p_z = -0.5p_y - 0.87p_z \\ V_{III} &= -\frac{p}{2}\cos\alpha - \frac{\sqrt{3}}{2}p\sin\alpha = -\frac{1}{2}p_y - \frac{\sqrt{3}}{2}p_z = -0.5p_y - 0.87p_z \end{aligned} \tag{11.19}$$

1.4.1. ECG SIGNAL

Before we discuss the generation of the ECG signal in detail, we consider a simple example explaining what kind of signal a propagating activation front produces in a volume conductor.

A volume conductor and a pair of electrodes on its opposite surfaces. The figure is divided into four cases, where both the depolarization and repolarization fronts propagate toward both positive and negative electrodes. In various cases the detected signals have the following polarities:

Case A: When the depolarization front propagates toward a positive electrode, it produces a positive signal (see the detailed description below).

Case B: When the propagation of activation is away from the positive electrode, the signal has the corresponding negative polarity.

Case C: It is easy to understand that when the repolarization front propagates toward a positive electrode, the signal is negative (see the detailed description below). Although it is known that repolarization does not actually propagate, a boundary between repolarized and still active regions can be defined as a function of time. It is "propagation" in this sense that is described here.

Case D: When the direction of propagation of a repolarization front is away from the positive electrode, a positive signal is produced.

The positive polarity of the signal in case A can be confirmed in the following way. First we note that the transmembrane voltage ahead of the wave is negative since this region is still at rest. Behind the wave front, the transmembrane voltage is in the plateau stage; hence it is positive (indicated by the positive signs). If Equation 8.25 is applied to evaluate the double layer sources associated with this arrangement, as discussed in Section 8.2.4, and if the transmembrane voltage under resting or plateau conditions is recognized as being uniform, then a double layer source arises only at the wave front.

What is important here is that the orientation of the double layer, given by the negative spatial derivative of V_m, is entirely to the left (which corresponds to the direction of propagation). Because the dipoles are directed toward the positive electrode, the signal is positive. (The actual time-varying signal depends on the evolving geometry of the source double layer and its relationship to the volume conductor and the leads. In this example we describe only the gross behavior.).

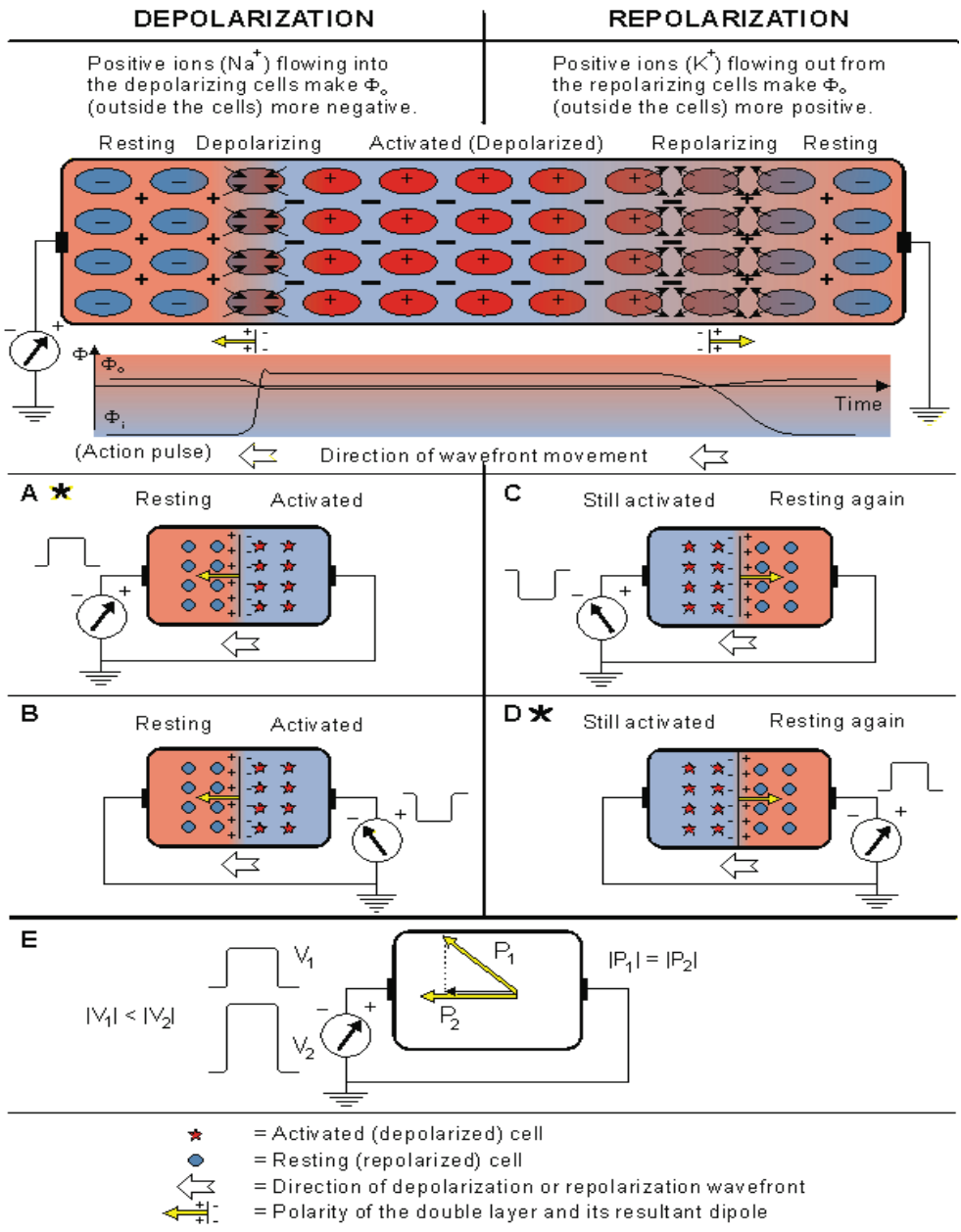


Figure 1.8. Depolarization and repolarization.

1.4.2. FORMATION OF THE ECG SIGNAL

The cells that constitute the ventricular myocardium are coupled together by gap junctions which, for the normal healthy heart, have a very low resistance. As a consequence, activity in one cell is readily propagated to neighboring cells. It is said that the heart behaves as a syncytium; a propagating wave once initiated continues to propagate uniformly into the region that is still at rest. We have quantitatively examined the electrophysiological behavior of a uniform fiber. Now we can apply these results to the heart if we consider it to be composed of uniform fibers. These equivalent fibers are a valid representation because they are consistent with the syncytial nature of the heart. In fact, because the syncytium reflects connectivity in all directions, we may choose the fiber orientation at our convenience (so long as the quantitative values of conductivity assigned to the fibers correspond to those that are actually measured).

Much of what we know about the activation sequence in the heart comes from canine studies. These studies show that activation wave fronts proceed relatively uniformly, from endocardium to epicardium and from apex to base. One way of describing cardiac activation is to plot the sequence of instantaneous depolarization wave fronts. Since these surfaces connect all points in the same temporal phase, the wave front surfaces are also referred to as *isochrones* (i.e., they are *isochronous*). An evaluation of dipole sources can be achieved by applying generalized Equation to each equivalent fiber. This process involves taking the spatial gradient of V_m. If we assume that on one side cells are entirely at rest, while on the other cells are entirely in the plateau phase, then the source is zero everywhere except at the wave front. Consequently, the wave front or is ochrone not only describes the activation surface but also shows the location of the double layer sources.

From the above it should be possible to examine the actual generation of the ECG by taking into account a realistic progression of activation double layers. Such a description is contained in the figure. After the electric activation of the heart has begun at the sinus node, it spreads along the atrial walls. The resultant vector of the atrial electric activity is illustrated with a thick arrow. The projections of this resultant vector

on each of the three Einthoven limb leads is positive, and therefore, the measured signals are also positive.

After the depolarization has propagated over the atrial walls, it reaches the AV node. The propagation through the AV junction is very slow and involves negligible amount of tissue; it results in a delay in the progress of activation. (This is a desirable pause which allows completion of ventricular filling.)

Once activation has reached the ventricles, propagation proceeds along the Purkinje fibers to the inner walls of the ventricles. The ventricular depolarization starts first from the left side of the interventricular septum, and therefore, the resultant dipole from this septal activation points to the right.

In the next phase, depolarization waves occur on both sides of the septum, and their electric forces cancel. However, early apical activation is also occurring, so the resultant vector points to the apex.

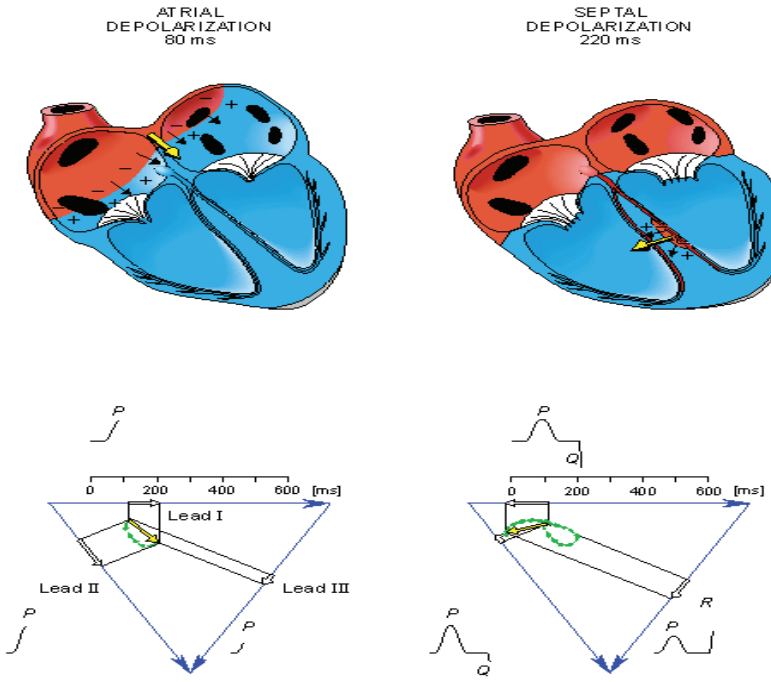


Figure 1.9. Generation of ECG signals.

The figure also includes definitions for various segments and intervals in the ECG. The deflections in this signal are denoted in alphabetic order starting with the letter P, which represents atrial depolarization. The ventricular depolarization causes the QRS complex, and repolarization is responsible for the T-wave. Atrial repolarization occurs during the QRS complex and produces such a low signal amplitude that it cannot be seen apart from the normal ECG.

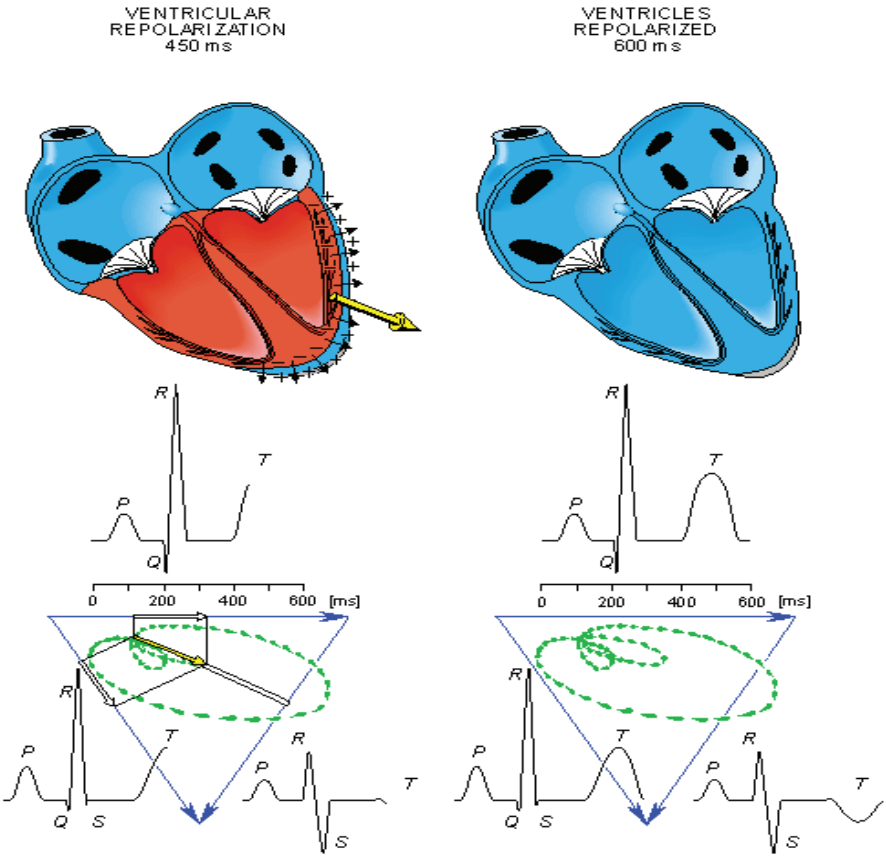


Figure 1.10. The generation of the ECG signal in the Einthoven limb leads

After a while the depolarization front has propagated through the wall of the right ventricle; when it first arrives at the epicardial surface of the right-ventricular free wall, the event is called *breakthrough*. Because the left ventricular wall is thicker, activation of the left ventricular free

wall continues even after depolarization of a large part of the right ventricle. Because there are no compensating electric forces on the right, the resultant vector reaches its maximum in this phase, and it points leftward. The depolarization front continues propagation along the left ventricular wall toward the back. Because its surface area now continuously decreases, the magnitude of the resultant vector also decreases until the whole ventricular muscle is depolarized. The last to depolarize are basal regions of both left and right ventricles. Because there is no longer a propagating activation front, there is no signal either.

Ventricular repolarization begins from the outer side of the ventricles and the repolarization front "propagates" inward. This seems paradoxical, but even though the epicardium is the last to depolarize, its action potential durations are relatively short, and it is the first to recover. Although recovery of one cell does not propagate to neighboring cells, one notices that recovery generally does move from the epicardium toward the endocardium. The inward spread of the repolarization front generates a signal with the same sign as the outward depolarization front, as pointed out in Figure (recall that both direction of repolarization and orientation of dipole sources are opposite). Because of the diffuse form of the repolarization, the amplitude of the signal is much smaller than that of the depolarization wave and it lasts longer.

1.4.3. WILSON CENTRAL TERMINAL

Frank Norman Wilson (1890-1952) investigated how electrocardiographic *unipolar* potentials could be defined. Ideally, those are measured with respect to a remote reference (infinity). Wilson and colleagues (Wilson, Macleod, and Barker, 1931; Wilson et al., 1934) suggested the use of the *central terminal* as this reference. This was formed by connecting a 5 kΩ resistor from each terminal of the limb leads to a common point called the central terminal, as shown. Wilson suggested that unipolar potentials should be measured with respect to this terminal which approximates the potential at infinity.

Actually, the Wilson central terminal is not independent of but, rather, is the average of the limb potentials. This is easily demonstrated by noting that in an ideal voltmeter there is no lead current. Consequently,

the total current into the central terminal from the limb leads must add to zero to satisfy the conservation of current

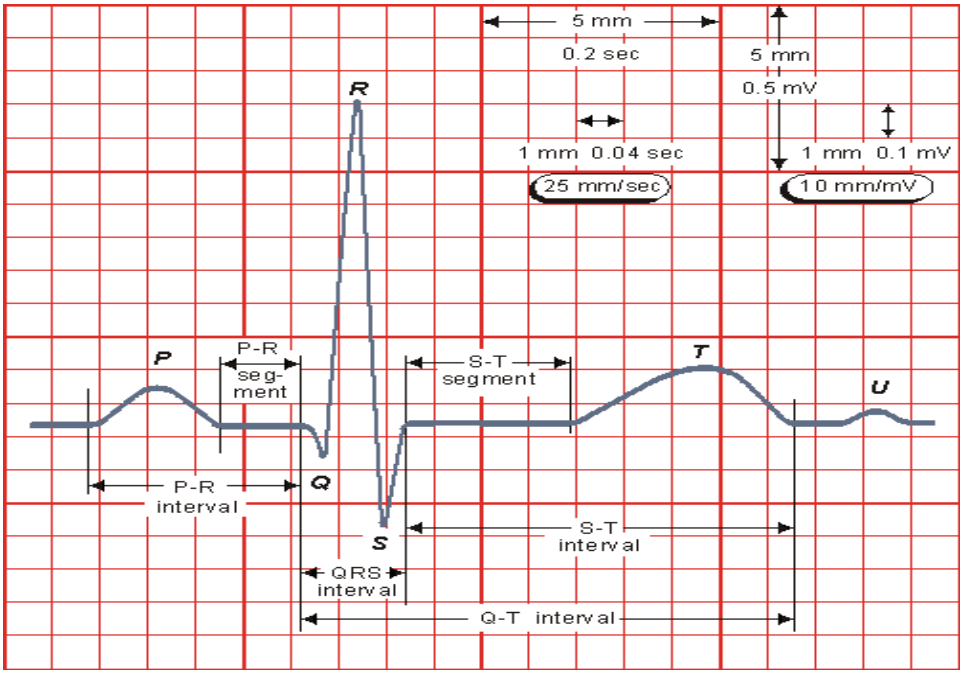


Figure 1.11. Wilson central terminal

Accordingly, we require that

$$I_R + I_L + I_F = \frac{\Phi_{CT} - \Phi_R}{5000} + \frac{\Phi_{CT} - \Phi_L}{5000} + \frac{\Phi_{CT} - \Phi_F}{5000}$$

from which it follows that

$$\Phi_{CT} = \frac{\Phi_R + \Phi_L + \Phi_F}{3}$$

Since the central terminal potential is the average of the extremity potentials it can be argued that it is then somewhat independent of any one in particular and therefore a satisfactory reference. In clinical practice good reproducibility of the measurement system is vital. Results appear to be quite consistent in clinical applications.

Wilson advocated 5 kΩ resistances; these are still widely used, though at present the high-input impedance of the ECG amplifiers

would allow much higher resistances. A higher resistance increases the CMRR and diminishes the size of the artifact introduced by the electrode/skin resistance.

It is easy to show that in the image space the Wilson central terminal is found at the center of the Einthoven triangle, as shown in Figure.

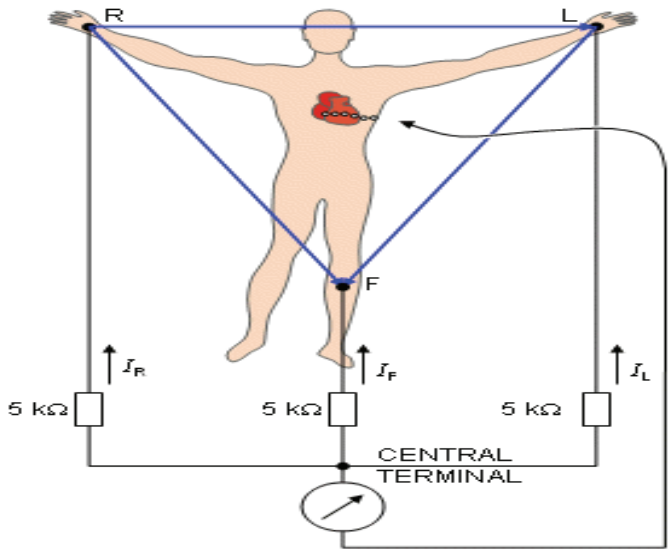


Fig. 1.12. The Wilson central terminal (CT) is formed by connecting a 5 kΩ resistance to each limb electrode and interconnecting the free wires; the CT is the common point. The Wilson central terminal represents the average of the limb potentials. Because no current flows through a high-impedance voltmeter, Kirchhoff's law requires that $I_R + I_L + I_F = 0$.

1.4.4. PRECORDIAL LEADS

(15.5) For measuring the potentials close to the heart, Wilson introduced the *precordial leads* (chest leads) in 1944. These leads, V_1-V_6 are located over the left chest as described in Figure. The points V_1 and V_2 are located at the fourth intercostal space on the right and left side of the sternum; V_4 is located in the fifth intercostal space at the midclavicular line; V_3 is located between the points V_2 and V_4; V_5 is at the same horizontal level as V_4 but on the anterior axillary line; V_6 is at the same horizontal level as V_4 but at the midline. The location of the precordial leads is illustrated in Figure.

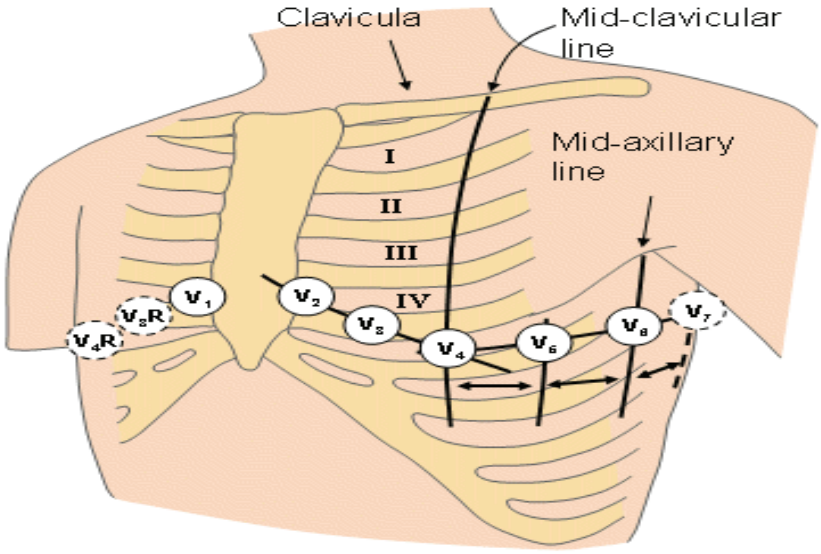


Figure 1.13. Precordial leads.

1.4.5. MODIFICATIONS OF THE 12-LEAD SYSTEM

The 12-lead system as described here is the one with the greatest clinical use. There are also some other modifications of the 12-lead system for particular applications.

In exercise ECG, the signal is distorted because of muscular activity, respiration, and electrode artifacts due to perspiration and electrode movements. The distortion due to muscular activation can be minimized by placing the electrodes on the shoulders and on the hip instead of the arms and the leg, as suggested by R. E. Mason and I. Likar (1966). The Mason-Likar modification is the most important modification of the 12-lead system used in exercise ECG.

The accurate location for the right arm electrode in the Mason-Likar modification is a point in the infraclavicular fossa medial to the border of the deltoid muscle and 2 cm below the lower border of the clavicle. The left arm electrode is located similarly on the left side. The left leg electrode is placed at the left iliac crest. The right leg electrode is placed in the region of the right iliac fossa. The precordial leads are located in the Mason-Likar modification in the standard places of the 12-lead sys-

tem. In ambulatory monitoring of the ECG, as in the Holter recording, the electrodes are also placed on the surface of the thorax instead of the extremities.

1.4.6. THE INFORMATION CONTENT OF THE 12-LEAD SYSTEM

The most commonly used clinical ECG-system, the 12-lead ECG system, consists of the following 12 leads, which are:

I, II, III
aV_R, aV_L, aV_F
V_1, V_2, V_3, V_4, V_5, V_6

Of these 12 leads, the first six are derived from the same three measurement points. Therefore, any two of these six leads include exactly the same information as the other four.

The main reason for recording all 12 leads is that it enhances pattern recognition. This combination of leads gives the clinician an opportunity to compare the projections of the resultant vectors in two orthogonal planes and at different angles. This is further facilitated when the polarity of the lead aV_R can be changed; the lead $-aV_R$ is included in many ECG recorders.

1.5. ELECTROENCEPHALOGRAPHY

The first recording of the electric field of the human brain was made by the German psychiatrist Hans Berger in 1924 in Jena. He gave this recording the name *electroencephalogram (EEG)*. (Berger, 1929). In this recording evoked potentials, and bioelectric events produced by single neurons.

Spontaneous activity is measured on the scalp or on the brain and is called the electroencephalogram. The amplitude of the EEG is about 100 V when measured on the scalp, and about 1-2 mV when measured on the surface of the brain. The bandwidth of this signal is from under 1 Hz to about 50 Hz, as demonstrated in Figure 13.1. As the phrase "spontaneous activity" implies, this activity goes on continuously in the living individual.

Evoked potentials are those components of the EEG that arise in response to a stimulus (which may be electric, auditory, visual, etc.) Such signals are usually below the noise level and thus not readily distinguished, and one must use a train of stimuli and signal averaging to improve the signal-to-noise ratio.

Single-neuron behavior can be examined through the use of microelectrodes which impale the cells of interest. Through studies of the single cell, one hopes to build models of cell networks that will reflect actual tissue properties.

1.5.1 THE BRAIN AS A BIOELECTRIC GENERATOR

The number of nerve cells in the brain has been estimated to be on the order of 10^{11}. Cortical neurons are strongly interconnected. Here the surface of a single neuron may be covered with 1,000-100,000 synapses (Nunez, 1981). The electric behavior of the neuron corresponds to the description of excitable cells introduced in the earlier chapters. The resting voltage is around -70 mV, and the peak of the action potential is positive. The amplitude of the nerve impulse is about 100 mV; it lasts about 1 ms.

The bioelectric impressed current density associated with neuronal activation produces an electric field, which can be measured on the surface of the head or directly on the brain tissue.while for most excitable tissue the basis for the impressed current density $\overline{J}^{i}$ is the propagating action potential, for the EEG it appears to arise from the action of a chemical transmitter on postsynaptic cortical neurons. The action causes localized depolarization that is, an excitatory postsynaptic potential (EPSP) - or hyperpolarization - that is, an inhibitory postsynaptic potential (IPSP). The result in either case is a spatially distributed discontinuity in the function $\sigma\Phi$ (i.e., $\sigma_o\Phi_o - \sigma_i\Phi_i$) which, as pointed out in Equation 8.28, evaluates a double layer source in the membranes of all cells. This will be zero for resting cells; however, when a cell is active by any of the aforementioned processes (in which case $\Phi_o - \Phi_i = V_m$ varies over a cell surface), a nonzero primary source will result.

For distant field points the double layer can be summed up vectorially, yielding a net dipole for each active cell. Since neural tissue is generally composed of a very large number of small, densely packed

cells, the discussion in Section 8.5 applies, leading to the identification of a continuous volume source distribution $\overline{J}^{i}$ which appears in Equations

Although in principle the EEG can be found from the evaluation of Equation 7.10, the complexity of brain structure and its electrophysiological behavior have thus far precluded the evaluation of the source function $\overline{J}^{i}$. Consequently, the quantitative study of the EEG differs from that of the ECG or EMG, in which it is possible to evaluate the source function. Under these conditions the quantitative EEG is based on a statistical treatment, whereas the clinical EEG is largely empirical.

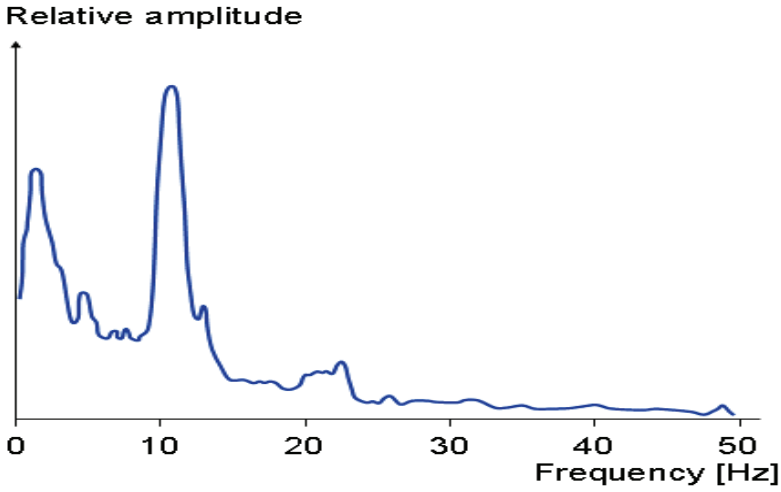


Figure 1.14. Frequency spectrum of normal EEG.

1.5.2. EEG LEAD SYSTEMS

The internationally standardized *10-20 system* is usually employed to record the spontaneous EEG. In this system 21 electrodes are located on the surface of the scalp, as shown in Figure. The positions are determined as follows: Reference points are *nasion*, which is the delve at the top of the nose, level with the eyes; and *inion*, which is the bony lump at the base of the skull on the midline at the back of the head. 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, as shown.

In addition to the 21 electrodes of the international 10-20 system, intermediate 10% electrode positions are also used. The locations and nomenclature of these electrodes are standardized by the American Electroencephalographic Society. In this recommendation, four electrodes have different names compared to the 10-20 system; these are T_7, T_8, P_7, and P_8. These electrodes are drawn black with white text in the figure.

Besides the international 10-20 system, many other electrode systems exist for recording electric potentials on the scalp. The *Queen Square system* of electrode placement has been proposed as a standard in recording the pattern of evoked potentials in clinical testings.Bipolar or unipolar electrodes can be used in the EEG measurement. 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.

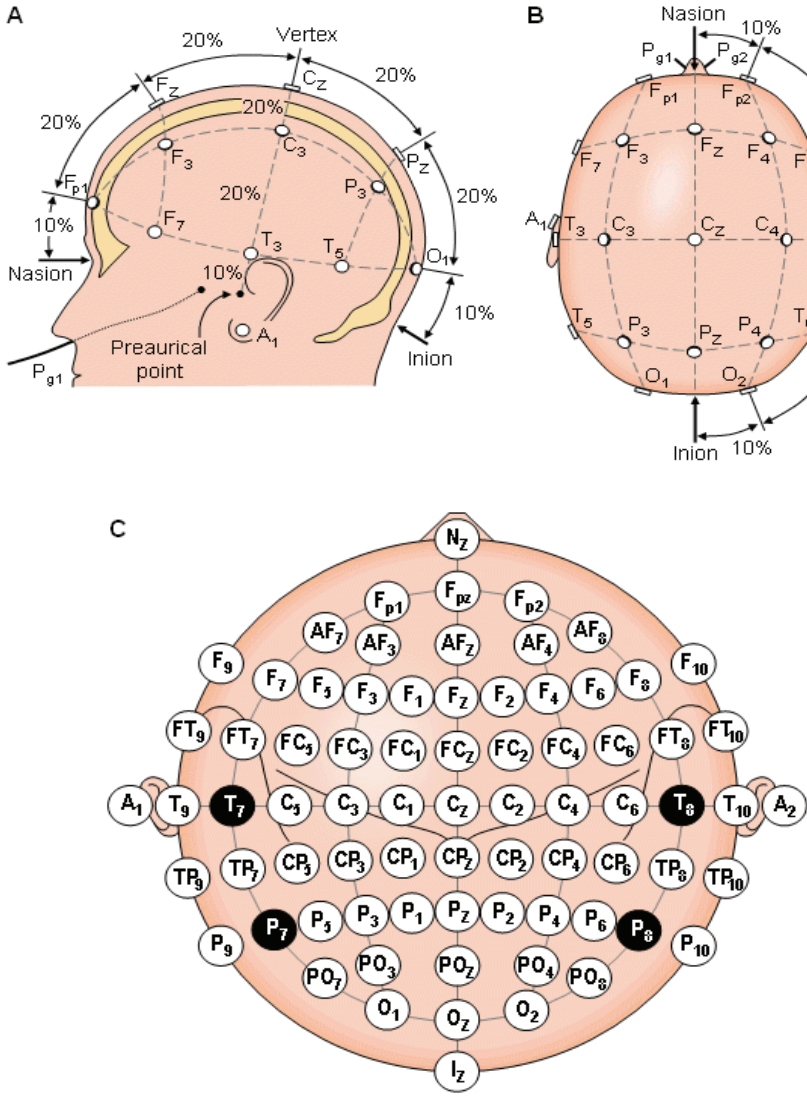


Figure 1.15. The international 10-20 system seen from (A) left and (B) above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital. (C) Location and nomenclature of the intermediate 10% electrodes, as standardized by the American Electroencephalographic Society. (Redrawn from Sharbrough, 1991.)

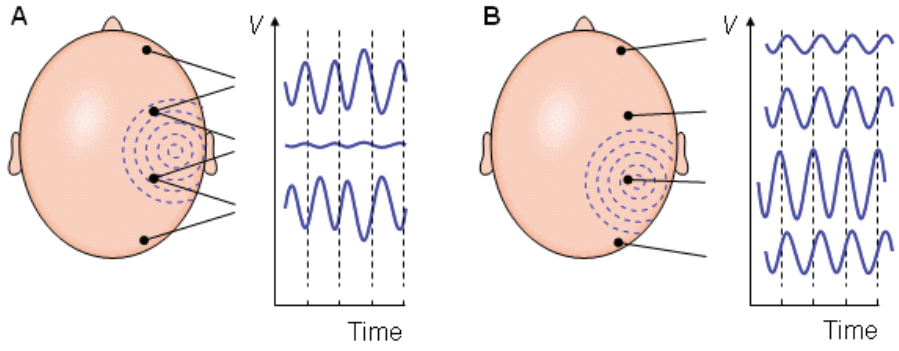


Figure 1.16. (A) Bipolar and (B) unipolar measurements. Note that the waveform of the EEG depends on the measurement location

1.5.3. SENSITIVITY DISTRIBUTION OF EEG ELECTRODES

Rush and Driscoll (1969) calculated the sensitivity distribution of bipolar surface electrodes on the scalp based on a concentric spherical head model. They published the results in the form of lead field is potential lines. The direction of the lead field current density - that is, the direction of the sensitivity - is a negative gradient of the potential field. This is not immediately evident from such a display.

Puikkonen and Malmivuo (1987) recalculated the sensitivity distribution of EEG electrodes with the same model as Rush and Driscoll, but they presented the results with the lead field current flow lines instead of the is potential lines of the lead field. This display is illustrative since it is easy to find the direction of the sensitivity from the lead field current flow lines. Also the magnitude of the sensitivity can be seen from the density of the flow lines. A minor problem in this display is that because the lead field current distributes both in the plane of the illustration as well as in the plane normal to it, part of the flow lines must break in order to illustrate correctly the current density with the flow line density in a three-dimensional problem. Suihko, Malmivuo and Eskola (1993) calculated further the is sensitivity lines and the *half-sensitivity volume* for the electric leads.

The concept half-sensitivity volume denotes the area where the lead field current density is at least one half from its maximum value. Thus

this concept is a figure of merit to describe how concentrated the sensitivity distribution of the lead. When the conductivity is isotropic, as it is in this head model, the is sensitivity lines equal to the is field lines of the (reciprocal) electric field. If the lead would exhibit such a symmetry that adjacent is potential surfaces would be a constant distance apart, the is sensitivity lines would coincide with the is potential lines.

Displays the lead field current flow lines, is sensitivity lines and half-sensitivity volumes for the spherical head model with the electrodes located within 180°, 120°, 60°, 40°, and 20° angles. Note that in each case the two electrodes are connected with 10 continuous lead field flow lines. Between them are three flow lines which are broken from the center, indicating that the lead field current distributes also in the plane normal to the paper. The figure shows clearly the strong effect of the poorly conducting skull to the lead field. Though in a homogeneous model the sensitivity would be highly concentrated at the electrodes, in the 180° case the skull allows the sensitivity to be very homogeneously distributed throughout the brain region. The closer the electrodes are to each other, the smaller the part of the sensitivity that locates within the brain region. Locating the electrodes closer and closer to each other causes the lead field current to flow more and more within the skin region, decreasing the sensitivity to the brain region and increasing the noise.

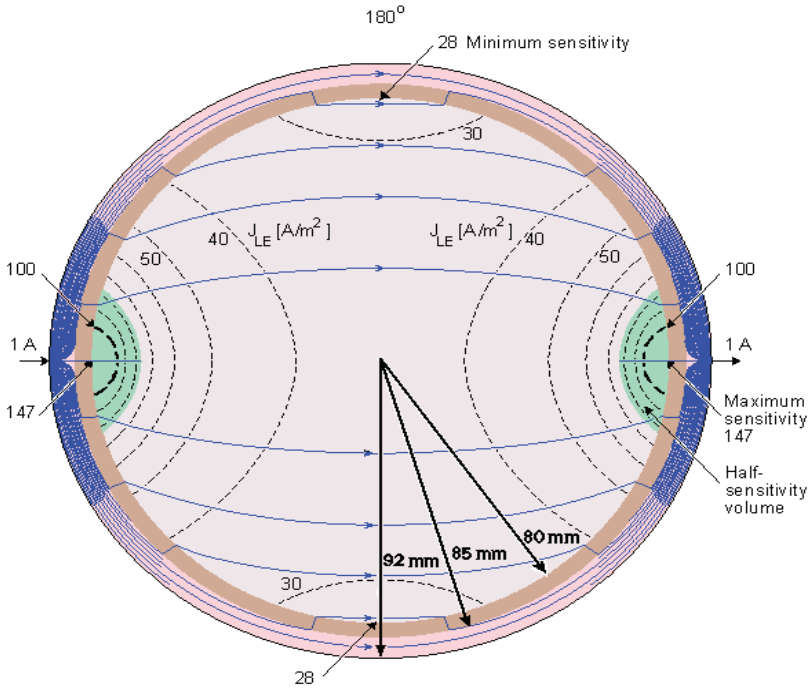


Figure 1.17. Sensitivity distribution of EEG electrodes in the spherical head model

The figure illustrates the lead field current flow lines (thin solid lines), is sensitivity lines (dotted lines) and the half-sensitivity volumes (shaded region). The sensitivity distribution is in the direction of the flow lines, and its magnitude is proportional to the density of the flow lines. The lead pair are designated by small arrows at the surface of the scalp and are separated by an angle of 180°, 120°, 60°, 40°, and 20° shown at the top of each figure.

1.5.4. THE BEHAVIOR OF THE EEG SIGNAL

From the EEG signal it is possible to differentiate alpha (α), beta (β), delta (δ), and theta (Θ) waves as well as spikes associated with epilepsy. An example of each waveform is given in Figure.

The alpha waves have the frequency spectrum of 8-13 Hz and can be measured from the occipital region in an awake person when the eyes

are closed. The frequency band of the beta waves is 13-30 Hz; these are detectable over the parietal and frontal lobes. The delta waves have the frequency range of 0.5-4 Hz and are detectable in infants and sleeping adults. The theta waves have the frequency range of 4-8 Hz and are obtained from children and sleeping adults.

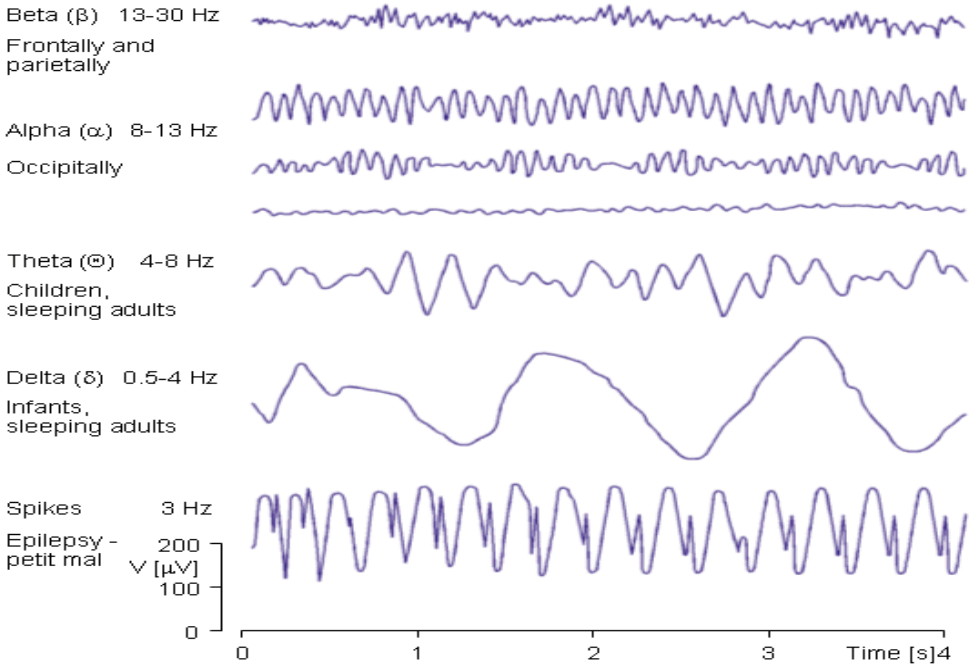


Figure 1.18. Examples of brain waveforms.

1.5.5. THE BASIC PRINCIPLES OF EEG DIAGNOSIS

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. Examples of the above-mentioned waveforms are given in Figure.

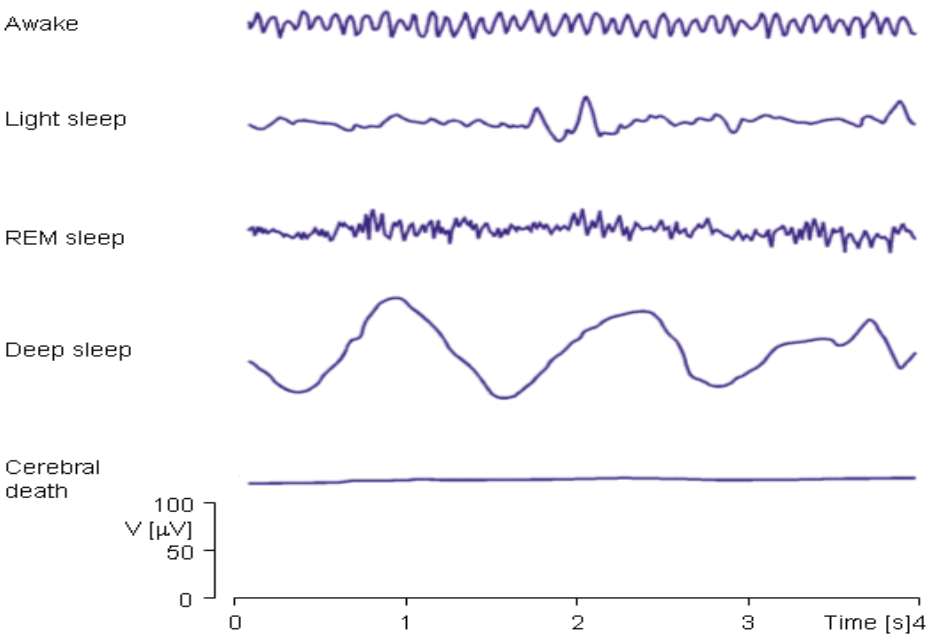


Figure 1.19. EEG activity is dependent on the level of consciousness

1.5. PHONOCARDIOGRAM

A **Phonocardiogram** or **PCG** is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiograph, or "Recording of the sounds made by the heart during a cardiac cycle. The sounds are thought to result from vibrations created by closure of the heart valves. There are at least two: the first when the atrioventricular valves close at the beginning of systole and the second when the aortic valve and pulmonary valve close at the end of systole. It allows the detection of sub audible sounds and murmurs, and makes a permanent record of these events. In contrast, the ordinary stethoscope cannot detect such sounds or murmurs, and provides no record of their occurrence. The ability to quantitate the sounds made by the heart provides information not readily available from more sophisticated tests, and provides vital information about the effects of

certain cardiac drugs upon the heart. It is also an effective method for tracking the progress of the patient's disease.

In PCG, different types of heart sounds are measured. These heart sounds are due to the

vibrations set up in the blood inside the heart by the sudden closure of valves. In abnormal heart

additional sounds are heard between the normal heart sound. These additional sounds are known

as murmurs. Murmers is generally caused by improper opening of the valves or by regurgitation.

CLASSIFICATION OF HEART SOUND

It is divided into four types;

- Valve closure sound
- Ventricular filling sound
- Valve opening sound
- Extra cardiac sound.

Valve closure sound

This sound occurs at the beginning of systole and at the beginning of diastole.

Ventricular filling sound

This sound is occurred at the time of filling of the ventricles.

Valve opening sound

This sound occurs at the time of opening of atrio- ventricular valves and semi lunar valves.

Extra cardiac sound

This sound occur in mid systole or late systole or early diastole

Systole: The contraction of the heart muscle. The systolic pressure is 120mm of Hg.

Diastole: The relaxation of the heart muscle. The diastolic pressure is 80 mm of Hg.

1.6.1. PCG RECORDING SYSTEM

Microphone is used to convert heart sound into the electrical signals. Certain positions are recommended to pick up the heart sound by using microphone. The electrical signal picked up by the microphone is amplified by the amplifier block. The amplified output is given to filter block. Here high pass filter is used. Its cut of frequency is 1 kHz. Here ECG electrode system and ECG amplifiers are used for reference for PCG. So ECG and PCG outputs are connected to FM tape recorder and output display unit.

TYPES OF MICROPHONES USED IN PCG

1. Air coupled microphone- Movement of chest is transferred through the air cushion. It provides low mechanical impedance to the chest.

2. Contact microphone – it is directly coupled to the chest wall and provides high impedance, high sensitivity, and low noise. Its light weight is also one of the advantageous factor. The first heart sound is developed during the opening of aortic valve and during the closing of mitral valve.

1.6.2. PCG Waveform

Frequency of first heart sound consists of 30 to 45 Hz. Second heart sound is usually higher in pitch than the first. Its frequency range is 50Hz to 70 Hz. Third heart sound is extremely weak vibrate sound is extremely weak vibration. Its frequency is below 600 Hz. Aortic stenos are murmur occurred when the blood is ejected from the left ventricle through aortic valve due to resistance to ejection, the pressure in the left ventricle increased. So turbulent blood flow occur. This turbulent blood impinging the aortic valve. So intense vibration is produced. It produces loud murmur.

Mitral regurgitation murmur- In this murmur, blood flows in backward direction through the mitral valve during systole.

Aortic regurgitation murmur – During diastole, sound is heard. In diastole blood flows in the backward direction from aorta to left ventricles when valves are damaged, then this sound is heard.

Mitral stenosis murmur – This murmur is produced when blood is passed from left atrium to left ventricle. This sound is very weak.

1.7. ELECTROMYOGRAM

Movement and position of limbs are controlled by electrical signals traveling back and forth between the muscles and the peripheral and central nervous system. When pathologic conditions arise in the motor system, whether in the spinal cord, the motor neurons, the muscle, or the neuromuscular junctions, the characteristics of the electrical signals in the muscle change. Careful registration and study of electrical signals in muscle (electromyograms) can thus be a valuable aid in discovering and diagnosing abnormalities not only in the muscles but also in the motor system as a whole. Electromyography (EMG) is the registration and interpretation of these muscle action potentials. Until recently, electromyograms were recorded primarily for exploratory or diagnostic purposes; however, with the advancement of bioelectric technology, electromyograms also have become a fundamental tool in achieving artificial control of limb movement, i.e., functional electrical stimulation (FES) and rehabilitation. The concentric needle electrode introduced by Adrian and Bronk in 1929 provided an easy-to-use electrode with high mechanical qualities and stable, reproducible measurements. Replacement of galvanometers with high-gain amplifiers allowed smaller electrodes with higher impedances to be used and potentials of smaller amplitudes to be recorded.

With these technical achievements, clinical EMG soon evolved into a highly specialized field where electromyogram graphic's with many years of experience read and interpreted long paper EMG records based on the visual appearance of the electromyograms. Slowly, a more quantitative approach emerged, where features such as potential duration, peak-to-peak amplitude, and number of phases were measured on the paper records and compared with a set of normal data gathered from healthy subjects of all ages. In the last decade, the general-purpose rack-mounted equipment of the past have been replaced by ergonomi-

cally designed EMG units with integrated computers. Electromyograms are digitized, processed, stored on removable media, and displayed on computer monitors with screen layouts that change in accordance with the type of recording and analysis chosen by the investigator.

1.7.1 The Structure and Function of Muscle

Muscles account for about 40% of the human mass, ranging from the small extraocular muscles that turn the eyeball in its socket to the large limb muscles that produce locomotion and control posture. The design of muscles varies depending on the range of motion and the force exerted In the most simple arrangement (*fusiform*), parallel fibers extend the full length of the muscle and attach to tendons at both ends. Muscles producing a large force have a more complicated structure in which many short muscle fibers attach to a flat tendon that extends over a large fraction of the muscle. This arrangement (*unipennate*) increases the cross-sectional area and thus the contractile force of the muscle. When muscle fibers fan out from both sides of the tendon, the muscle structure is referred to as *bipennate.*A lipid bilayer (*sarcolemma*) encloses the muscle fiber and separates the intracellular myoplasma from the interstitial fluid. Between neighboring fibers runs a layer of connective tissue, the *endomysium,* composed mainly of collagen and elastin. Bundles of fibers, *fascicles,*are held together by a thicker layer of connective-tissue called the *perimysium.* The whole muscle is wrapped in a layer of connective tissue called the *epimysium*. The connective tissue is continuous with the tendons attaching the muscle to the skeleton. In the mycoplasma, thin and thick filaments interdigitate and form short, serially connected identical units called *sarcomeres.*

Numerous sarcomeres connect end to end, thereby forming longitudinal strands of myofibrils that extend the entire length of the muscle fiber. The total shortening of a muscle during contraction is the net effect of all sarcomeres shortening in series simultaneously. The individual sarcomeres shorten by forming cross-bridges between the thick and thin filaments. The cross bridges pull the filaments toward each other, thereby increasing the amount of longitudinal overlap between the thick and thin filaments. The dense matrix of myofibrils is held in place by

a structural framework of intermediate filaments composed of desmin, vimetin, and synemin.

At the site of the neuromuscular junction, each motor neuron forms collateral sprouts (Fig. 14.2) and innervates several muscle fibers distributed almost evenly within an elliptical or circular region ranging from 2 to 10 mm in diameter. The motor neuron and the muscle fibers it innervates constitute a functional unit, the motor unit. The cross section of muscle occupied by a motor unit is called the motor unit territory (MUT). A typical muscle fiber is only innervated at a single point, located within a cross sectional band referred to as the *end-plate zone.*

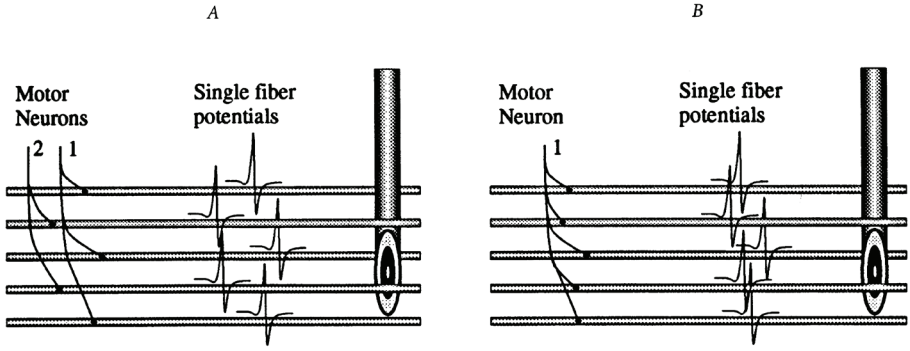


Figure 1.20. Innervation and reinnervation of muscle of muscle fibres.

The fibers of the same motor unit are thought to be randomly or evenly distributed within the motor unit territory; however, reinnervation of denervated fibers often results in the formation of fiber clusters.

1.7.2. The Origin of Electromyograms

Unlike the myocardium, skeletal muscles do not contain pacemaker cells from which excitations arise and spread. Electrical excitation of skeletal muscle is initiated and regulated by the central and peripheral nervous systems. Motor neurons carry nerve impulses from the anterior horn cells of the spinal cord to the nerve endings, where the axonal action potential triggers the release of the neurotransmitter acetylcholine (Ach) into the narrow clefts separating the sarcolemma from the axon terminals. As Ach binds to the sarcolemma, Ach-sensitive sodium channels open, and miniature end-plate potentials arise in the sarcolemma.

If sufficient Ach is released, the summation of miniature end-plate potentials, i.e., the endplate potential, reaches the excitation threshold, and sarcolemma action potentials propagate in opposite directions toward the tendons. As excitation propagates down the fiber, it spreads into a highly branched transverse network of tubules (T system) which interpenetrate the myofibrils. The effective radial conduction velocity (~4 cm/s) is about two orders of magnitude slower than the longitudinal conduction velocity (2 to 5 m/s). This is due to the fact that the main portion of the total membrane capacitance is located in the T system and that the lumen of the T system constitutes a higher electrical resistance than the myoplasma.

The slower tubular conduction velocity implies an increasingly delayed onset of tubular action potentials toward the center of the fiber relative to that of the sarcolemmal action potential.

However, compared with the time course of the subsequent contraction, the spread of excitation along and within the muscle fiber is essentially instantaneous, thereby ensuring simultaneous release of calcium from the sarcoplasmic reticulum throughout the entire volume of the muscle. If calcium release were restricted to a small longitudinal section of the muscle fiber, only sarcomeres in this region would contract, and sarcomeres in the rest of the fiber would stretch accordingly. Similarly, experiments in detubulated muscle fibers, i.e., fibers in which the continuation between the sarcolemmal and the tubular membrane has been disrupted, have demonstrated that only a thin layer of superficial myofibrils contracts when tubular action potentials fail to trigger calcium release deep in the muscle fiber.

All fibers are assumed to be of the same size and with identical, perfectly axisymmetric potential distributions. The net single-fiber current source is an increasing function of fiber size; thus the magnitude of the potential distribution will vary with varying fiber size. Fibers can to a good approximation be considered as constant current sources; hence if the resistivity of the muscle tissue increases, e.g., due to increased fiber packing density, the potential difference between an observation point and a reference point also will increase. It follows that local variations in fiber packing density in the region of an active fiber will destroy the axisymmetric appearance of its potential distribution. Muscle fibers are

not perfect cylinders, and angular variation in the shape of the sarcolemma must be expected to create angular variations in the potential distribution. However, due to the relatively high conductivity of the volume conductor, it is plausible that such variations become increasingly insignificant as the distance to the fiber is increased.

1.7.3. Electromyography Recordings

A considerable amount of information regarding the bioelectrical state of a muscle is hidden in the time varying spatial distribution of potentials in the muscle. Unfortunately, it is not clinically feasible to obtain high-resolution three-dimensional samples of the spatial potential distribution, since this would require the insertion of hundreds of electrodes into the muscles. In order to minimize the discomfort of the patient, routine EMG procedures usually employ only a single electrode that is inserted into different regions of the muscle. As the SFAPs of an active motor unit pass by the electrode, only their summation, i.e., the MUP, will be registered by the electrode. The electrode is effectively integrating out the spatial information hidden in the passing potential complex, leaving only a time-variant potential waveform to be recorded and interpreted. It goes without saying that such a constraint on the recording procedure puts the electromyographies at a considerable disadvantage. To partially circumvent this setback, technical innovations and new procedures have continued to refine EMG examinations to such a level that some of the spatial information originally obscured by the electrode can be extracted intuitively from the temporal waveforms by an experienced electromyography's. With a detailed understanding of the bioelectric principles involved, e.g., the bioelectric sources, the volume conductor, and the recording properties of the electrode, the electromyography's can quickly recognize and explain the waveform characteristics associated with various neuromuscular abnormalities. To increase the amount of diagnostic information, several sets of EMG investigations may be performed using electrodes with different recording characteristics. Three of the most popular EMG needle electrodes are used. The concentric and monopolar electrodes have an intermediate pickup range and are used in conventional recordings. The single-fiber electrode is a more

recent innovation. It has a very small pickup range and is used to obtain recordings from only one or two muscle fibers.

1.7.4 ELECTRODES USED FOR EMG

Two types of electrodes

Surface electrodes- Usually this electrode is used for EMG. But by using this electrode, it is not possible to take the deeper potential.

Needle electrodes – These are inserted into tissue or closer to tissue to measure the electrical activity of muscle.

1.7.5 EMG RECORDING SYSTEM

EMG potentials are taken from the tissue by using electrodes. These EMG potentials are given to differential amplifier. This is the high gain amplifier. Its frequency range is given as 10 Hz to 10 KHz. Bandwidth of EMG is large. CMRR (Common mode Rejection Ratio) of this differential amplifier is 80 to 100 db. Input Impedance of this amplifier is 10 MΩ. Here there is no lead selector switch. Because only two electrodes are available. The output of the differential amplifier is given to loudspeaker system, tape recorder and CRO. Before giving the output of differential amplifier to loudspeaker, it is given to power amplifier. Power amplifier amplifies the signal that is received by loudspeaker. The amplified signal from the output of the differential amplifier is displayed by using CRO. Here storage oscilloscope is used. Output cab be displayed and the same can be stored in the CRO. The signal from the differential amplifier is recorded by using tape recorder. It is used for the future purpose.

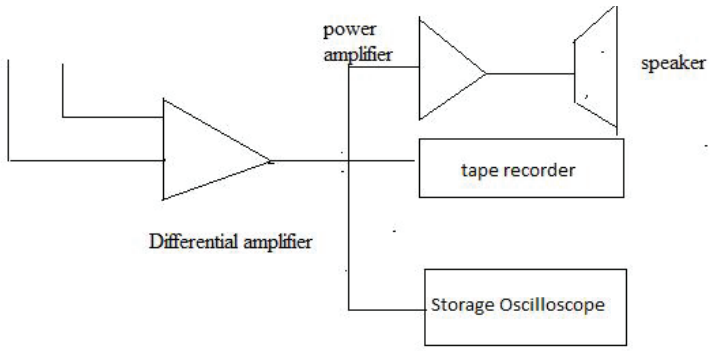


Figure 1.21. EMG recording system

1.7.6. MEASUREMENT OF CONDUCTION VELOCITY IN MOTOR NERVES

In modern EMG systems, nerve conduction time and nerve velocity are measured. For this measurement, initially nerve is stimulated and EMG is measured. This conduction velocity measurement is used to indicate the location and type of nerve lesion.

Steps Involved in Measurement of Conduction Velocity

- Stimulate is applied at point A
- Electrical activity of muscle is measured at point B
- The space between A and B is noted as l1 meters.
- The time delay between applying stimulus and receiving action potential is known as latency. This time delay is denoted as t1 second.
- Now change the position of A into C. Now the space is reduced. It is noted as l2meters.
- The time delay noted is t2 second.
- Usually, l2<l1 and t2 <t1.
- Now, the conduction velocity is given as, V= l1-l2/t1-t2.
- Usually V= 50 m/sec.
- If V<40 m/s. It means there is some disorder in nerve conduction.
- Thus conduction velocity is measured in motor nerves.
- Skeletal muscle is organized functionally on the basis of the motor unit.

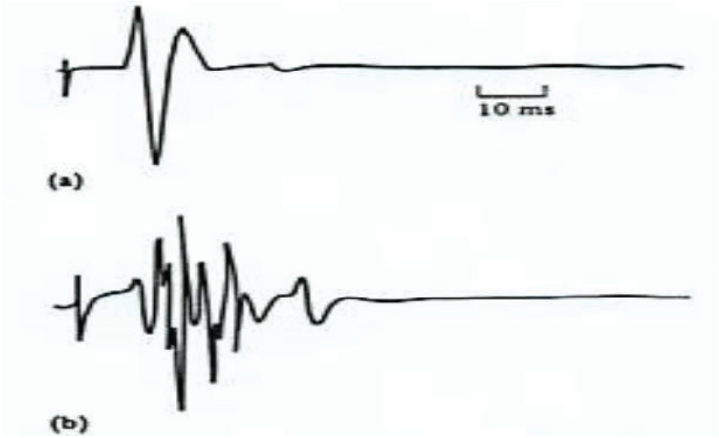


Figure 1.22. EMG response of a normal and an abnormal wave forms

Applications of EMG

EMG is used in the field of

-Electrophysiological testing.

-Clinical neurophysiology.

-Neurology

- Psychiatry.

1.8. EOG (ELECTROCULOGRAM)

EOG is the recording of the bio potentials generated by the movement of eyes. Here, corneal retinal potentials associated with eye movement is recorded. Electrode used in EOG are **surface electrodes**.

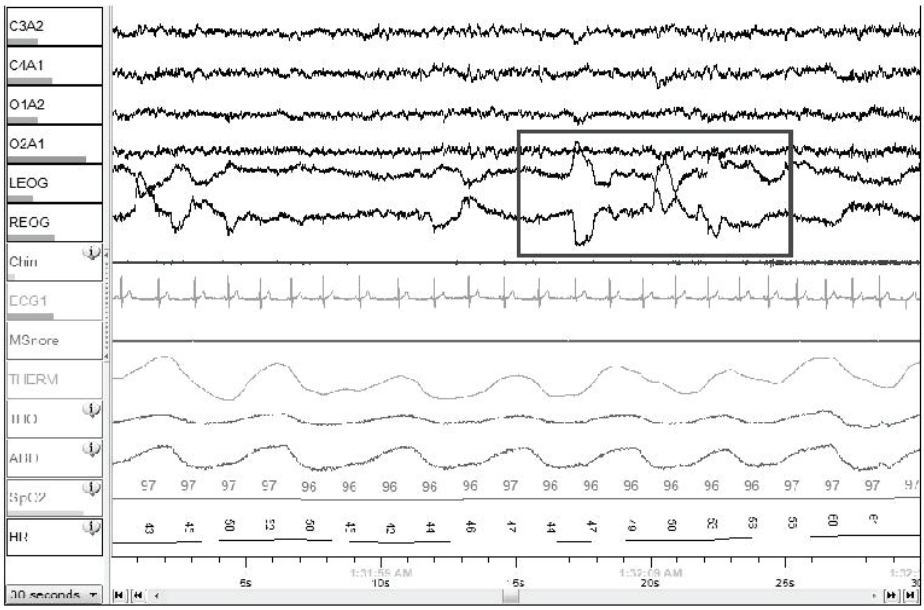


Figure 1.23. EOG waveforms

1.8.1. EOG MEASUREMENT

- Block diagram of EOG measurement system is shown. In the figure, position of electrodes is shown.
- One pair of electrodes is placed above and below the nose. These electrodes are used to measure the vertical movement of eye. The signals from these two pairs of electrodes are given to the amplifier.
- Another pair of electrodes is placed in the left side and right side of the eye. Horizontal movement of an eye is measured by using these electrodes.
- The signals from these electrodes are given to the amplifier circuit.

Applications of EOG

- The effect of some drugs on the eye movement systems can be identified by using EOG.

- It is used to analyze the state of semicircular canals.
- Diagnosis of the neurologic disorders is possible.
- The level of anesthesia can be indicated by the characteristic of eye movement

UNIT II.
BIO-CHEMICAL AND NON ELECTRICAL PARAMETER MEASUREMENT

2.1. PH MEASUREMENT

The chemical balance in the body can be determined by the pH value of blood and other body fluids.ph is defined as the hydrogen ion concentration of a fluid. It is the logarithm of the reciprocal value of H+ concentration. The pH equation is given as, PH= - log10 [H+] = log10 1/ [H+]. pH is the measure of acid- base balance in a fluid, A neutral solution has the ph value as 7. Solutions with pH value less than 7 are acidic and above 7 are basic. Most of the body fluids are slightly basic in nature.

Construction and Working

The ph meter is made up of a thin glass membrane and it allows only the hydrogen ions to pass through it. The glass electrode provides a membrane interface for H+ ions. The glass bulb at the lower end of the ph meter contains a highly acidic buffer solution. The glass tube consists of a sliver-sliver chloride (Ag/Agcl) electrode and the reference electrode which is made up of calomel sliver-sliver chloride(Ag/Agcl) is tan placed in the solution in which ph is being measured.

The potential is measured across the two electrodes. The electrochemical measurement, which should be obtained by each of the electrodes called half- cell. The electrode potential is called as half-cell potential. Here the glass electrode inside the tube constitutes one half –cell and the calomel or reference electrode is considered as the other half-cell.

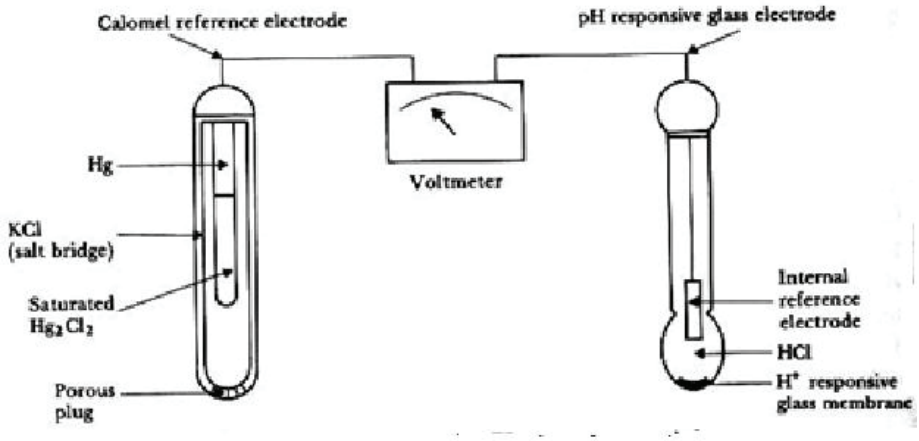


Figure 2.1. pH electrode

For easier pH measurement combination electrodes are used. In this type both the active glass electrode and reference electrode are present in the same meter. The glass electrodes are suitable only to measure pH values around 7. Since this type of glass electrodes produce considerable errors during the measurement of high PH values, special type of PH electrodes are used. After every measurement the pH meter is washed with 20% ammonium difluoride solution, for accurate results. The PH meter with hydroscopic glass absorbs water readily and provides best pH value.

2.2. pO2 MEASUREMENT

The term po2 is defined as the partial pressure of oxygen respectively. The determination of po2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by $P0_2$ measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood. The platinum wire, which is an active electrode, is embedded in glass for insulation and only its tip is exposed. It is kept in the electrolyte solution in which the oxygen is allowed to diffuse. The reference electrode is made up of silver-silver chloride (Ab/AgCl). A voltage of 0.7 is applied between the platinum wire and the reference electrode. The

negative terminal is connected to the active electrode through a micro ammeter and the positive terminal is given to the reference electrode.

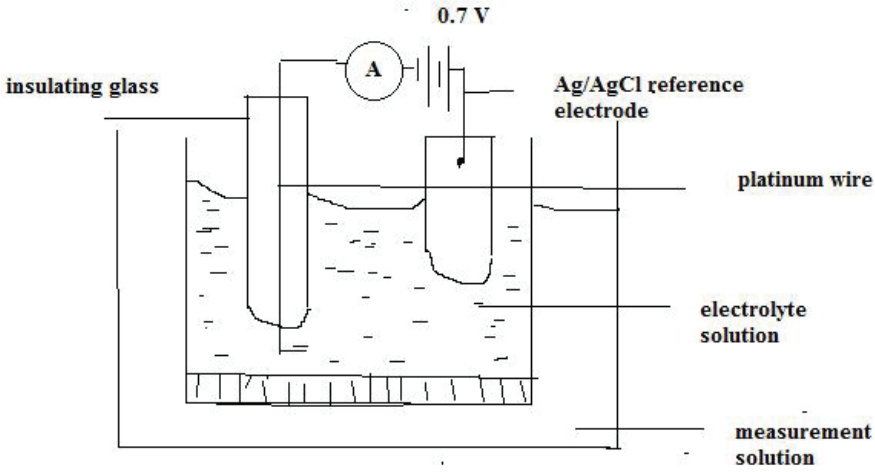


Figure 2.2. pO2 electrode

Due to the negative terminal, the oxygen reduction takes place at the platinum cathode. Finally, the oxidation reduction current proportional to the partial pressure of oxygen diffused into the electrolyte can be measured in the micro ammeter. The electrolyte is generally scaled in the electrode chamber by means of a membrane through which the oxygen can diffuse from the blood or sample solution.

There are two types of pO2 measurement.

They are;

I) Vitro measurement

II) Vivo measurement

In case of dark electrode the platinum cathode and the reference electrode is present in a single unit. This electrode is used for vitro and vivo measurements.

In Vitro Measurements

In this method the blood sample is taken and the measurement for oxygen saturation is made in the laboratory. The electrode is placed in the sample blood solution and the pO2 value is determined.

In Vivo Measurements

In this method the oxygen saturation is determined while the blood is flowing in the circulatory system. A micro version of the pO2 electrode is placed at the tip of the catheter so that it can be inserted into various parts of the heart or circulatory system.

The pO2 measurement also has some disadvantages in it. The reduction process in the platinum cathode removes a finite amount of the oxygen from the cathode. And there is a gradual reduction of current with respect to time. However careful design and proper procedures in modern pO2 electrodes reduce the errors.

2.3. pCO2 MEASUREMENT

The term pco2 is defined as the partial pressure of carbon dioxide respectively. The determination of pco2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by pCO_2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood. The partial pressure of carbon dioxide can be measured with the help of pCO2 electrodes Since there is a linear relationship between the logarithm of pCO2 and pH of a solution. The pCO2 measurement is made by surrounding a pH electrode with a membrane selectively permeable to CO2.

The modern improved pCO2 electrode is called as severinghous electrode. In this electrode the membrane permeable to CO2 is made up of Teflon which is not permeable to other ions which affects the pH value. The space between the Teflon and glass contains a matrix layer which allows only the CO2 gas molecules to diffuse through it.

One of the demerits in older CO2 electrode is, it requires a length of time for the CO2 molecules to diffuse through the membrane. The modern CO2 electrode is designed in such a way to overcome this demerit. Here the CO2 molecules diffuse rapidly through the membrane and the measurement can be done easily.

2.1. MEASUREMENT OF pHCO3

- Blood gas analyzers are used to measure the content of pH, pCO and PO2 from the blood.

- Two gases of accurately known O2 and CO2 percentages are required for calibrating the analyzer in pO2 and pCO2 modes. These gases are used with precision regulators for flow and pressure control. Two standard buffers of known pH are required for calibration of the analyzer in the pH mode.
- Input signal to the calculator is obtained from the outputs of the pH and pCO2 amplifiers
- The outputs are adjusted by multiplying with a constant and are given to an adder circuit
- The output of adder is passed to antilog generators circuit. Then it is passed to A/D converter for display. Resistance R is used to adjust zero at the output.
- Total CO2 is calculated by summing the output signals of the calculators and the output of the pCO2 amplifier

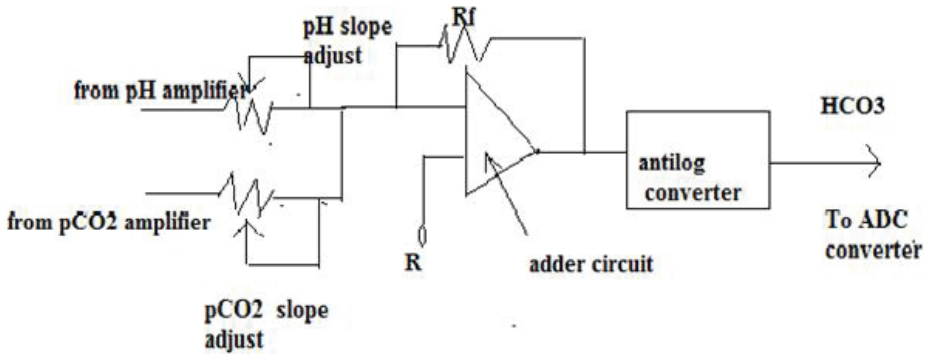


Figure 2.3. Circuit diagram of computation of bicarbonate

2.5 ELECTROPHORESIS

In clinical laboratories, various devices are used based on the electrophoretic principle.

These Devices are Used for the Following Applications

Ø To measure the quantity of protein in plasma, urine, etc.

Ø To separate enzymes into their components is enzymes.

Ø To identify antibodies.

Electrophoresis is an analytical method frequently used in molecular biology and medicine. It is applied for the separation and characterization of proteins, nucleic acids and sub cellular-sized particles like viruses and small organelles. Its principle is that the charged particles of a sample migrate in an applied electrical field. If conducted in solution, samples are separated according to their surface net charge density. The most frequent applications, however, use gels (polyacrylamide, agarose) as a support medium. The presence of such a matrix adds a sieving effect so that particles can be characterized by both charge and size.

Protein electrophoresis is often performed in the presence of a charged detergent like sodium dodecyl sulfate (SDS) which usually equalizes the surface charge and, therefore, allows for the determination of protein sizes on a single gel. Additives are not necessary for nucleic acids which have a similar surface charge irrespective of their size.

Electrophoresis is the motion of dispersed particles relative to a fluid under the influence of a spatially uniform electric field. It is ultimately caused by the presence of a charged interface between the particle surface and the surrounding fluid. It is the basis for a number of analytical techniques used in biochemistry for separating molecules by size, charge, or binding affinity.

Electrophoresis of positively charged particles (cations) is called cataphoresis, while electrophoresis of negatively charged particles (anions) is called anaphoresis. Electrophoresis is a technique used in laboratories in order to separate macromolecules based on size. The technique applies a negative charge so proteins move towards a positive charge. This is used for both DNA and RNA analysis. Polyacrylamide gel electrophoresis (PAGE) has a clearer resolution than agarose and is more suitable for quantitative analysis. In this technique DNA foot-printing can identify how proteins bind to DNA. It can be used to separate proteins by size, density and purity. It can also be used for plasmid analysis, which develops our understanding of bacteria becoming resistant to antibiotics.

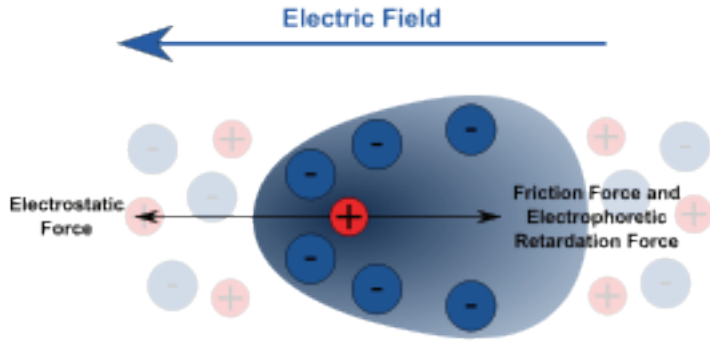


Figure 2.4. Illustration of electrophoresis

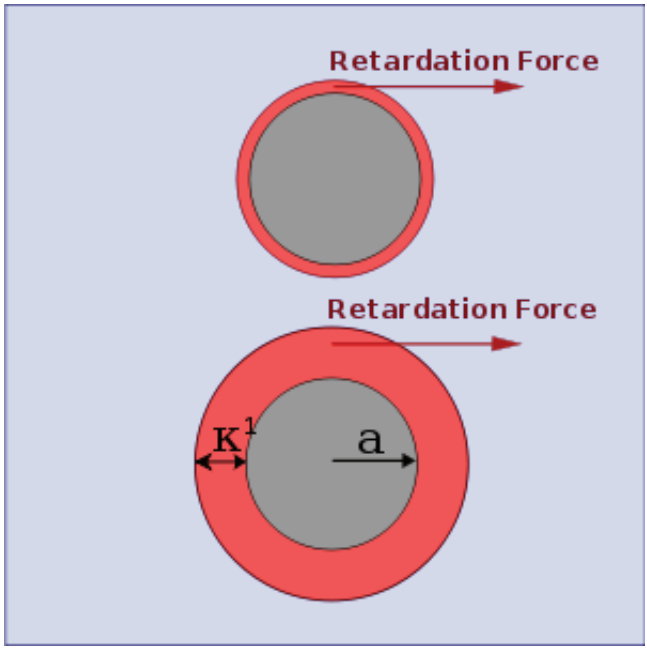


Figure 2.5. Lustration of electrophoresis retardation

2.6. COLORIMETER

A **colorimeter** is a device used in colorimetry. In scientific fields the word generally refers to the device that measures the absorbance of particular wavelengths of light by a specific solution. This device is most

commonly used to determine the concentration of a known solute in a given solution by the application of the Beer-Lambert law, which states that the concentration of a solute is proportional to the absorbance.

2.6.1. Construction

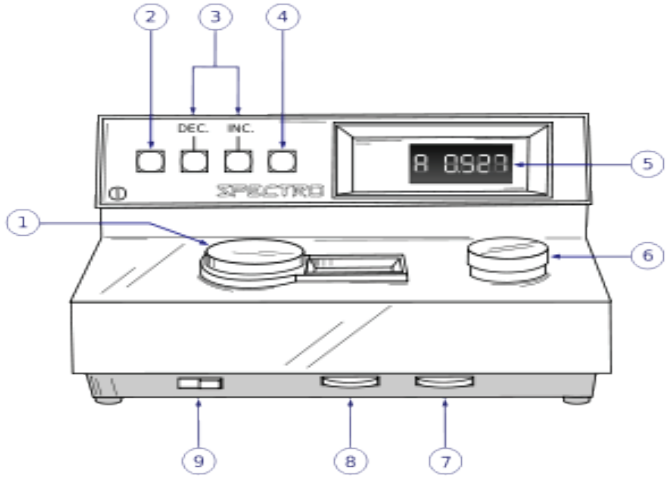


Figure 2.6. (1) Wavelength selection, (2) Printer butt on, (3) Concentration factor adjustment, (4) UV mode selector (Deuterium lamp), (5) Readout, (6) Sample compartment, (7) Zero control (100% T), (8) Sensitivity switch, (9) ON/ OFF switch

The essential parts of a colorimeter are:

- a **light source**
- an adjustable aperture
- a set of colored filters
- a cuvette to hold the working solution
- a detector (usually a photo resistor) to measure the transmitted light
- a meter to display the output from the detector

In addition, there may be:

- a voltage regulator, to protect the instrument from fluctuations in mains voltage.

- a second light path, cuvette and detector. This enables comparison between the working solution and a "blank", consisting of pure solvent, to improve accuracy.

There are many commercialized colorimeters as well as open source versions with construction documentation for education and for research.

Filters

Changeable optics filters are used in the colorimeter to select the wavelength of light which the solute absorbs the most, in order to maximize accuracy. The usual wavelength range is from 400 to 700 nanometers (nm). If it is necessary to operate in the ultraviolet range (below 400 nm) then some modifications to the colorimeter are needed. In modern colorimeters the filament lamp and filters may be replaced by several light-emitting diodes of different colors.

Cuvettes

In a manual colorimeter the cuvettes are inserted and removed by hand. An automated colorimeter (as used in an Auto Analyzer) is fitted with a **flow cell** through which solution flows continuously.

Output

- Illuminance
- Irradiance
- Light absorption
- Scattering of light.

Reflection of light The output from a colorimeter may be displayed by an analogue or digital meter and may be shown as transmittance (a linear scale from 0-100%) or as absorbance (a logarithmic scale from zero to infinity). The useful range of the absorbance scale is from 0-2 but it is desirable to keep within the range 0-1 because, above 1, the results become unreliable due to scattering of light. In addition, the output may be sent to a chart recorder, data logger, or computer.

2.7. PHOTOMETER

A **photometer**, generally, is an instrument that measures light intensity or optical properties of solutions or surfaces.

Photometers Measure

- Fluorescence
- Phosphorescence
- Luminescence

Before electronic light sensitive elements were developed, photometry was done by estimation by the eye. The relative luminous flux of a source was compared with a standard source. The photometer is placed such that the illuminance from the source being investigated is equal to the standard source, as the human eye can judge equal illuminance. The relative luminous fluxes can then be calculated as the illuminance decreases proportionally to the inverse square of distance. A standard example of such a photometer consists of a piece of paper with an oil spot on it that makes the paper slightly more transparent. When the spot is not visible from either side, the illuminance from the two sides is equal.

By 1861, three types were in common use. These were Rumford's photometer, Ritchie's photometer, and photometers that used the extinction of shadows, which was considered to be the most precise.

2.7.1. Principle of Photometers

Most photometers detect the light with photo resistors, photodiodes or photomultipliers. To analyze the light, the photometer may measure the light after it has passed through a filter or through a monochromator for determination at defined wavelengths or for analysis of the spectral distribution of the light.

Photon Counting

Some photometers measure light by counting individual photons rather than incoming flux. The operating principles are the same but the results are given in units such as photons/cm^2 or photons $\cdot cm^{-2} \cdot sr^{-1}$ rather than W/cm^2 or $W \cdot cm^{-2} \cdot sr^{-1}$.

Due to their individual photon counting nature, these instruments are limited to observations where the irradiance is low. The irradiance is limited by the time resolution of its associated detector readout electronics. With current technology this is in the megahertz range. The maximum irradiance is also limited by the throughput and gain parameters of the detector itself.

The light sensing element in photon counting devices in NIR, visible and ultraviolet wavelengths is a photomultiplier to achieve sufficient sensitivity.

In airborne and space-based remote sensing such photon counters are used at the upper reaches of the electromagnetic spectrum such as the X-ray to far ultraviolet. This is usually due to the lower radiant intensity of the objects being measured as well as the difficulty of measuring light at higher energies using its particle-like nature as compared to the wavelike nature of light at lower frequencies. Conversely, radiometers are typically used for remote sensing from the visible, infrared though radio frequency range.

2.7.2. Photography

Photometers are used to determine the correct exposure in photography. In modern cameras, the photometer is usually built in. As the illumination of different parts of the picture varies, advanced photometers measure the light intensity in different parts of the potential picture and use an algorithm to determine the most suitable exposure for the final picture, adapting the algorithm to the type of picture intended. Historically, a photometer was separate from the camera and known as an exposure meter. The advanced photometers then could be used either to measure the light from the potential picture as a whole, to measure from elements of the picture to ascertain that the most important parts of the picture are optimally exposed, or to measure the incident light to the scene with an integrating adapter.

2.7.3. Visible Light Reflectance Photometry

A reflectance photometer measures the reflectance of a surface as a function of wavelength. The surface is illuminated with white light, and the reflected light is measured after passing through a monochromator.

This type of measurement has mainly practical applications, for instance in the paint industry to characterize the colour of a surface objectively.

2.7.4. UV and Visible Light Transmission Photometry

These are optical instruments for measurement of the absorption of light of a given wavelength (or a given range of wavelengths) of colored substances in solution. From the light absorption, Beer's law makes it possible to calculate the concentration of the colored substance in the solution. Due to its wide range of application and its reliability and robustness, the photometer has become one of the principal instruments in biochemistry and analytical chemistry. Absorption photometers for work in aqueous solution work in the ultraviolet and visible ranges, from wavelength around 240 nm up to 750 nm.

2.7.5. RUMFORD'S PHOTOMETER

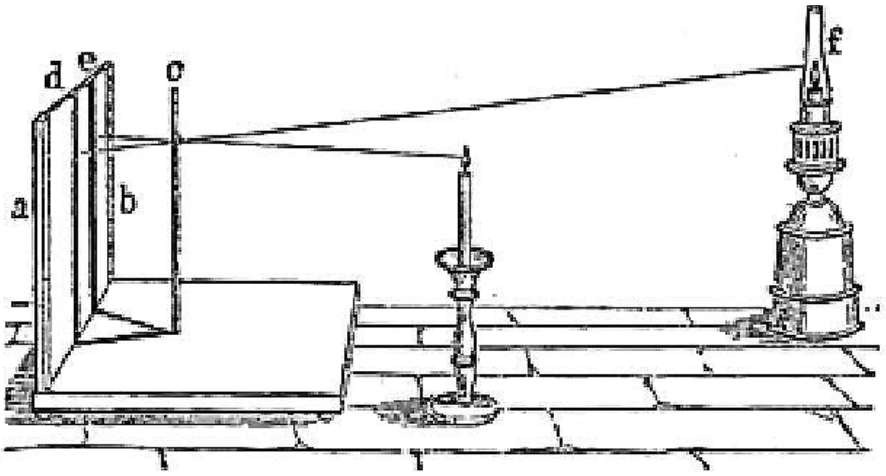


Figure 2.7. Rumford's Photometer

Rumford's photometer (also called a shadow photometer) depended on the principle that a brighter light would cast a deeper shadow. The two lights to be compared were used to cast a shadow onto paper. If the shadows were of the same depth, the difference in distance of the lights would indicate the difference in intensity (e.g. a light twice as far would be four times the intensity).

2.7.6. Ritchie's Photometer

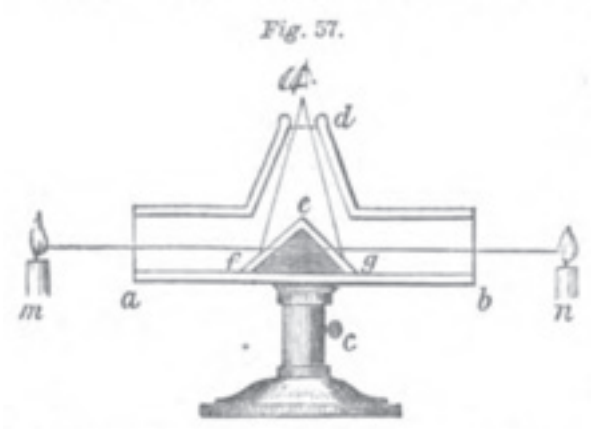


Figure 2.8. Ritchie's photometer

Ritchie's photometer depended on equal illumination of surfaces. It consisted of a box (a,b) six or eight inches long, and one in width and depth. In the middle, a wedge of wood (f,e,g) was angled upwards and covered with white paper. The user's eye looked through a tube (d) at the top of a box. The height of the apparatus was also adjustable via the stand (c). The lights to compare were placed at the side of the box (m, n)—which illuminated the paper surfaces so that the eye saw both surfaces at once. By changing the position of the lights, they were made to illuminate both surfaces equally, with the difference in intensity corresponding to the square of the difference in distance.

2.7.7. Method of Extinction of Shadows

This type of photometer depended on the fact that if a light throws the shadow of an opaque object onto a white screen, there is a certain distance that, if a second light is brought there, obliterates all traces of the shadow

Figure 2.9. A photometer

2.8. AUTO ANALYZER

The **Auto Analyzer** is an automated analyzer using a flow technique called continuous flow analysis (CFA), first made by the Technicon Corporation. The instrument was invented 1957 by Leonard Skeggs, PhD and commercialized by Jack Whitehead's Technicon Corporation. The first applications were for clinical analysis, but methods for industrial analysis soon followed. The design is based on separating a continuously flowing stream with air bubbles.

2.8.1. Operating Principle

In continuous flow analysis (CFA) a continuous stream of material is divided by air bubbles into discrete segments in which chemical reactions occur. The continuous stream of liquid samples and reagents are combined and transported in tubing and mixing coils. The tubing passes the samples from one apparatus to the other with each apparatus performing different functions, such as distillation, dialysis, extraction, ion exchange, heating, incubation, and subsequent recording of a signal. An essential principle of the system is the introduction of air bubbles. The air bubbles segment each sample into discrete packets and act as a barrier between packets to prevent cross contamination as they travel down the length of the tubing. The air bubbles also assist mixing by creating turbulent flow (bolus flow), and provide operators with a quick and easy

check of the flow characteristics of the liquid. Samples and standards are treated in an exactly identical manner as they travel the length of the tubing, eliminating the necessity of a steady state signal, however, since the presence of bubbles create an almost square wave profile, bringing the system to steady state does not significantly decrease throughput (third generation CFA analyzers average 90 or more samples per hour) and is desirable in that steady state signals (chemical equilibrium) are more accurate and reproducible. A continuous flow analyzer (CFA) consists of different modules including a sampler, pump, mixing coils, optional sample treatments (dialysis, distillation, heating, etc.), a detector, and data generator. Most continuous flow analyzers depend on color reactions using a flow through photometer, however, also methods have been developed that use ISE, flame photometry, ICAP, fluorometry, and so forth.

An auto analyzer sequentially measures blood chemistry through a series of steps of mixing, reagent reaction and colorimetric measurements. It consists of;

Sampler: Aspirates samples, standards, wash solutions into the system

Proportioning pump: Mixes samples with the reagents so that proper chemical color reactions can take place, which are then read by the colorimeter

Dialyzer: separates interfacing substances from the sample by permitting selective passage of sample components through a semi permeable membrane

Heating bath: Controls temperature (typically at 37 °C), as temp is critical in color development

Colorimeter: monitors the changes in optical density of the fluid stream flowing through a tubular flow cell. Color intensities proportional to the substance concentrations are converted to equivalent electrical voltages.

Recorder: Displays the output information in a graphical form.

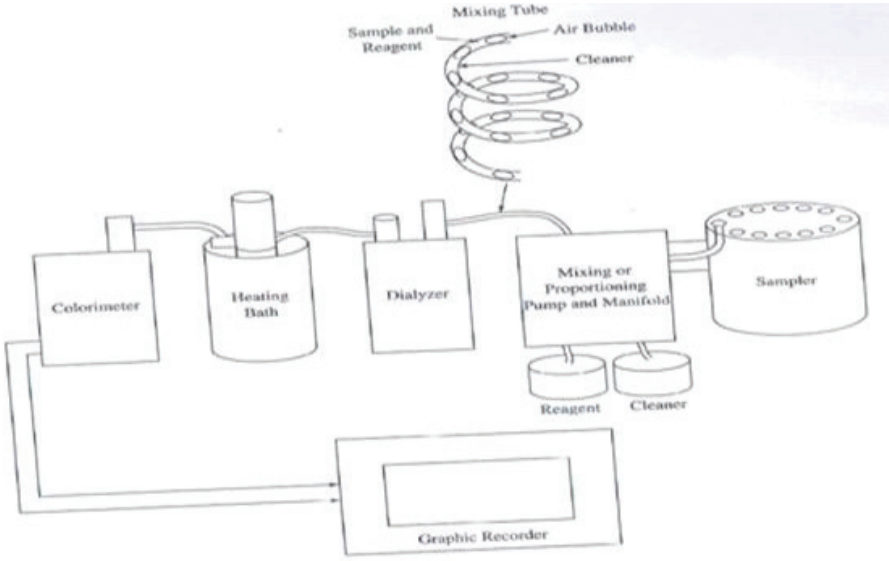


Figure 2.10. Block diagram of auto analyzer

2.8.2. USES

Auto Analyzers are still used for a few clinical applications such as neonatal screening or Anti-D, but the majority of instruments are now used for industrial and environmental work. Standardized methods published by the ASTM (ASTM International), the US Environmental Protection Agency (EPA) as well as the International Organization for Standardization (ISO) for environmental analytic such as nitrite, nitrate, ammonia, cyanide, and phenol. Auto analyzers are also commonly used in soil testing laboratories, fertilizer analysis, process control, seawater analysis, air contaminants, and tobacco leaf analysis.

The partial pressures of oxygen and carbon dioxide in the blood are important indicators of the acid-base balance of the patient. Samples of arterial blood may be taken to the laboratory, but it is also common to have a blood gas analyser on hand in the intensive care unit, in the special care baby unit, and the labor ward. Modern analysers only require a very small sample of blood, but are relatively expensive and internally complex.

2.9. BLOOD FLOWMETER

Blood flow meters are used to monitor the blood flow in various blood vessels and to measure cardiac output.

Types

- Electromagnetic blood flow meters,
- Ultrasonic blood flow meters,
- Laser based blood flow meters.

2.9.1. ELECTROMAGNETIC FLOWMETERS

- Electromagnetic blood flow meters measure blood flow in blood vessels,
- Consists of a probe connected to a flow sensor box.

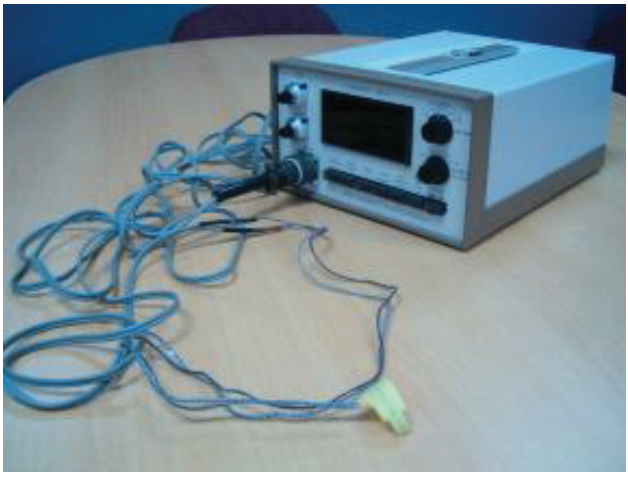


Figure 2.11. Blood flow meter

An Electromagnetic Flow Meter is a device capable of measuring the mass flow of a fluid. Unlike the common flow meter you can find on the market it has no moving parts, and for this reason it can be made to withstand any pressure (without leakage) and any fluid (corrosive and noncorrosive). This kind of flow meter use a magnet and two electrodes to peek the voltage that appears across the fluid moving in the magnetic field.

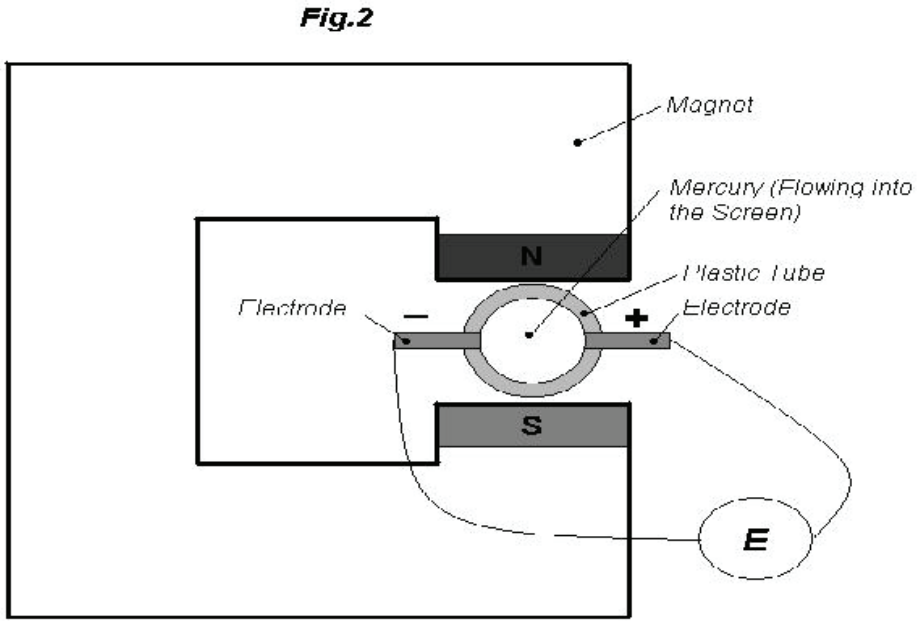


Figure 2.14. Magnetic blood flowmeter principle

Now imagine you have a plastic tube with two electrodes on the diameter and Mercury flowing into it (fig.2). A voltage will appear on the electrodes and it will be (***E=B*L*V)*** As in the previous example (***L*** in this case is the inner diameter of the tube).Mercury as tiny conductive wires next to each other: each wire, moving in the tube, will touch the two electrodes, and thus you can measure their voltage.

Measuring the flow

A perfect axisimmetric construction cannot be achieved and thus some magnetic flux lines will 'wet' the connecting wires to the electrodes. The alternating magnetic field will create an offset voltage in this wire and even if the fluid is not moving, the measured voltage will not be zero.

2.9.2. ULTRASONIC FLOWMETERS

The blood cells in the fluid scatter the Doppler signal diffusively. In the recent year's ultrasound contrast agents have been used in order to

increase the echoes. The ultrasound beam is focused by a suitable transducer geometry and a lens.

fd = 2fcv/c

f = *2- 10 MHz*

c = 1500 - 1600 m/s (1540 m/s)

f = *1,3 – 13 kHz*

In order to know where along the beam the blood flow data is collected, a pulsed Doppler must be used. The flow velocity is obtained from the spectral estimation of the received Doppler signal The ultrasound Doppler device can be either *a continuous wave* or *a pulsed Doppler.*

A Continuous Wave

No minimum range

Simpler hardware

Range ambiguity

Low flow cannot be detected.

A Pulsed Doppler Flow meter

Accuracy

No minimum flow

Minimum range

(Maximum flow) x (range)= limited the power decays exponentially because of the heating of the tissue. The absorption coefficient ~ proportional to frequency the far field operation should be avoided due to beam divergence.

$Dnf = D^2/4\lambda$

D = Transducer diameter (e.g. 1 – 5 mm) the backscattered power is

Proportional to *f.*

The resolution and SNR are related to the pulse duration. Improving either one of the parameters always affects inversely to the other.

2.9.3. LASER DOPPLER FLOWMETR

The principle of measurement is the same as with ultrasound Doppler.

The laser parameter may have the following properties: 5 mWHe-Ne-laser 632,8 nm. wavelength. The moving red blood cells cause Doppler frequency 30 – 12 000 Hz. The method is used for capillary (microvascular) blood flow measurements.

2.10. CARDIAC OUTPUT MEASUREMENT

Cardiac output and blood pressure are two important measures of the health and function of the cardiovascular system. You need to understand these measures as a fitness professional in order to design and deliver safe, effective exercise sessions, and in the case of blood pressure, be able to conduct and interpret blood pressure measurements for your clients.

Cardiac output (known as 'Q') is a measure of the amount of blood that is pumped out of the heart in one minute Such devices have proved useful when the patient is immobile (in intensive care and under an aesthesia) but may be subject to patient movement artefacts in other situations. 'Q' specifically refers to the amount of blood pumped out of the left ventricle as this is the ventricle that supplies blood to the muscles and organs of the body.

Cardiac output is made up of two components, heart rate (HR) and stroke volume (SV).

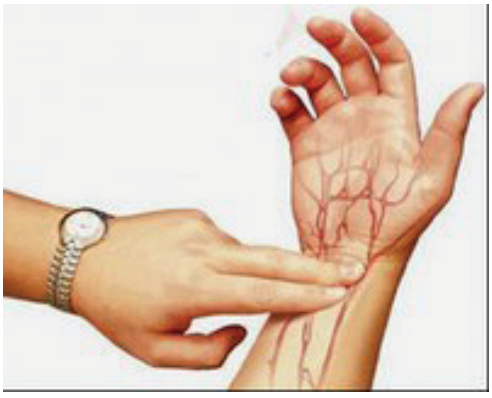


Figure 2.15. Heart rate (HR) refers to the number of times the heart beats every minute (bpm)

This can be easily measured through the use of heart rate monitors or taking ones pulse (counting the 'pulses' at the radial artery for example over a one minute period).

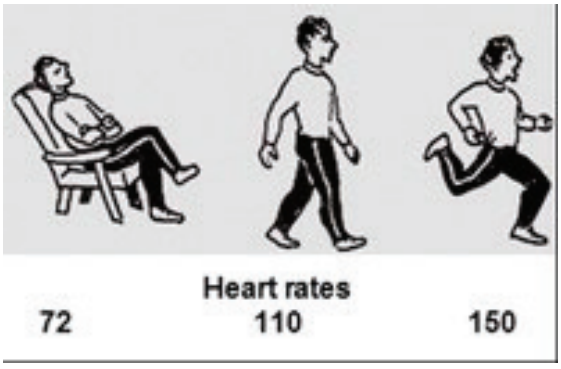


Figure 2.16. Heart rate

Heart rates increase as the intensity of activity increases, as shown in the adjacent picture. This is because the working muscles demand more energy, so the heart beats increasingly faster in order to deliver the nutrients and O_2 needed to meet these increased energy demands.

The normal resting heart rate range for an adult is between 60-100 bpm. However when a resting heart rate is greater than 100bpm it is called 'tachycardia' and when it's below 60bpm it is called 'bradycardia'.

These can both indicate possible heart conditions or complications and if you notice these in a personal training client of your's you should advise your client to have a medical check. The exception to this is that bradycardia may be present in extremely fit (international level multisport, triathlon, ironman etc) individuals and not something to be concerned about.

Stroke - Volume (SV) refers to the quantity of blood pumped out of the left ventricle with every heartbeat. The exact volumes are not easily measured, so they are often estimated based on what we know about stroke volume and the factors that it affects such as blood pressure which we can measure.

The equation for cardiac output is:

$$HR \times SV = Q.$$

Therefore to calculate Q we must first establish HR and SV. An example at rest is shown below.

HR (70BPM) x SV (70ml) = 4900ml/min or 4.9 liters per minute

An increase in HR, SV or both will increase someone's Q. SV on the whole does not fluctuate too much, with only relatively small increases with exercise. HR on the other hand increases quite dramatically and thus is the biggest influencer of increasing someone's Q.

Increases in Q with exercise are vital, as it is essentially your CV system trying to meet the demands of the body for the supply of oxygen rich blood and the removal of waste.

However it is highly unlikely that you will ever have to measure a client's Q, but because Q affects blood pressure, which you will measure, its important that you know what HR & SV are and how they along with Q influence blood pressure.

2.11 BLOOD PRESSURE MEASUREMENT

The measurement is indirect (i.e. there is no sensor inside the body) and is subjective, and therefore can result in large errors, particularly if the operator is inexperienced. The pressure is usually measured by a mercury-in-glass manometer but an aneroid gauge is sometimes used.

A rubber bag is attached to the upper arm under a cuff which is wrapped around the arm and secured by Velcro tape. The bag is connected by tubing to the manometer and to an inflating device in the form of a bulb. The bag is inflated by squeezing the bulb until the pressure exceeds the arterial pressure. This condition is detected by a stethoscope placed over the brachial artery just below the elbow since no sound is heard from the closed artery. A valve adjacent to the bulb is then partially opened so that the bag deflates slowly. Sounds from the artery are first heard when the applied pressure just fails to occlude the artery at the peak of the arterial pressure cycle (the systolic pressure). This pressure is noted and the applied pressure allowed to continue falling until the artery fails to occlude even at the lowest point of the arterial pressure cycle (the diastolic pressure). This point is identified from characteristic sounds (the Korotkoff sounds) at this point, which the operator learns to recognize. The two pressures, systolic and diastolic, are recorded as

the patient's blood pressure and are typically around 120 and 80 mmHg respectively.

Automatic indirect blood pressure recording devices exist which operate the pressurizing and depressurizing cycle and which detect the systolic and diastolic pressures from pulsations in the cuff pressure, sounds detected by a microphone under the cuff or from the arterial movements as detected by an ultrasonic doppler transducer under the cuff.

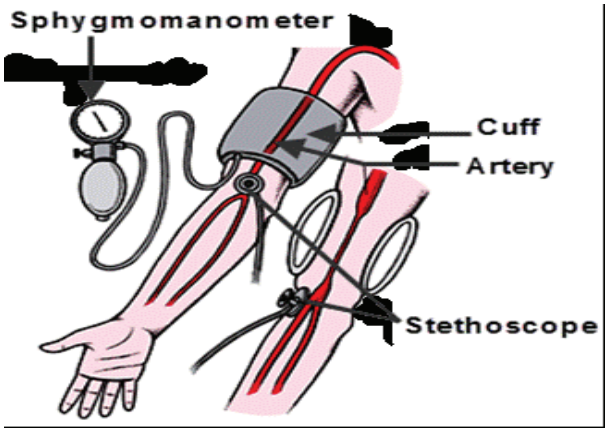


Figure 2.17. Spghy momanometer

Blood pressure (BP) is a measure of the force being exerted on the walls of arteries as blood is pumped out of the heart.

BP measurements are usually taken on the upper arm with a 'sphygmomanometer' and a stethoscope as pictured on the adjacent diagram. The sphygmomanometer consists of an inflatable cuff with a pressure gauge.

When inflated the cuff blocks the flow of blood to the arm below the cuff. As the cuff is allowed to slowly deflate, the measurer listens through the stethoscope to sounds as the artery opens and allows blood flow to continue again.

The measurer is listening for two specific sounds as the blood flows through the artery, as shown on the below image.

The first sound heard as the artery opens enough for the first pumps of blood to come through is known as the 'systolic' pressure. This mea-

sures the force the heart has to pump against to get the blood to flow around the body.

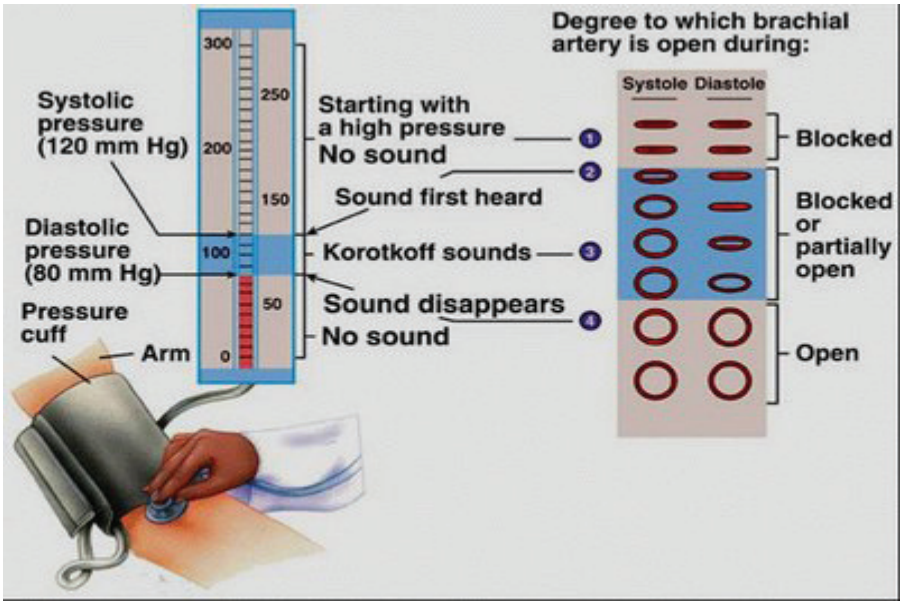


Figure 2.18. Measurement of blood pressure

The second sound recorded is known as the 'diastolic' pressure. This measure is recorded at the point where the measurer stops hearing the 'pump'; essentially it measures the pressure in the arteries as the heart relaxes.

The systolic number is placed over the diastolic number and is always the higher of the two numbers. For example blood pressure of 110 (systolic) and 70 (diastolic) is read as 110/70mmHg. The measurement of blood pressure is expressed in millimeters of mercury (mmHg).

High blood pressure at rest is an indicator that the cardiovascular system is in a less than ideal state of health. High blood pressure (known as 'hypertension) occurs when systolic blood pressure readings consistently exceed 140mmHg and or diastolic readings exceed 90mmHg. 'Normal', healthy BP is regarded as 120/80mmHg or thereabouts.

BP is also used as a 'risk factor' for many diseases and illnesses, such as heart disease. Doctors and fitness professionals alike use blood pres-

sure to screen for potential problems before making judgements as to what exercise a person can safely take part in.

A person's BP is determined by the following three factors;

1. Cardiac output (as we have already discussed)
2. Blood viscosity (the thickness of the blood)
3. Total peripheral resistance 'TPR' (the resistance the blood encounters on its voyage within the blood vessels).

2.11.1. Cardiac - Output

Cardiac output as you know is made up of heart rate and stroke volume. At rest these are relatively constant however with exercise the heart beats faster and more blood is pumped out with each beat. These factors both contribute to a rise in BP, as would any other factor that caused the heart to speed up.

Changes in the volume of blood within the cardiovascular system will also affect BP. If a person was severely dehydrated or lost a large quantity of blood through a wound there would be less blood for the heart to pump, thereby reducing cardiac output and BP.

If the volume of blood increased (waste products not being removed to the kidneys due to kidney failure for example) then there would be a greater quantity of blood within the system increasing the pressure within. Think about putting more air into an already inflated balloon and you'll get the picture!

2.11.2. Blood Viscosity

The thicker (or more 'viscous') blood is, the harder the heart has to work to pump it around the body and consequently more pressure is created within the vessels.

Blood can thicken for many reasons but the main ones are a lack of water and or a high glucose (blood sugar) concentration.

For diabetics, if they don't control their blood sugar levels these can quickly become high and cause problems with high blood pressure. Low hydration levels can also result in thick blood and therefore higher blood pressure.

This is why it is important to always remain well hydrated, as it helps to reduce the pressure within the blood vessels and therefore the load on the heart to pump the blood. For this reason people with a history of heart problems are often prescribed medications to keep their blood thin.

2.11.3. Total Peripheral Resistance

When we were kids we used to take the garden hose and put our thumb over the end of it to get the water to squirt further (usually to make sure a sibling got wet!). We increased the pressure by decreasing the space the flow of water could go through.

The same principle applies in the body with blood and the vessels. In cardiovascular terms this is known as 'total peripheral resistance' (TPR). If the area available for blood to flow through is reduced then pressure will increase. If pressure remains very high for long periods of time the danger of a vessel bursting increases significantly, in the case of the aorta this would result in a virtually instantaneous death through massive immediate blood loss.

The major concern with a BP that is consistently elevated is that there may be a potential obstruction within the blood vessel which narrows the available area blood has to flow through.

Such obstructions are usually due to the buildup of fatty 'plaques' which stick to the walls of blood vessels and build up over a period of time. A diet high in fat, low in vegetables and a sedentary lifestyle can all contribute to the buildup of these fatty plaques.

This is known as 'atherosclerosis' and if untreated these plaques can build up to completely block a vessel, or a chunk of the plaque can break off and cause a blockage further down the vessel where the vessel narrows. If the blockage is not cleared quickly then the tissues that receive oxygen and nutrients from that vessel are likely to die. Depending on where the blockage occurs the effects can range from minor to fatal.

If the blockage occurs in the coronary (heart) arteries then a heart attack (usually fatal) will result, if the blockage occurs in a cerebral (brain) blood vessel then a stroke will occur with usually irreversible damage to the part of the brain that is affected. Blood vessels can also narrow

when stress hormones (e.g. cortisol) are released by the body causing the smooth muscle within the walls of the vessel to contract (vasoconstriction). This again 'constricts' blood flow and increases blood pressure, as can be seen in the adjacent picture 'C'.

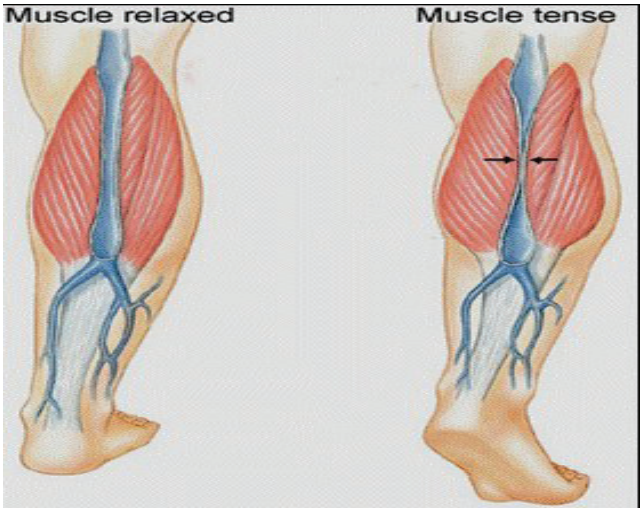


Figure 2.19. Vasoconstriction of muscles

Tense muscles around a blood vessel can also 'constrict' the flow of blood and increase BP. This can occur when someone is very stressed or has a lot of tightened muscles due to exercise stress, as can be seen in the adjacent picture.

In summary, any increases in cardiac output (HR and/or SV), blood viscosity or total peripheral resistance will result in increases in BP.

As BP is a key measure of the health of the cardiovascular system it should be measured regularly and people whose readings are consistently elevated at rest should be treated accordingly, usually by referral to medical personnel, restriction of exercise to low intensity and a focus on dietary and lifestyle modifications to reduce stress and the intake of fatty foods.

The volume of blood pumped by the heart per minute is called the cardiac output (CO) and is the product of the stroke volume (SV) and the heart rate (HR).

At rest, in the average adult, the CO is 5 L/min and in exercise it may rise to 35 L/min.

The CO is often corrected for body surface area (cardiac index=2.5-4.2 L/min/m^2).

The CO is pivotal in maintaining arterial BP (BP=CO X SVR) and oxygen delivery.

Distribution of normal CO

Hear	5%
Brain	14%
Muscle	20%
Kidneys	22%
Liver	25%
Rest of the body	14%

2.11.4 The Fick Principle

Fick described the following relationship in the 19th century:

$Q = M / (V - A)$

Where Q is the volume of blood flowing through an organ in a minute, M the number of moles of a substance added to the blood by an organ in one minute, and V and A are the venous and arterial concentrations of that substance. This principle can be used to measure the blood flow through any organ that adds substances to, or removes substances from, the blood. The heart does not do either of these but the CO equals the pulmonary blood flow, and the lungs add oxygen to the blood and remove carbon dioxide from it.

The concentration of the oxygen in the blood in the pulmonary veins is 200 ml/L and in the pulmonary artery is 150 ml/L, so each liter of blood going through the lungs takes up 50 ml. At rest, the blood takes up 250 ml/min of oxygen from the lungs and this 250 ml must be carried away in 50 ml portions; therefore, the CO must be 250/50 or 5 L/min.

Limitations

The original method described by Fick in 1870 is difficult to carry out. Oxygen consumption is derived by measuring the expired gas vol-

ume over a known time and the difference in oxygen concentration between this expired gas and inspired gas. Accurate collection of the gas is difficult unless the patient has an endotracheal tube, because of leaks around a facemask or mouthpiece. Analysis of the gas is straightforward if the inspired gas is air, but if it is oxygen-enriched air there are two problems, (a) the addition of oxygen may fluctuate and produce an error due to the non-constancy of the inspired oxygen concentration, and (b) it is difficult to measure small changes in oxygen concentration at the top end of the scale. The denominator of the equation, the arteriovenous oxygen content difference, presents a further problem, in that the mixed venous (i.e. pulmonary arterial) oxygen content has to be measured and therefore a pulmonary artery catheter is needed to obtain the sample. Complications may arise from these catheters. If carefully carried out, the Fick method is accurate, but it is not practicable in routine clinical practice. Several variants of the basic method have been devised, but usually their accuracy is less good.

2.11.5. Dilution Techniques

Invasive Measurement of Blood Pressure Dye Dilution

A known amount of dye is injected into the pulmonary artery, and its concentration is measured peripherally. Indocyanine green is suitable due to its low toxicity and short half-life. A curve is achieved, which is replotted semi-logarithmically to correct for recirculation of the dye. CO is calculated from the injected dose, the area under the curve (AUC) and its duration. (Short duration indicates high CO). Lithium has also been used as an alternative to in docyanine green. It is injected via a central venous catheter and measured by a lithium-sensitive electrode incorporated into the radial arterial cannula.

Thermodilution

The 5-10 ml cold saline injected through the port of a pulmonary artery catheter. Temperature changes are measured by a distal thermistor. A plot of temperature change against time gives a similar curve to the dye curve (but without the second peak). Calculation of CO is achieved using the Stewart-Hamilton equation. Application of this equation assumes three major conditions; complete mixing of blood and indicator,

no loss of indicator between place of injection and place of detection and constant blood flow. The errors made are primarily related to the violation of these conditions.

$$\dot{Q} = \frac{n}{\int c\ dt} = \frac{k(T_{core} - T_{indicator})V_{indicator}}{\int_{t_1}^{t_2} -\Delta T\ dt}$$

The amount of indicator (n) is related to its mean concentration (c), cardiac output (Q) and the time for which it is detected (t_2 - t_1).

2.12. RESPIRATORY MEASUREMENT

The respiratory rate is the number of breaths that a patient takes each minute. The rate should be taken when the patient is at rest, and it is assessed by counting the number of times the chest rises in one minute.

Common factors that influence respiration rate are as follows:

- Age
- Emotional status
- Air quality and altitude
- Exercise
- Internal temperature
- Disease (i.e., cardiopulmonary)
- O_2 and CO_2 level (i.e., pulmonary status)
- Effectiveness of breathing pattern.

Common Respiratory Values are Listed Below

Age	Breaths per minute
Infant	30 or more
Child	22-28
Adolescent	16 -20
Adult – normal	14-18*
Adult – abnormal	<10 and >20

It has been shown that women typically have higher respiratory rates than men.

2.12.1. Plethysmography

Plethysmography is used to measure changes in volume in different parts of the body. This can help check blood. The test may be done to check for blood clots in the arms and legs, or to measure how much air you can hold in your lungs.

2.12.2. The Respiratory System - Structure and Function

The respiratory system is the system in the human body that enables us to breathe.

The act of breathing includes: inhaling and exhaling air in the body; the absorption of oxygen from the air in order to produce energy; the discharge of carbon dioxide, which is the byproduct of the process.

The Parts of the Respiratory System

The respiratory system is divided into two parts:

- Upper respiratory tract
- Lower respiratory tract

Upper Respiratory Tract

This includes the nose, mouth, and the beginning of the trachea (the section that takes air in and lets it out).

Lower Respiratory Tract

This includes the trachea, the bronchi, broncheoli and the lungs (the act of breathing takes place in this part of the system).

The organs of the lower respiratory tract are located in the chest cavity. They are delineated and protected by the ribcage, the chest bone (sternum), and the muscles between the ribs and the diaphragm (that constitute a muscular partition between the chest and the abdominal cavity).

The trachea – the tube connecting the throat to the bronchi.

The bronchi – the trachea divides into two bronchi (tubes). One leads to the left lung, the other to the right lung. Inside the lungs each of the bronchi divides into smaller bronchi.

The broncheoli - the bronchi branches off into smaller tubes called broncheoli which end in the pulmonary alveolus.

Pulmonary alveoli – tiny sacs (air sacs) delineated by a single-layer membrane with blood capillaries at the other end.

The exchange of gases takes place through the membrane of the pulmonary alveolus, which always contains air: oxygen (O2) is absorbed from the air into the blood capillaries and the action of the heart circulates it through all the tissues in the body. At the same time, carbon dioxide (CO2) is transmitted from the blood capillaries into the alveoli and then expelled through the bronchi and the upper respiratory tract.

The inner surface of the lungs where the exchange of gases takes place is very large, due to the structure of the air sacs of the alveoli.

The lungs – a pair of organs found in all vertebrates.

The structure of the lungs includes the bronchial tree – air tubes branching off from the bronchi into smaller and smaller air tubes, each one ending in a pulmonary alveolus.

The act of breathing has two stages – inhalation and exhalation

- Inhalation – the intake of air into the lungs through expansion of chest volume.
- Exhalation – the expulsion of air from the lungs through contraction of chest volume.

Inhalation and Exhalation Involves Muscles

1. **Rib muscles** = the muscles between the ribs in the chest.
2. **Diaphragm muscle**

Muscle movement – the **diaphragm and rib muscles** are constantly contracting and relaxing (approximately 16 times per minute), thus causing the chest cavity to increase and decrease.

During Inhalation – the Muscles Contract

Contraction of the diaphragm muscle – causes the diaphragm to flatten, thus enlarging the chest cavity. Contraction of the rib muscles – causes the ribs to rise, thus increasing the chest volume.

The chest cavity expands, thus reducing air pressure and causing air to be passively drawn into the lungs. Air passes from the high pressure outside the lungs to the low pressure inside the lungs.

During Exhalation – the Muscles Relax

The muscles are no longer contracting, they are relaxed. The diaphragm curves and rises, the ribs descend – and chest volume decreases. The chest cavity contracts thus increasing air pressure and causing the air in the lungs to be expelled through the upper respiratory tract. Exhalation, too, is passive. Air passes from the high pressure in the lungs to the low pressure in the upper respiratory tract.

Inhalation and exhalation are involuntary and therefore their control requires an effort.

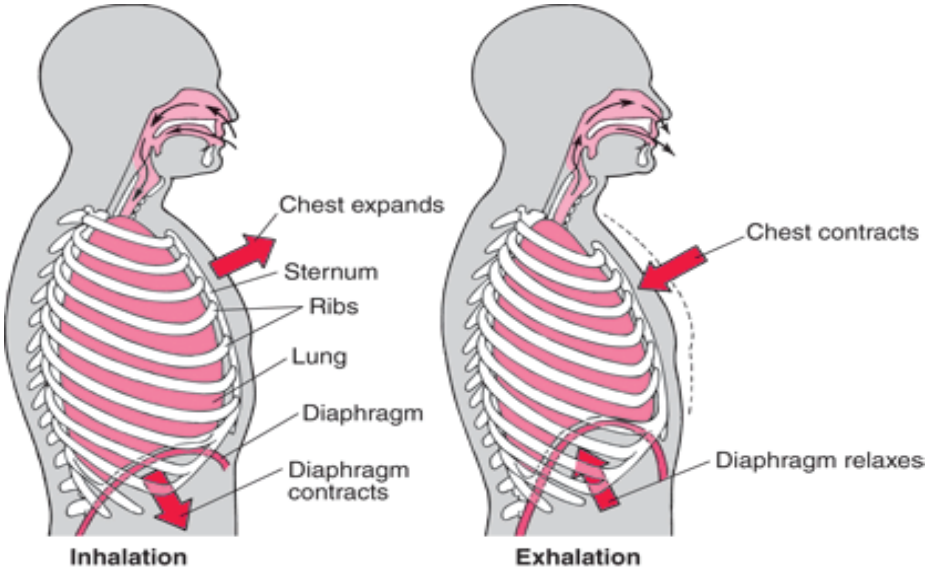


Figure 2.20. The act of breathing – illustration

2.12.3. What Do We Measure And How Do We Measure It?

The respiratory airways include the respiratory apertures (mouth and nose), the trachea and a branching system of long, flexible tubes (bronchi) that branch of to shorter and narrower tubes (bronchiole) until they end in sacs called the pulmonary alveoli.

The lungs encompass the entire system of tubes branching out from the main bronchi to the alveoli. Measuring the functioning of the lungs is a medical tool for diagnosing problems in the respiratory system.

2.12.4. Measurements of Lung Function

Air volume (in liters) – lung capacity,

- **Maximum lung volume** is known as TLC (total lung capacity). It can be obtained by maximum strenuous inhalation.

The maximum lung volume of a healthy adult is up to 5-6 liters. In children the maximum lung volume is up to 2-3 liters, depending on age. In infants it is up to 600-1000 milliliters.

Note! Differences in lung volume can only be caused by gender, age, and height.

- **Essential air volume** is the maximum volume utilized by the lungs for inhalation, also known as VC (vital capacity).

- **Residual volume** (RV) is the volume of air remaining in the lungs after strenuous exhalation when the lungs feel completely empty. Residual volume prevents the broncheoli and the alveoli from sticking together. Residual volume is approximately 1.5 liters (adults).

- The differential between total lung capacity and residual volume is the **maximal volume utilized by the lungs in order to breath. It is known as vital capacity** (VC). In an adult, the VC is between 3.5 and 4.5 liters.

- **Tidal Volume** or VT is the volume of air displaced between normal inspiration and expiration. In a healthy adult the tidal volume is approximately 500 milliliters.

3. **Rate of airflow** through the respiratory airways (into and out of the lungs).This measures the effectiveness of airflow.

4. **Efficiency of diffusion** of oxygen from the pulmonary alveoli into the blood (not dealt with in this unit).

2.12.5. Examining Lung Function

The most common, accessible and efficient method of measuring lung function is by means of **a spirometer**. Its purpose is to diagnose obstructive diseases of the respiratory system. It produces a diagram (graphic depiction) of the volume of air expired in a given time (liter/minute)

The spirometer shows the rate at which air is expelled from the lungs. It measures the total lung capacity up to the residual volume (this test does not show the rate at which oxygen is absorbed).

If the airways are blocked the rate of the airflow of the lungs decreases. This will show on the diagram and thus indicate that there is a problem in the airways. The most common obstruction stems from excessive phlegm, or from swelling of the inner wall of the air ways.

The most common problem of blockage of the air ways is asthma. people suffering from asthma it take longer to empty the lungs than healthy people. For example, during the first second of exhalation, only half of the vital air capacity in their lungs is expelled as opposed to 90% in healthy people. The rest is exhaled much later.

A spirometer examination takes only a few seconds. It is completely safe but there is a need for the patient to cooperate in order to obtain accurate results.

Stages of the Examination

1. The patient is asked to inhale as deeply as possible.
2. The patient is asked to exhale strenuously into the spirometer.
3. The patient is asked to continue to expel air for a few seconds, despite the strong urge to breathe in.
4. The test is repeated twice or three times.

2.12.6 Respiratory Rate

Children in the upper classes of elementary school breathe about 20 times per minute. Every breath causes an inhalation of approximately 7 milliliters of air volume per kilogram of body weight. A child who weighs 30 kilos inhales approximately 210 milliliters of air volume (210X30). In other words, in the duration of a minute some 4200 milliliters of air volume enters and be expelled from the lungs.

Athletes breathe slightly deeper and slower. With every breath they inhale approximately 10 milliliters of air per kilogram. Thus an athletic child who weighs 30 kilos will only breathe 15 times in the duration space of a minute. Each inhalation will require some 300 milliliters of air volume. In the space of a minute 4500 milliliters of air volume will enter

and be expelled from his lungs. We can deduct from this that athletes ventilate their airways in a much more efficient way.

When we are under strain we breathe faster and more deeply. Since the lungs contain a reserve of air, we do not become tired because lack of air (oxygen) is causing respiratory restriction, but because of strain and tiredness in our respiratory and heart muscles.

When we are under emotional stress (before an exam, in distress, or feeling very frightened) we breathe faster, but our breathing is shallower. For example, under stress we inhale 30 times per minute but at a rate of only 4 milliliters per kilo. In other words, overall only 3600 milliliters per minute are passing through our airways, so we feel "short of breath." During severe asthma attacks, the breathing of asthma patients is shallower and at a higher rate. Their breathing is thus not very efficient.

Figure 2.21. Plethysmograph for Lung Parameters Measurement.

2.13 Temperature Measurement

Non-electrical methods

2.13.1 Mercury Thermometer

Commonest method in clinical use depends on expansion of mercury with increase in temperature

Main Clinical Disadvantages

- Takes 2-3 mins for complete thermal equilibrium between mercury and its surroundings,
- Risk of breaking alcohol can be used instead of mercury but relationship between volume and temperature less linear.
- Values of temperature that can be measured are lower.

Dial Thermometers

Either use bimetallic strip or Bourdon gauge. Bourdon gauge actually measures pressure in a sensing chamber containing a small volume of mercury or a volatile liquid. Gauge is calibrated in units of temperature.

Electrical Techniques

- Response time depends mainly on size with smaller probes having shorter response times due to lower heat capacities

- Response times: 0.1-15 sec.

Resistance Wire Thermometer

- Relies on a linear increase in resistance of metal wire (usually platinum) with increase in temperature,

- Usually incorporated into Wheatstone bridge circuit to increase sensitivity,

3.13.2. Thermistor

- Thermistors are semi-conductor temperature sensors that have advantage that their change in resistance is greater with temperature than resistance wire thermometer. However change is not entirely linear and calibration may drift with ageing. May be extremely small; small enough to be attached to tympanic membrane,

- Usual type is a small bead of metal oxide resistance of which falls exponentially as temperature, rises
- Special thermistors are available in which resistance rises with temperature
- Often used in Wheatstone bridge circuit
- Cheaper to manufacture than platinum wire resistor

- Calibration liable to change if thermistor is subjected to severe changes of temperature (eg in heat sterilization),

Thermocouple Thermometers

- Rely on See beck effect
- Potential difference occurs at a junction between 2 dissimilar metals when they complete an electrical circuit
- Magnitude of potential difference depends on temperature of metals
- Voltage is very small and needs either amplification or a very sensitive galvanometer.
- Second junction needed to form complete electrical circuit. Temperature dependent potential difference will also develop at this junction. For thermocouple to be used as a thermometer one of the junctions must be kept at a constant temperature while the other junction acts as a measuring probe. Alternatively equipment may provide electrical compensation for for changes in reference junction temperature
- Usually made of copper and constantan (alloy of copper and nickel),

Advantages

- All couples made of the same material will behave identically and therefore calibration will not change should couple be replaced,
- Measuring junction can be manufactured and used in the form of a needle,

2.13.3. Other Methods

Infrared ear thermometers: detect radiant energy from tympanic membrane and external auditory canal through an orthoscopic probe inaccurate if either structure inflamed or if there is obstruction of the external canal,

Measuring sites

Rectum

- Risk of perforation of or trauma to anus or rectum. Particular problem in small babies, neutropaenic or coagulopathic patients or patients who have recently undergone rectal surgery

-Rectal temperature slow to equilibrate with core temperature in adults

- Rectal temperature measurements have been implicated in the spread of enteric organisms eg *Clostridium difficile,* vancomycin resistant *Enterococcus,*

Oesophagus

- important to use lower oesophagus as upper oesphagus may be cooled by cold inspiratory air in adjacent trachea

- in cardiothoracic surgery oesophageal temperature may not reflect core temperature due to cooling as a result of open chest and ice/cardioplegia,

Nose

- Only useful in intubated patients when nasal passages are not cooled by inspired air.

Oral

- Only suitable for alert and cooperative patients and therefore not usually suitable for ICU patients
- Inaccuracies may result from mouth breathing, heated gases, hot/cold fluids
- Can damage oral mucosa,

2.14. Pulse Measurement

Your pulse is the rate at which your heart beats. Your pulse is usually called your heart rate, which is the number of times your heart beats each minute (bpm). But the rhythm and strength of the heartbeat can also be noted, as well as whether the blood vessel feels hard or soft.

Changes in your heart rate or rhythm, a weak pulse, or a hard blood vessel may be caused by heart disease or another problem.

As your 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. Counting your pulse rate is a simple way to find out how fast your heart is beating.

You check your pulse rate by counting the beats in a set period of time (at least 15 to 20 seconds) and multiplying that number to get the number of beats per minute. Your pulse changes from minute to minute. It will be faster when you exercise, have a fever, or are under stress. It will be slower when you are resting.

Why it is Done

Your pulse is checked to:

- See how well the heart is working. In an emergency situation, your pulse rate can help find out if the heart is pumping enough blood.
- Help find the cause of symptoms, such as an irregular or rapid heartbeat (palpitations), dizziness, fainting, chest pain, or shortness of breath.
- Check for blood flow after an injury or when a blood vessel may be blocked.
- Check on medicines or diseases that cause a slow heart rate. Your doctor may ask you to check your pulse every day if you have heart disease or if you are taking certain medicines that can slow your heart rate, such as digoxin or beta-blockers (such as atenolol or propranolol).
- Check your general health and fitness level. Checking your pulse rate at rest, during exercise, or immediately after vigorous exercise can give you important information about your overall fitness level.

You can easily check your pulse on the inside of your wrist, below your thumb.

- Gently place 2 fingers of your other hand on this artery.

- Do not use your thumb because it has its own pulse that you may feel.
- Count the beats for 30 seconds; then double the result to get the number of beats per minute.

You can also check your pulse in the carotid artery. This is located in your neck, on either side of your windpipe. Be careful when checking your pulse in this location, especially if you are older than 65. If you press too hard, you may become lightheaded and fall.

You can buy an electronic pulse meter to automatically check your pulse in your finger, wrist, or chest. These devices are helpful if you have trouble measuring your pulse or if you wish to check your pulse while you exercise.

Risks

Checking your pulse should not cause problems. Be careful when checking your pulse in your neck, especially if you are older than 65. If you press too hard, you may become lightheaded and fall.

Call your doctor if you have any of the following symptoms:

- An irregular or rapid heartbeat (palpitations). Palpitations can be persistent or may come and go (episodic).
- Chest pain
- Dizziness
- Fainting
- Lightheadedness
- Shortness of breath

Talk to your doctor if you have a fast heart rate, many skipped or extra beats, or if the blood vessel where you check your pulse feels hard.

Your pulse is the rate at which your heart beats. Your pulse is usually called your heart rate, which is the number of times your heart beats each minute (bpm).

The pulse can be measured at the:

- Back of the knees
- Groin

- Neck
- Temple
- Top or inner side of the foot
- Wrist

In these areas, an artery passes close to the skin.

Normal Results

For resting heart rate:

- Newborns 0 - 1 month old: 70 - 190 beats per minute
- Infants 1 - 11 months old: 80 - 160 beats per minute
- Children 1 - 2 years old: 80 - 130 beats per minute
- Children 3 - 4 years old: 80 - 120 beats per minute
- Children 5 - 6 years old: 75 - 115 beats per minute
- Children 7 - 9 years old: 70 - 110 beats per minute
- Children 10 years and older, and adults (including seniors): 60 - 100 beats per minute
- Well-trained athletes: 40 - 60 beats per minute,

What Abnormal Results Mean

Resting heart rates that are continually high (tachycardia) may mean a problem. Talk to a health care provider about this. Also discuss resting heart rates that are below the normal values (bradycardia).

A pulse that is very firm (bounding pulse) and that lasts for more than a few minutes should be checked by your health care provider as well. An irregular pulse can also indicate a problem.

A pulse that is hard to locate may mean blockages in the artery. These blockages are common in people with diabetes or atherosclerosis from high cholesterol. Your health care provider may order a test known as a Doppler study to evaluate the blockages.

2.15. Cell Counters

Automated cell counters sample the blood, and quantify, classify, and describe cell populations using both electrical and optical techniques. Electrical analysis involves passing a dilute solution of the blood

through an aperture across which an electrical current is flowing. The passage of cells through the current changes the impedance between the terminals (the Coulter principle).A lytic reagent is added to the blood solution to selectively lyse the red cells (RBCs), leaving only white cells (WBCs), and platelets intact. Then the solution is passed through a second detector. This allows the counts of RBCs, WBCs, and platelets to be obtained. The platelet count is easily separated from the WBC count by the smaller impedance spikes they produce in the detector due to their lower cell volumes.

Optical detection may be utilised to gain a differential count of the populations of white cell types. A dilute suspension of cells is passed through a flow cell, which passes cells one at a time through a capillary tube past a laser beam. The reflectance, transmission and scattering of light from each cell is analysed by sophisticated software giving a numerical epresentation of the likely overall distribution of cell populations.

2.15.1. The Need for Cell Counting

Numerous procedures in biology and medicine require the counting of cells. By the counting of cells in a known small volume, the concentration can be mediated. Here are several examples for the need for cell counting:

- In medicine, the concentration of various blood cells, such as red blood cells and white blood cells, can give crucial information regarding the health situation of a person (see: complete blood count).
- Similarly, the concentration of bacteria, viruses and other pathogens in the blood or in other bodily fluids can reveal information about the progress of an infectious disease and about the degree of success with which the immune system is dealing with the infection.
- The cell concentration needs to be known for many experiments in molecular biology, in order to adjust accordingly the amount of reagents and chemicals that are to be applied in the experiment.

- Studies that examine the growth rate of microorganisms (in other words: how fast they divide to create new cells) require cell counting.
- Measurements of cell viability, i.e. measuring and calculating the fraction of dead and live cells, for example of cells exposed to poison.

1.1.2. COULTER COUNTER

- Constant current source (CCS) and voltage amplifier replace the ohmmeter
- RA is the resistance of the aperture and will be either high or low, depending on whether or not the blood cell is inside the aperture.
- Amplifier convert the current pulse to voltage pulse,

FLOW CYTOMETRY CELL COUNTERS

- Optical flow cytometry sensing
- The optical cytometry sensor consists of a quartz sensing sheath designed with a
- hydrodynamic focusing region
- cell path region that passes only a single cell at time.
- Focusing is done by decreasing the diameter of the aperture.
- Light source is (He-Ne) Laser
- Two Photodetectors (photosensors)
- Photodetector A detects forward scatted light
- Photodetector B detects orthogonal scatted light
- Blood sample enters the analyzer
- Optical counter → WBC count
- Colorimeter → hemoglobin
- Optical flow sensor → RBC count

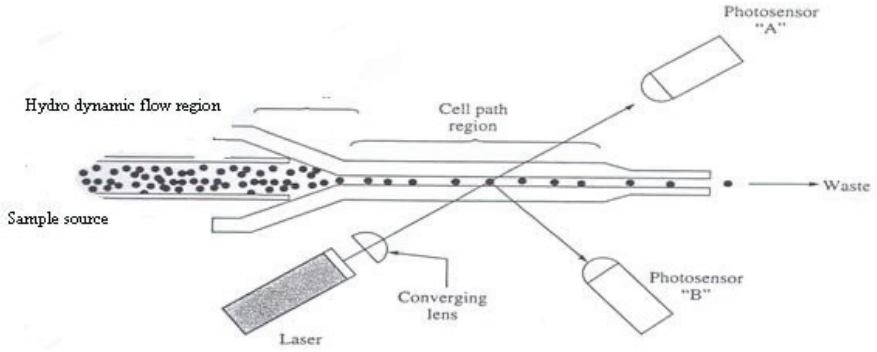


Figure 2.22. Optical low cytometry

The blood is actually split into different chambers, where in each chamber it is diluted /mixed to differentiate different cell types. WBC and RBC are separated (using lysing)

2.15.3 Flow Cytometry

Figure 2.23: A flow cytometer

Flow cytometry is by far the most sophisticated and expensive method for cell counting. In a flow cytometer the cells flow in a narrow stream in front of a laser beam. The beam hits them one by one, and a light detector picks up the light that is reflected from the cells.

Flow cytometers have many other abilities, such as analyzing the shape of cells and their internal and external structures, as well as measuring the amount of specific proteins and other biochemical in the cells. Therefore, flow cytometers are rarely purchased for the sole purpose of counting cells.

Image Analysis

Recent approaches consider the use of high-quality microscopy images over which a statistical classification algorithm is used to perform automated cell detection and counting as an image analysis task.[2] Generally performs with a constant error rate as an off-line (batch) type process. A range of image classification techniques can be employed for this purpose.

UNIT III.
ASSIST DEVICES AND BIO-TELEMETRY

3.1 CARDIAC PACEMAKERS

Pacemaker is an electrical pulse generator for starting /maintaining the normal heart beat.

The output of the pacemaker is either externally to the chest or internally to the heart muscle. In the case of cardiac stand still, the use of the pacemaker is temporary – just long enough to start a normal heart rhythm. In the cases requiring long term pacing, the pacemaker is surgically implanted in the body and its electrodes are in direct contact with the heart. The contraction of heart (cardiac) muscle in all animals with hearts is initiated by electrical impulses. The rate at which these impulses fire controls the heart rate. The cells that create these rhythmical impulses are called **pacemaker cells**, and they directly control the heart rate. The normal heart rate is 60-100 beats per minute. A higher rate than this (above 100 beats per minute) is called Tachycardia. Slower rate (Below 60 beats per minute) than this is called Bradycardia

Definition of Pacemaker

A small battery powered device, implanted into a patient Paces the heart when normal rhythm is slow, when there is a heart block not allowing the ventricles to contract when the SA node fires, or any arrhythmia causing a slow rate

The **sinoatrial node** (SA node) is a group of cells positioned on the wall of the right atrium, near the entrance of the superior venacava. These cells are modified cardio myocyte. They possess rudimentary contractile filaments, but contract relatively weakly.

Primary Pacemaker

Cells in the SA node spontaneously depolarize, resulting in contraction, approximately 100 times per minute. This native rate is constantly modified by the activity of sympathetic and parasympathetic nerve fibers, so that the average resting cardiac rate in adult humans is about 70 beats per minute. Because the sinoatrial node is responsible for the rest of the heart's electrical activity, it is sometimes called the primary pacemaker.

Secondary Pacemaker

If the SA node does not function, a group of cells further down the heart will become the ectopic pacemaker of the heart. These cells form the atrioventricular node (or **AV node**), which is an area between the left atrium and the right ventricle, within the atrial septum. The cells of the AV node normally discharge at about 40-60 beats per minute, and are called the secondary pacemaker.

Pacemaker Potential

The **pacemaker potential** (also called the **pacemaker current**) is the slow, positive increase in voltage across the cell's membrane (the membrane potential) that occurs between the end of one action potential and the beginning of the next action potential. This increase in membrane potential is what causes the cell membrane, which typically maintains a resting membrane potential of -70 mV, to reach the threshold potential and consequently fire the next action potential; thus, the pacemaker potential is what drives the self-generated rhythmic firing (automaticity) of pacemaker cells, and the rate of change (i.e., the slope) of the pacemaker potential is what determines the timing of the next action potential and thus the intrinsic firing rate of the cell.

3.1.1 Artificial Cardiac Pacemaker

A **pacemaker** (or **artificial pacemaker**, so as not to be confused with the heart's natural pacemaker) is a medical device that uses electrical impulses, delivered by electrodes contracting the heart muscles, to regulate the beating of the heart. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's natural

pacemaker is not fast enough, or there is a block in the heart electrical conduction system. Modern pacemakers are externally programmable and allow the cardiologist to select the optimum pacing modes for individual patients. Some combine a pacemaker and defibrillator in a single implantable device. Others have multiple electrodes stimulating differing positions within the heart to improve synchronization of the lower chambers (ventricles) of the heart.

Pacemaker Pulses

- These Pulses should have the pulse to space ratio 1:10000.
- It should be negatively going pulses to avoid the ionization of the muscles.
- The pulse voltage is made variable to allow adjustments in the energy delivered by the pacemaker to the heart during each pulse.

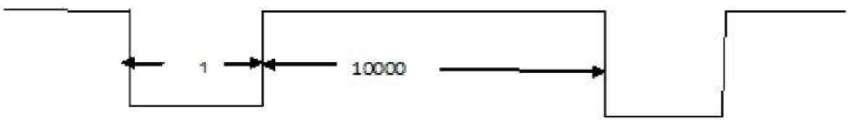


Figure 3.1. Pacemaker pulses

3.1.2. Methods of Stimulation

- External stimulation
- Internal stimulation

External stimulation is employed to restart the normal rhythm of the heart in the case of cardiac standstill. Internal stimulation is employed in cases requiring long term pacing because of permanent damage that prevents normal self-triggering of the heart.

External Stimulation

It is employed to restart the normal rhythm of the heart in the case of cardiac stand still. Stand still can occur during open-heart surgery or whenever there is a sudden physical shock or accident.

Internal Stimulation

Internal stimulation is employed in cases requiring long term pacing because of permanent damage that prevents normal self-triggering of the heart.

3.1.3. Comparison Between External Pacemaker and Internal Pacemaker

External Pacemaker

1. It does not necessitate open heart surgery,
2. The skin near the chest or abdomen with its output leads are connected directly to the heart muscle,
3. These are used for temporary heart irregularities. There is no safety for pacemaker.

Internal Pacemaker

1. The pacemaker is surgically implanted beneath
2. It requires open chest minor surgery to place the circuit
3. These are used for permanent heart damages. There is cent percent safety for circuit from external disturbances.

Electrodes for Stimulation

1. Bipolar and unipolar electrodes are used.
2. In the bipolar electrode, there are stimulating electrode and contact electrode which serves as a return path for current to the pacemaker.
3. In the unipolar electrode, there is only stimulating electrode.
4. The return path for current to the pacemaker is made through the body fluids.

3.1.4. Modes of Operation of Pacemaker

1. Ventricular asynchronous pacemaker (Fixed rate pacemaker),
2. Ventricular synchronous pacemaker,
3. Ventricular inhibited pacemaker (Demand pacemaker),
4. Atrial synchronous pacemaker.

5. Atrial sequential ventricular inhibited pacemaker.

3.1.4.1. Ventricular Asynchronous Pacemaker

It can be used in atrium or ventricle. It has simplest mechanism and longest battery life. This pacemaker is suitable for patients with either a stable, total AV block, a slow atrial rate or atrial arrhythmia. This produces a stimulus at a fixed rate irrespective of the behavior of heart rhythm. There may be competition between the natural heart beats and pacemaker beats. It is possible that such an event can be dangerous because if the pacemaker impulse reaches the heart during a certain vulnerable period, the ventricular fibrillation may occur.

Advantages and Disadvantages of Ventricular Synchronous Pacemaker

Advantages

To arrest the ventricular fibrillation, this circuit can be used.

If the R wave occurs with its normal value in amplitude and frequency, then it would not work.

Therefore, the power consumption is reduced, and there is no chance of getting side effects due to competition between natural and artificial pacemaker pulses.

Disadvantages

Atrial and ventricular are not synchronized. I the olden type when the pacemaker is attached with the patients, the circuit is more sensitive to external electromagnetic interferences such as electric shavers, microwave ovens, ignition systems.

3.1.4.2. Ventricular Synchronous Pacemaker

Patients with only short periods of AV block or bundle block can be supplied with a ventricular synchronized pacemaker. This type of pacemaker does not compete with normal heart activity

Working of Ventricular Synchronous Pacemaker

Using the sensing electrode, the heart rate is detected and is given to the timing circuit in the pacemaker. If the detected heart rate is below a

certain minimum level, the fixed rate pacemaker is turned on to pace the heart. The lead used to detect the R wave is now used to stimulate the heart. If the natural contraction occurs, the asynchronous pacer's timing circuit is reset so that it will time its next pulse to detect the heartbeat,

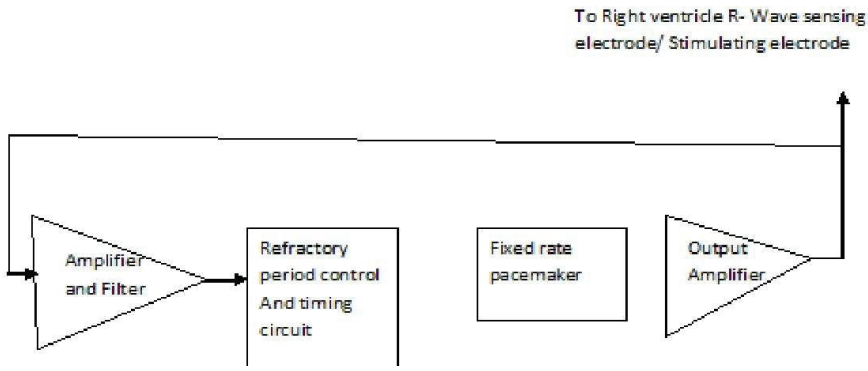


Figure 3.2. Ventricular synchronous pacemaker

Advantages of Ventricular Synchronous Pacemaker

- To arrest the ventricular fibrillation, this circuit can be used.
- If the R wave occurs with its normal value in amplitude and frequency, then it would not work. Therefore, the power consumption is reduced, and there is no chance of getting side effects due to competition between natural and artificial pacemaker pulses.

Disadvantages of Ventricular Synchronous Pacemaker

1. Atrial and ventricular are not synchronized.
2. I the olden type when the pacemaker is attached with the patients, the circuit is more sensitive to external electromagnetic interferences such as electric shavers, microwave ovens, ignition systems.

3.1.4.3. Ventricular Inhibited Pacemaker (Demand Pacemaker)

The R- Wave inhibited pacemaker also allows the heart to pace at its normal rhythm when it is able to. However, if the R- wave is missing for a preset period of time, the pacer will supply the stimulus. Therefore, if the heart rate is below a predetermined minimum, pacemaker will turn

on and provide the heart a stimulus. For this reason it is called demand pacemaker.

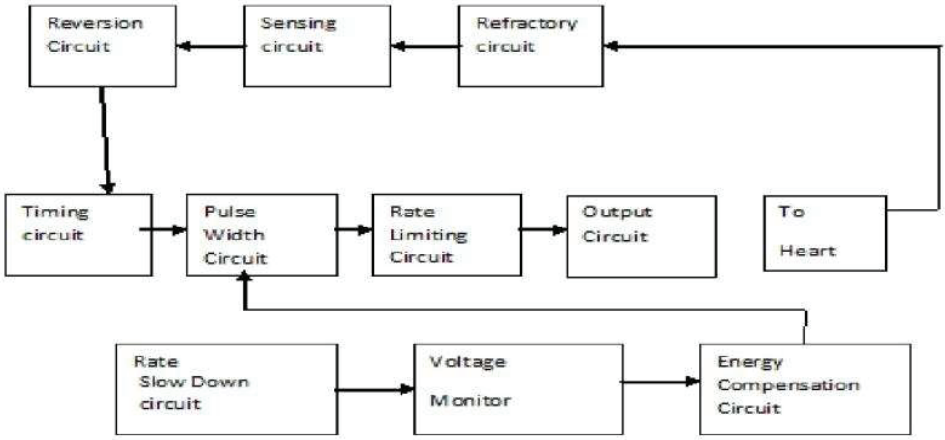


Figure 3.3. Ventricular inhibited pacemaker

The sensing electrode pickup R wave. The refractory circuit provides a period of time following an output pulse or a signals. The sensing circuit detects the R wave and resets the oscillator. The reversion circuit allows the amplifier to detect the R- wave in low level signal to noise ratio. In the absence of R wave, it allows the oscillator in the timing circuit to deliver pulses at its preset rate. The timing circuit consists of an RC network, a reference voltage source and a comparator which determines the basic pulse rate of the pulse generator. The output of the timing circuit is fed into pulse delivered to the heart. Then the output of the pulse width circuit is fed into the rate limiting circuit which limits the racing rate to a maximum of 120 pulses per minute.

3.1.4.4. Atrial Synchronous Pacemaker

This type of pacing is used for young patients with a mostly stable block. Atrial pacing as a temporary pacing is used in stress testing and coronary artery diseases. It is used to terminate atrial flutter and in the evaluation of various conduction mechanisms. The atrial activity is picked up by a sensing electrode placed in a tissue close to the dorsal wall of the atrium. The detected P wave is amplified and a delay of 0.12 second is provided by the AV delay circuit. This is necessary corre-

sponding to the actual delay in conducting the P wave to the AV node in the heart. The signal is then used to trigger the resettable multivibrator and the output of the multivibrator is given to the amplifier which produces the desired stimulus to be applied to the heart

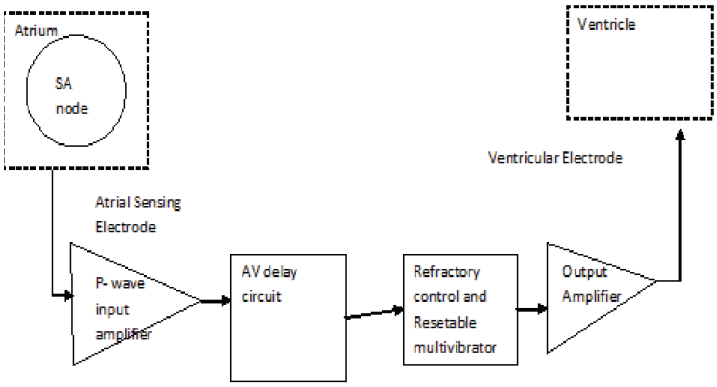


Figure 3.4. Atrial synchronous pacemaker

3.2 DC DEFIBRILLATORS

In 1962, Bernard lawn from Harward school of public health and peter bent of Brigham hospital developed a new method known as dc defibrillation. In this dc defibrillation method, a capacitors charged to a high dc voltage and then rapidly discharged through electrodes across the chest of patient. DC defibrillation is capable of correcting both the atrial fibrillation and ventricular fibrillation. DC method produces some harm to the patient. Depending on the energy setting in the defibrillator, the amount of electrical energy discharged by the capacitor ranges between 100 to 400 joules. Discharge portion is approximately 5 ms. In discharge waveform, the peak value ofs current is nearly20 A and the wave is monophasic in nature. Monophasic means most of the excursion of curve is above the base line.

Energy level of a defibrillator can be controlling:

The voltage amplitude *VP*of the defibrillator by varying the setting onthe varactor or Duration of the defibrillator pulse,

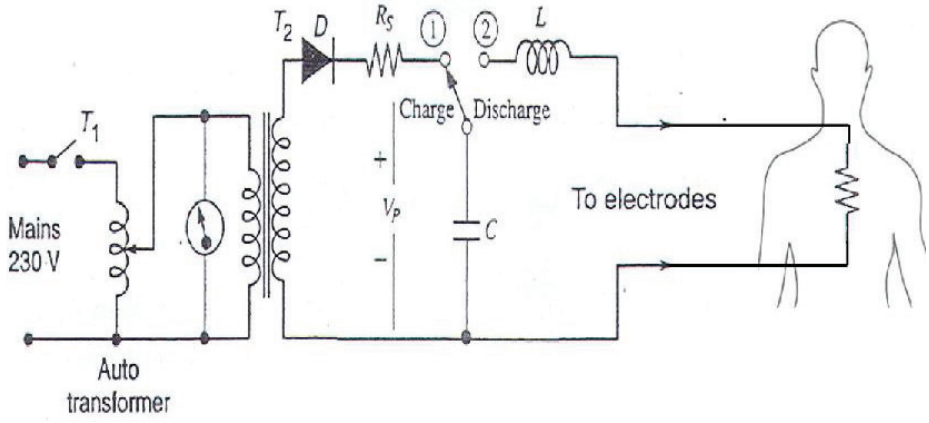


Figure 3.5. DC defibrillator circuit

3.2.1. DUAL PEAK DC DEFIBRILLATOR

- If peak voltage is as high as 6000V is used there is a possibility of damaging myocardium and the chest walls.
- Produce dual peak wavereform of longer duraoltation at lower voltage.
- Effective defibrillation is achieved in adults with lower level of delivered energy.
- Energy range is between 50 to 200W-sec or joules.
- Effective defibrillation at the desirable lower voltage levels is also possible with the truncated waveform.
- The amplitude of the waveform is relatively constant, but is varied to get required energy.
- Large electrodes are used for the proper delivery of large current through the surface of the skin.
- These electrodes are called as paddles.

3.2.2. EXTERNAL DEFIBRILLATOR

- A unit based on computer technology and designed to analyze the heart rhythm itself, and then advise whether a shock is required.

- It is designed to be used by lay persons, who require little training.
- It is usually limited in their interventions to delivering high joule shocks for *VF*and *VT* rhythms
- The automatic units also take time (generally 10-20 seconds) to diagnose the rhythm, where a professional could diagnose and treat the condition far quicker with a manual unit.
- Automated external defibrillators (AEDS) are generally either held by trained personnel who will attend incidents, or are public access units which can be found in places including corporate and government offices, shopping centers, airports, restaurants,

AEDS require self-adhesive electrodes instead of hand-held paddles for the two following reasons:

- The ECG signal acquired from self-adhesive electrodes usually contains less noise and has higher quality ⇒ allows faster and more accurate analysis of the ECG ⇒ better shock decisions. Hands off‖ defibrillation is a safer procedure for the operator, especially if the operator has little or no training.

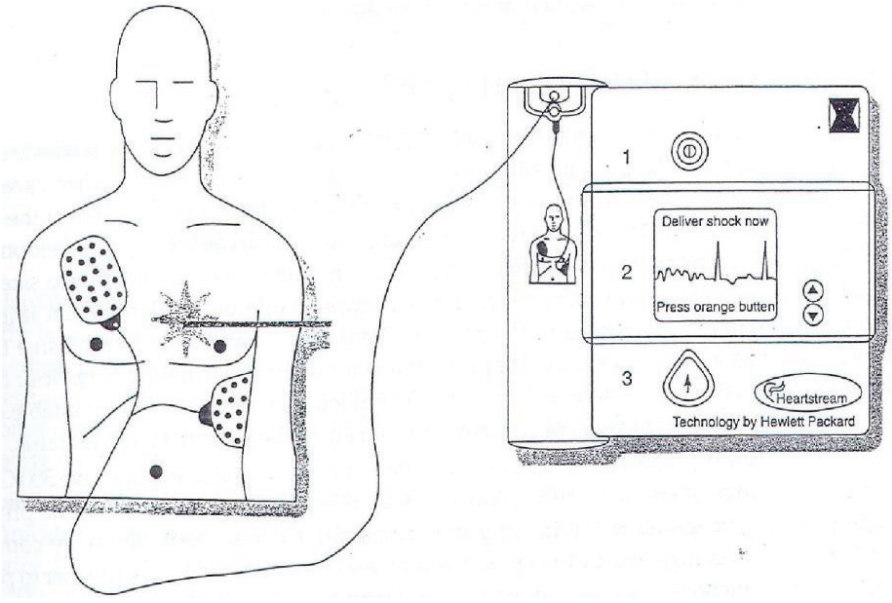


Figure 3.6. External defibrillator

3.2.3. DC DEFIBRILLATOR WITH SYNCHRONIZER

- Synchronization means, synchronized the working of the heart with the pacemaker. Synchronized DC defibrillator allows the electric shock at the right point on the ECG of the patient.
- Electric shock is delivered approximately 20 to 30 ms after the peak of R wave of patients ECG.

Working

- ECG waveform is traced from the patient.
- R-wave in the output of ECG amplifier triggers the time delay circuit .It gives the delay of ECG amplifier Time delay circuit Defibrillator circuit 30 ms approximately. After that, defibrillator circuit is switched ON. So that, the capacitor discharges the electric shock to the patient's heart.
- The moment at which electric shock occurs is noted by producing the marker pulse on monitoring display.
- This type of circuit is preferred in cardiac emergencies
- The sudden cardiac arrest can be treated using a defibrillator and 80 percent of the patients will be cured from the cardiac arrest if the is given within one minute of the attack.

3.2.4. ELECTRODES USED FOR DEFIBRILLATION

These paddles have metal disks of 8 to 10 cm in diameter for external use.

- For internal use smaller paddles are used on infants and children.
- For external use, pair of electrodes are firmly pressed against the patient's chest.

Need of Insulation Handle

- To prevent the person applying the electrodes from accidential electric shock specially insulated handles are provided in the paddles.
- When paddles are properly positioned, this prevents the patient from receiving a shock.

- In earlier equipment a foot switch is used instead of thumb switch.

Need of Thumb Switch

- There is a possibility of someone accidentally stepping on the foot switch in the excitement of an emergency before the paddles are placed. So thumb switches are mostly preferred.

Charging of Defibrillators

- In some defibrillators charging is done by means of a charge switch located in the front panel of the unit.
- The charge switch is located in the handle of one of its paddles.
- In few defibrillators the charging process begins automatically after discharge.

Types of Electrodes

Two electrodes are;

Ø Anterior-anterior,

Ø Anterior-posterior,

Anterior-anterior paddles are applied to the chest. Anterior-posterior paddles are applied to both the patient's chest wall and back so that energy is delivered through the heart.

- Specially designed pediatric paddles are available with diameter ranging from 2 to 6 cm.
- Internal paddles can be either sterilized or autoclaved.

Indication Meter

- Most of the defibrillators include a watt second meter to inducate the amount of energy stored in the capacitor before discharge.
- The energy indicated on the meter is lost or dissipated as heat in the components inside the unit.

3.3 TELEMETRY PRINCIPLES

Telemetry is a technology that allows remote measurement and reporting of information. The word is derived from Greek roots *tele* = remote, and *metron* = measure. Systems that need external instructions

and data to operate require the counterpart of telemetry, tele command. Although the term commonly refers to wireless data transfer mechanisms (e.g. using radio or infrared systems), it also encompasses data transferred over other media, such as a telephone or computer network, optical link or other wired communications. Many modern telemetry systems take advantage of the low cost and ubiquity of GSM networks by using SMS to receive and transmit telemetry data.

- Bio telemetry is the measurement of biological parameters over long distance.
- For conveying biological information from a living organism and its environment to a different location where this can be recorded.
- This involves radio frequency signal as a carrier for modulation, referred to as radio telemetry. The block schematic of a single-channel basic telemetry system, was described below. Using this schematic as the basis, schematics of specific telemetry systems will be developed in this Chapter.

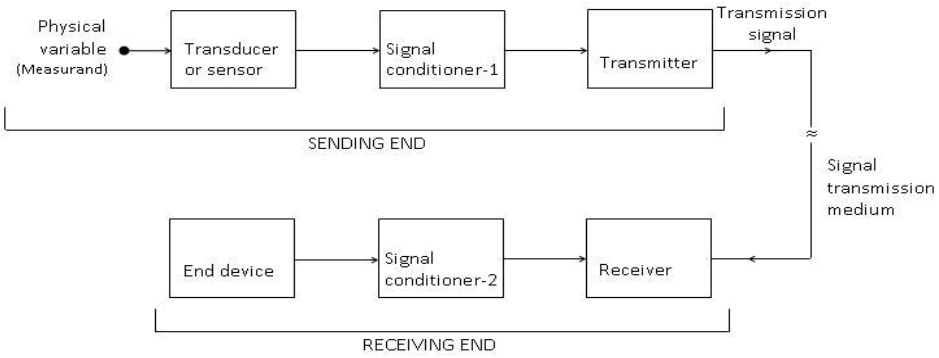


Figure 3.7. Block schematic basic telemetry system

3.3.1. Classification of Telemetry Systems on the Basis of Signal Transmission Medium

Telemetry systems were classified on the basis of the signal transmission medium or link used in Chapter-1 as under:

(i) Wire-link or wire telemetry system

(ii) Radio or wireless telemetry system, with two special types:

1. Short-range radio telemetry system
2. Satellite radio telemetry system
3. Optical-fiber or fiber-optic telemetry system

(I) Wire-Link or Wire Telemetry System

(II)

A basic wire-link or wire telemetry system, block schematic of which is shown below, should be seen as a specific case of the basic telemetry system with the following specifics:

(a) The signal transmission medium here is a pair of copper wires.

(b) The transmitter comprises an audio-frequency (AF) AC modulator or pulse modulator, as per the needs of the application, and an amplifier to strengthen the modulated carrier signal before sending it on the copper wire-pair. Multiplexer is not included as the only a basic (single-channel) telemetry system is being considered.

(c) Like the transmitter, the receiver also has only two elements, viz. an amplifier to carry out necessary amplification of the attenuated signal received through wire-pair and a demodulator to recover the information signal from the modulated carrier signal

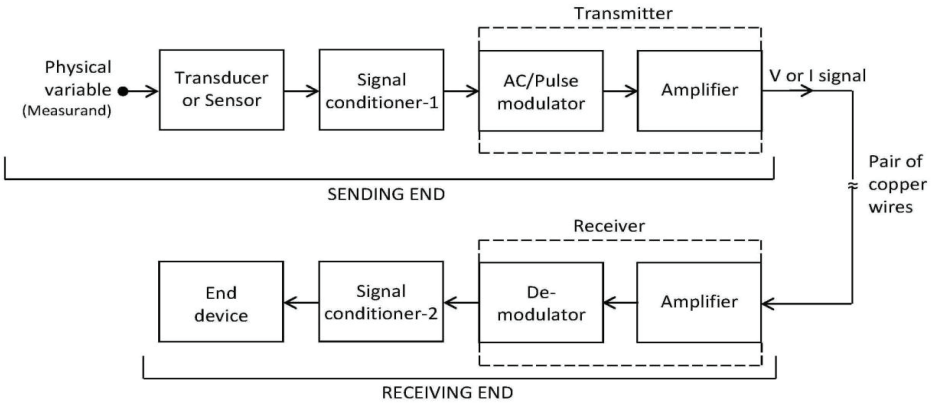


Figure 3.8. Wire telemetry system

(ii) Radio or Wireless Telemetry System

Block schematic of a basic radio telemetry system is shown below. This can also be treated as a specific case of the basic telemetry system as under:

(a) The signal transmission medium here is a radio link, comprising a transmitting antenna (TA), a receiving antenna (RA) and the space between the two used for propagation of radio wave from TA to RA.

(b) The transmitter comprises a RF modulator (AM or FM type, depending on the performance, bandwidth and cost considerations) and an amplifier.

(c) The receiver comprises an amplifier and a demodulator (AM or FM type as required to match the type of the modulator).

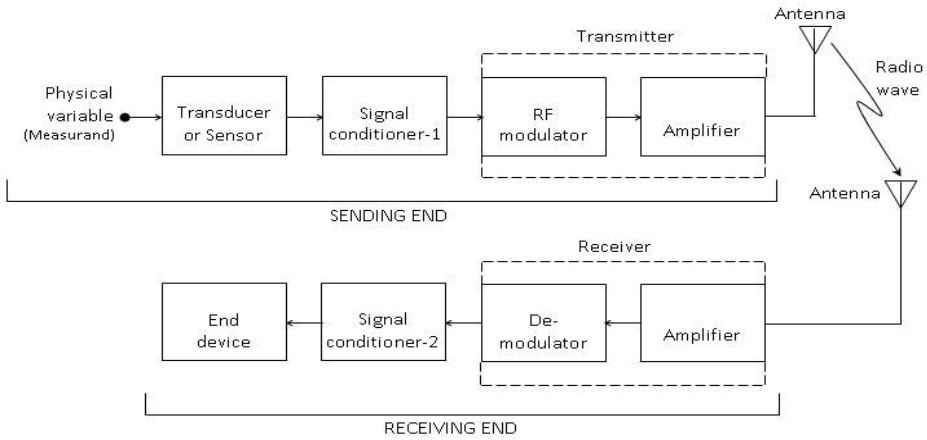


Figure 3.9. Radio telemetry and short range telemetry system

(iii) Short-Range Radio Telemetry System

The schematic given above is in principle valid for a basic short-range telemetry system also. The transmitter power may be very small as the range is very short, typically a few meters or a few tens of meters. The choice of radio frequency will be guided by the cost consideration and local requirements.

(iv) Satellite Radio Telemetry System

Block schematic of a basic satellite radio telemetry system is shown below. This system can be considered as an advanced version of the basic radio telemetry system discussed earlier with the following advanced features:

(a) The communication between the transmitter and receiver takes place via a communication satellite, which is a machine that keeps ro-

tating around the earth and is equipped with one or more transponders acting as radio-wave repeaters in the sky.

(b) The radio frequencies (RF) used are normally higher than 3.3 GHz, known as microwave frequencies.

(c) The transmitter in the sending earth-station incorporates, as shown in the figure, an intermediate-frequency (IF) modulator, an IF-to-RF up-converter and a power amplifier. The modulator typically uses FM in case of analog communication and PSK, QPSK or QAM in case of digital communication. The frequency converter comprises a mixer followed by a band-pass filter and its output is at the so-called uplink frequency.

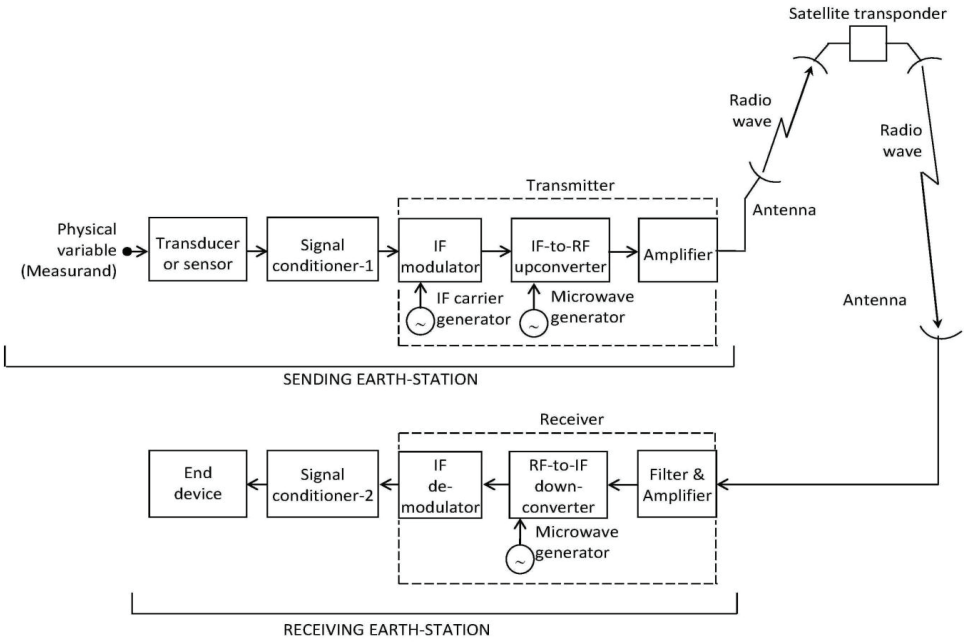


Figure 3.10. Satellite radio telemetry system

(d)The transponder has a frequency translator (mixer plus band-pass filter) in addition to filters and a power amplifier. Its role is to receive microwave signal from one earth station, amplify, convert the high-band uplink frequency to the low-band down-link frequency, amplify and re-transmit to the other earth station.

(e) The receiver in the receiving earth-station incorporates, as shown in the figure, a band-limiting filter, amplifier, RF-to-IF down-converter and an IF demodulator.

(V) Optical-Fiber or Fiber-Optic Telemetry System

Block schematic of a basic optical fiber telemetry system, presented in the figure below, shows the important components of the transmitter and receiver. The highlights of the system are as follows:

(a) The transmission signal is a high-intensity narrow infrared optical beam.

(b) The signal transmission medium is an optical fiber, which works on the principle of total internal reflection and thereby serves as the waveguide for the propagation of the optical beam from the transmitter to the receiver.

(c) The transmitter includes (i) a PCM modulator, which gets a digitized value of the measurand from signal conditioner-1 and produces binary voltage pulses in a coded sequence, (ii) a voltage-to-current converter, (iii) a light source, usually an injection laser diode (ILD) that converts the binary current pulses to binary optical pulses, and finally (iv) a light-source to optical-fibre coupling unit.

(d) The receiver includes components performing the complementary functions of the transmitter components in reverse order. These are:

(i) optical-fiber to light detector coupling unit,

(ii) Light detector, usually a PIN diode that detects the binary optical pulses it gets from the optical fiber and converts them to binary current pulses,

(iii) Current to voltage converter, and

(iv) Demodulator, which delivers digital voltage signal to the end device through signal conditioner-2.

In case the end device requires an analog input signal, the signal conditioner-2 would include a digital-to-analog converter (DAC). This is generally not the case as digital end devices are preferred to analog end devices these days. Thus, normally DAC is not present.

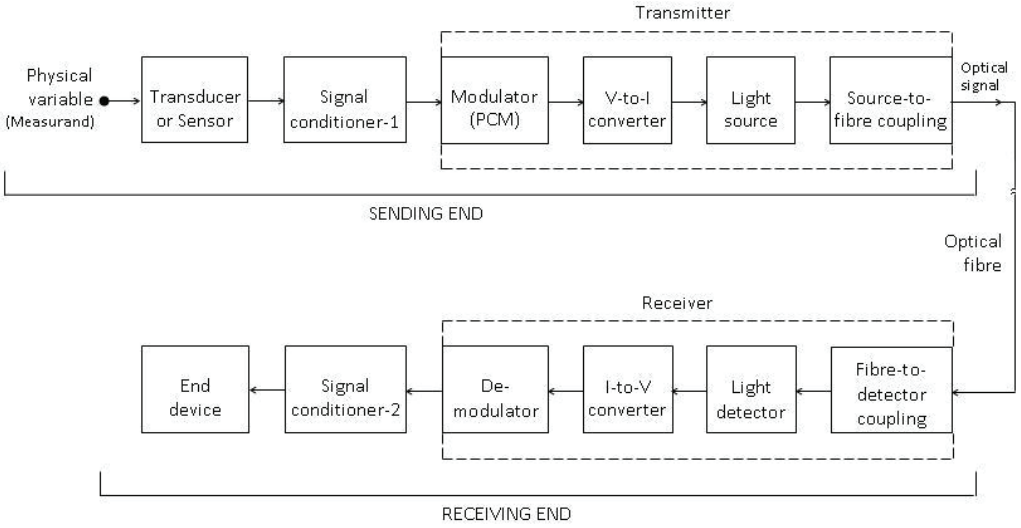


Figure 3.11. Optical fiber telemetry system

3.3.2. Further Classification of Telemetry Systems

Telemetry systems were classified on the basis of the modulation method used as under:

(i) DC telemetry systems

1. Direct voltage telemetry system,
2. Direct current telemetry system,

(ii) AC telemetry systems

1. Amplitude modulation (AM) telemetry system
2. Frequency modulation (FM) telemetry system,

(iii) Pulse telemetry systems

1. Pulse amplitude modulation (PAM) telemetry system
2. Pulse width modulation (PWM) telemetry system
3. Pulse phase modulation (PPM) telemetry system
4. Pulse frequency modulation (PFM) telemetry system
5. Pulse code modulation (PCM) telemetry system

The same were also classified on the basis of the type of information signal as under

(i) Analog telemetry systems

1. Direct voltage telemetry system
2. Direct current telemetry system
3. Amplitude modulation (AM) telemetry system
4. Frequency modulation (FM) telemetry system
5. Pulse amplitude modulation (PAM) telemetry system
6. Pulse width modulation (PWM) telemetry system
7. Pulse phase modulation (PPM) telemetry system
8. Pulse frequency modulation (PFM) telemetry system,

(ii) Digital telemetry system

1. Pulse code modulation (PCM) telemetry system

3.4. DESIGN OF BIO TELEMETRY

Telemetry system should be selected to transmit the bio –electric Signal with maximum fidelity and simplicity. The system should not affect the living system by any interference. Smaller in size light in weight. It should have more stability and reliability. The power consumption at the transmitter and receiver should be small. It should reject common mode interference rejection. Miniatured radio telemetry system should be used to reduce noise.

RADIO TELEMETRY SYSTEMS

- Single channel telemetry system
- Multi-channel telemetry system

3.4.1. SINGLE CHANNEL TELEMETRY SYSTEM

- For a single channel telemetry system, a miniature battery operated radio transmitter is connected to the electrodes of the patients.
- The transmitter broadcasts the bio potential to a remote place in which the receiver detects the radio signal and recovers signal for further processing.

- The receiving system can be located in a room separately from the patients.
- The only risk is shock to the patient.

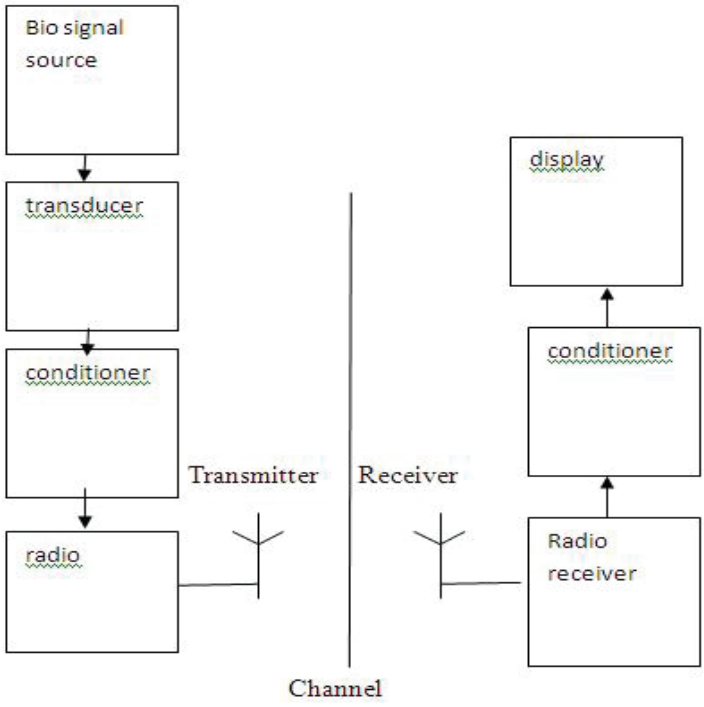


Figure 3.12. Block diagram of single channel telemetry system

Biosignal from the patient is converted into electrical signals by the transducer.

- They are amplified and filtered at the conditioner. Further they are frequency modulated or pulse modulated.Frequency modulation provides the high noise interference rejection and high stability.
- The biosignals are amplified to radio frequency range of few hundred KHz to about 300 KHz and then they are transmitted by transmitter antenna.s.
- At radio receiver the corresponding frequency are received and then they are demodulated, amplified and displayed.

Transmission of Bioelectric Variables

- Active measurements
- Passive measurements

Tunnel Diode FM Transmitter

- The tunnel diodes exhibit a specific characteristics known as negative resistance. They have extremely low values of inductance and capacitance.
- It is used for the transmission of EMG, ECG, respiration rates.
- Tunnel diodes are used as active devices and this circuit has higher fidelity and sensitivity.
- Total weight is 1.44 gm with battery and the size is small.
- Varactor diode is basically a reverse biased PN junction which utilizes the inherent capacitance of depletion layer.
- Varactor diodes are voltage capacitors used for frequency modulation.
- The signal is transmitted through the inductor L of the tank circuit of RF oscillator.

Advantages

- All the signal can be transmitted by using the circuit.
- No shielded room is needed.
- Interference is much reduced.

3.4.2. Radio Telemetry With Sub Carrier System

Transmitter Side

- When the position of transmitter to the body or other conduction object change, the carrier frequency and amplitude will change due to the loading change of the carrier frequency resonant circuit.
- If the signal has a frequency different from the loading effect, they can be separated by filters. .Otherwise the real signal will be distorted by loading effect.

- To avoid this loading effect the sub carrier system is needed. The signal is modulated on a sub carrier to convert the signal frequency to the neighborhood of the sub carrier frequency.
- Then the RF carrier is modulated by this sub carrier carrying the signal.
  - The 20 KHz sub carrier signal is given to amplitude modulator.
  - The signals are amplified and forwarded to the transmitter.

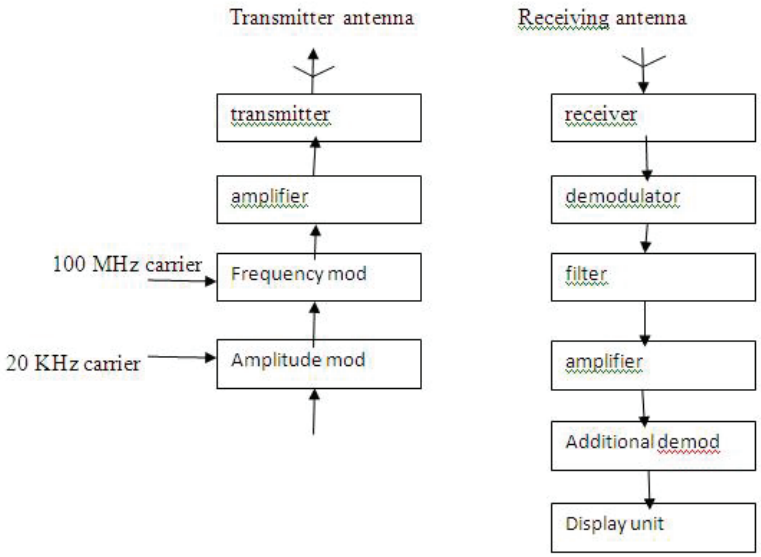


Figure 3.13. Bio telemetry using sub carrier system

Receiver Side

- At the receiver end the receiver detects the RF and recovers the sub carrier carrying the signal.
- At the receiver side, the signals are passed to demodulator, demodulated signal is filtered, amplified by amplifier and then they are given to additional demodulator. It is used to convert the signal from the modulated sub carrier system an to get the original signal.

- Finally the signal is displayed.

3.4.2 MULTI CHANNEL TELEMETRY SYSTEM

- For most biomedical applications, simultaneous recording of Bio signals are required for correlation study.
- Each signal is in need of one channel. When the number of channels is more than the two or three, the simultaneous operation of the several single channel is difficult. At that time multiple channel telemetry system is adopted.

Two Types of Multiplexing

I) FDM II) TDM,

Frequency Division Multiplex System

- Each signal is frequency modulated on a sub carrier frequency.
- Modulated sub carrier frequencies are combined to modulate the RF carrier.
- At receiver the modulated sub carrier can be separated by the proper band pass filter.
- Then the each signals are demodulated by using specified frequency.
- Frequency of the sub carrier has to be carefully selected to avoid interference.
- The low pass filter are used to extract the signals without any noise. Finally the output unit displays the original signal.

Time Division Multiplex Telemetry System

- Most biomedical signals have low frequency bandwidth requirement, we can use time division multiple system by time sharing scheme.
- Transmission channel is connected to each signal channel input for a short time to sample and transmit that signal.
- Transmitter is switched to the next input signal channel in a definite sequence.

- All the channels have been scanned once, a cycle is completed and the next cycle will start. Scanning follows a order from signal 1 to signal 3.
- At the receiver the process is reversed. The sequentially arranged, signal pulses are given to the individual channels by using gate signal generator
- If the number of scanning cycles per second is large and if the transmitter and the receiver are synchronized, the signal in each channel at the receiver side can be recovered. But the scanning frequency has to satisfy the following condition. fscan = 2fmax The maximum number of channels practically allowed is smaller than the calculated value of n to avoid the interference between channels.

Advantages of Biotelemetry

- Used to record the bio signals over long periods.
- Patient is not disturbed during recording
- For future reference or to study the treatment effect
- Monitor the athletes running a race.
- For monitoring the persons who are in action the biotelemetry is an ideal one.
- For recording on animals, particularly for research, the biotelemetry is greatly used.

APPLICATIONS OF BIOTELEMETRY

(a) Monitoring of astronauts during flight.

(b) Monitoring of patients in ambulance while transit to hospital.

(c) Monitoring of patients while obtaining their exercise electrocardiogram.

(d) Monitoring of patients who are permitted to stay away from the hospital.

(e) Monitoring of animals in their natural habitat.

(f) Transmission of ECG or other medical information through telephone links

(g) Isolating the patients from electricity operated measuring equipment such as ECG equipment in order to prevent any accidental shock to them.

3.5. RADIO-PILL AND TELE-SIMULATION

This TOPIC address the challenges to facilitate the development of a high capacity radio system for a small, miniaturized electronic pill device that can be swallow able or implantable in human body in order to detect biological signals or capture images that could eventually be used for diagnostic and therapeutic purposes. Recent development in electronic pill technology requires the integration of more complex systems on the same platform when compared to conventional implantable systems. A small miniaturized electronic pill can reach areas such as small intestine and deliver real time video images wirelessly to an external console. Fig. 1 shows a wireless endoscope (i.e. electronic pill) for a medical monitoring system. The device travels through the digestive system to collect image data and transfers them to a nearby computer for display with a distance 1 meter or more. A high resolution video based capsule endoscope produces a large amount of data, which should be delivered over a high capacity wireless link.

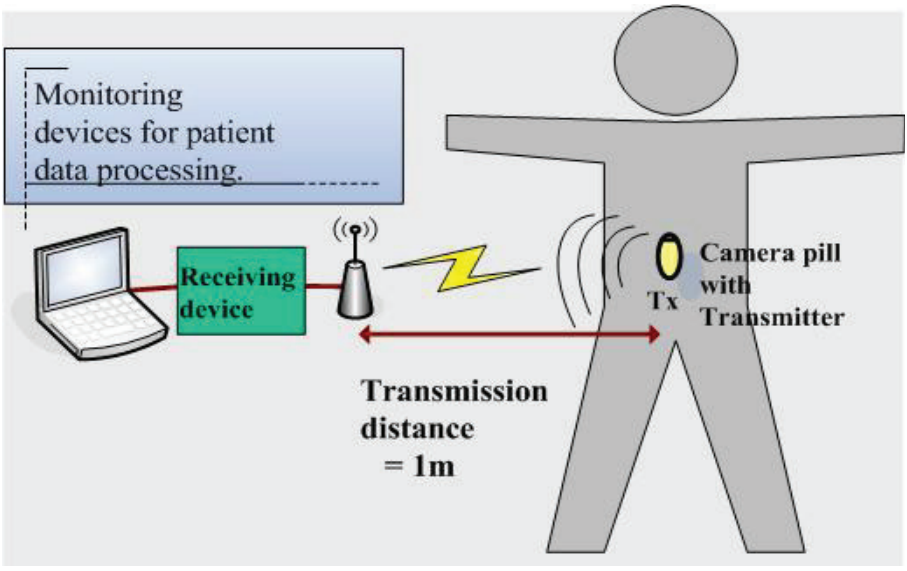


Figure 3.14. A wireless radio-pill endoscope monitoring system

Wideband technology- (UWB communication) is an ideal physical layer solution that achieves a data rate equal or higher than 100 Mbps. Its current applications are mostly for in-door entertainment, radar and imaging. Due to high losses in body tissue at high frequencies many are skeptical about using UWB for implanted and, moreover, ingested devices.

WIRELESS TELEMETRY USED IN ELECTRONIC PILL

As the electronic device should deeply be placed inside the body, which makes the wireless communication interesting due to its surrounding medium, the recent attempts in electronic pills have also been limited to low frequency transmissions (UHF-433 ISM or lower) a wireless endoscope system uses a commercial RF transceiver operating at 433 MHZ ISM with 267 kbps. The electronic pill includes a passive wireless link used for wake-up to reduce power consumption. The wake-up system recovers energy from a 915 MHz RF modulated signal with some sort of identification code. This capsule does image compressing techniques using an ASIC to enable higher transmission rate of images for low–data rate systems. The pill uses a simple OOK wireless system. Similar to the early developments, this device transfers the physiological data- pH and temperature

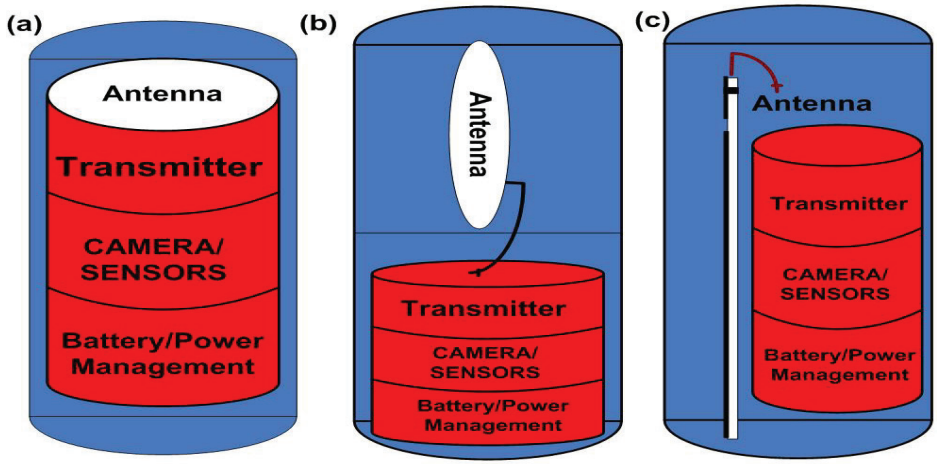


Figure 3.15. Possible physical shapes for electronic pills

Another type of capsule is the robotic endoscope which additionally has features such as locomotion and the energy transmission using electromagnetic coupling. Although the device size is quite large comparing to other proposed systems, it is probably because of these additional functionalities. Similar to smart pill, such a device can be used for precise drug delivery in the human gastrointestinal tract. Real-time energy transfer is necessary for these types of endoscopes to provide mechanical function as they require large power for continuous movement.

Another category of electronic pill technology is to use fluorescence spectroscopy and imaging, similar to those that are commercially available. Kfouri, *et al.*, studied a fluorescence-based electronic pill system that uses UV light with illumination LEDs to obtain clearer images. This is like flash based digital camera widely used by people. Due to the use of power hungry LEDS, such a device consumes power higher than the other available systems. An alternative power source together with battery is required to support the electronics continuously. A wireless power, from outside to inside, has been suggested. Although not specified, it probably used UHF frequency as the RF transmission.

Due to the limited transmission bandwidth used for the electronic pills that are currently being developed or the ones commercially available, the image transfer rate has been limited to 0-10 frames per second. As high definition cameras are continuously being developed, they will be attractive for use in electronic pill. However, a higher pixel camera will require higher image transfer rate. As an example, if 1920 x1080 pixel (2 megapixel) charge-coupled device (CCD) sensors to be integrated in an electronic pill, it will require a data rate of 33.2 Mbit/frame, considering 2 Bytes are used per frame. Currently such a high data rate is not possible with any of the available telemetry systems in electronic pills. If the allowable bandwidth used with UHF frequencies, transmission of this data rate will only give a transmission time of 10s or more per frame which will result in very small motion for a video streaming. Although compression techniques could be used to some extent, it reduces the image equality. Thus in future, a dedicated frequency band with larger bandwidth is required for high definition image transmission

A prototyping system including UWB transmitter/receiver and antennas has been developed to investigate the feasibility of a high data

rata transmission for the electronic pill technology. Integration of antenna with the UWB transmitter electronics has been considered in a capsule shaped structure. Due to the high data rate capacity (e.g. 100 Mbps), a wideband electronic pill can transmit raw video data without any compressing, resulting low-power, less delay in real-time and increased picture resolution. With a high definition camera such as 2 megapixels, UWB telemetry can send up to 10 frame per second (fps).

UNIT IV.
RADIOLOGICAL EQUIPMENTS

4.1. IONISING RADIATION

Ionizing (or **ionising** in British English) **radiation** is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Ionizing radiation is composed of energetic subatomic particles, ions or atoms moving at relativistic speeds, and electromagnetic waves on the high-energy end of the electromagnetic spectrum.

Gamma rays, X-rays, and the higher ultraviolet part of the electromagnetic spectrum are ionizing, whereas the lower ultraviolet part of the electromagnetic spectrum, visible light (including nearly all types of laser light), infrared, microwaves, and radio waves are considered non-ionizing radiation. The boundary between ionizing and non-ionizing electromagnetic radiation that occurs in the ultraviolet is not sharply defined, since different molecules and atoms ionize at different energies. Conventional definition places the boundary at a photon energy between 10 eV and 33 eV in the ultraviolet.

Typical ionizing subatomic particles from radioactivity include alpha particles, beta particles and neutrons. Almost all products of radioactive decay are ionizing because the energy of radioactive decay is typically far higher than that required to ionize. Other subatomic ionizing particles which occur naturally are muons, mesons, positrons, neutrons and other particles that constitute the secondary cosmic rays that are produced after primary cosmic rays interact with Earth's atmosphere.[1][2] Cosmic rays may also produce radioisotopes on Earth (for example, carbon-14), which in turn decay and produce ionizing radiation.

Cosmic rays and the decay of radioactive isotopes are the primary sources of natural ionizing radiation on Earth referred to as background radiation.

In space, natural thermal radiation emissions from matter at extremely high temperatures (e.g. plasma discharge or the corona of the Sun) may be ionizing. Ionizing radiation may be produced naturally by the acceleration of charged particles by natural electromagnetic fields (e.g. lightning), although this is rare on Earth. Natural supernova explosions in space produce a great deal of ionizing radiation near the explosion, which can be seen by its effects in the glowing nebulae associated with them.

Ionizing radiation can also be generated artificially using X-ray tubes, particle accelerators, and any of the various methods that produce radioisotopes artificially. Ionizing radiation is invisible and not directly detectable by human senses, so radiation detection instruments such as Geiger counters are required. However, ionizing radiation may lead to secondary emission of visible light upon interaction with matter, such as in Cherenkov radiation and radioluminescence.

Ionizing radiation is applied constructively in a wide variety of fields such as medicine, research, manufacturing, construction, and many other areas, but presents a health hazard if proper measures against undesired exposure aren't followed. Exposure to ionizing radiation causes damage to living tissue, and can result in mutation, radiation sickness, cancer, and death.

4.1.1. TYPES OF IONIZING RADIATION

Alpha (**α**) radiation consists of a fast-moving helium-4 (4He) nucleus and is stopped by a sheet of paper. Beta (**β**) radiation, consisting of electrons, is halted by an aluminums plate. Gamma (**γ**) radiation, consisting of energetic photons, is eventually absorbed as it penetrates a dense material. Neutron (**n**) radiation consists of free neutrons that are blocked using light elements, like hydrogen, which slow and/or capture them. Not shown: galactic cosmic rays that consist of energetic charged nuclei like protons, helium nuclei, and high-charged nuclei called HZE ions. Ionizing radiation is categorized by the nature of the particles or electromagnetic waves creating the ionising effect. These have different

ionization mechanisms, and may be grouped as directly or indirectly ionizing.

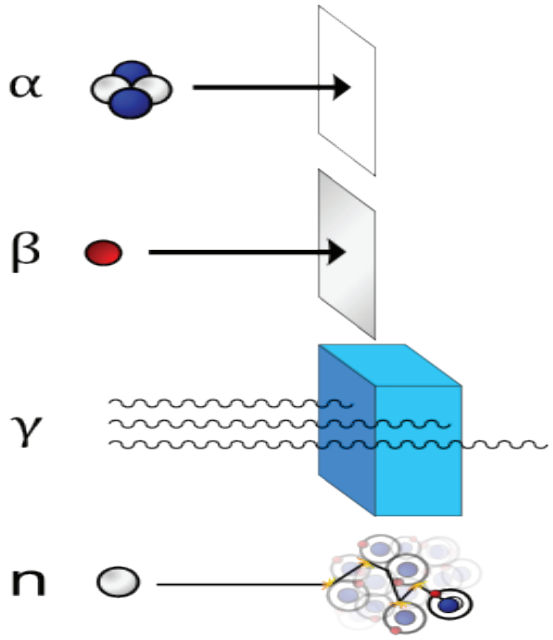


Figure 4.1. Different types of Ionizing radiation.

Directly Ionizing

Any charged massive particle can ionize atoms directly by fundamental interaction through the Coulomb force if it carries sufficient kinetic energy. This includes atomic nuclei, electrons, muons, charged pions, protons, and energetic charged nuclei stripped of their electrons, all of which must be moving at relativistic speeds to reach the required kinetic energy. The first two to be recognized were given special names, which are used today: Helium nuclei at relativistic speeds are called alpha particles, and electrons at relativistic speeds are called beta particles. Natural cosmic rays are made up primarily of relativistic protons but also include heavier atomic nuclei like helium ions and HZE ions and muons. Charged pions are very short lived and seen only in large amounts in particle accelerators.

Alpha Particles

Alpha particles consist of two protons and two neutrons bound together into a particle identical to a helium nucleus. They are generally produced in the process of alpha decay, but may also be produced in other ways. Alpha particles are named after the first letter in the Greek alphabet, α. The symbol for the alpha particle is α or α2+. Because they are identical to helium nuclei, they are also sometimes written as He2+or 42 He2+indicating a Helium ion with a +2 charge (missing its two electrons). If the ion gains electrons from its environment, the alpha particle can be written as a normal (electrically neutral) Helium atom 42He.

They are a highly ionizing form of particle radiation, and when resulting from radioactive alpha decay have low penetration depth. They can be stopped by a few centimetres of air, or by the skin. However, so-called long range alpha particles from ternary fission are three times as energetic, and penetrate three times as far. The helium nuclei that form 10-12% of cosmic rays are also usually of much higher energy than those produced by nuclear decay processes, and are thus capable of being highly penetrating and able to traverse the human body and dense shielding, depending on their energy.

Beta Particles

Beta particles are high-energy, high-speed electrons or positrons emitted by certain types of radioactive nuclei, such decay. They are designated by the Greek letter beta (β). There are two forms of beta decay, β− and β+, which respectively give rise to the electron and the positron. High energy beta particles may produce X-rays known as bremsstrahlung ("braking radiation") or secondary electrons (delta ray)as they pass through matter. Both of these can subsequently ionize as an indirect ionization effect.

Bremsstrahlung is of concern when shielding beta emitters, because interaction of beta particles with the shielding material produces Bremsstrahlung radiation. This effect is greater with material of high atomic numbers, so material with low atomic numbers is used for beta source shielding.

Positrons

The **positron** or **ant electron** is the antiparticle or the antimatter counterpart of the electron. The positron has an electric charge of +1e, a spin of ½, and has the same mass as an electron. When a low-energy positron collides with a low-energy electron, annihilation occurs, resulting in the production of two or more gamma ray photons (see electron–positron annihilation). Positrons may be generated by positron emission radioactive decay (through weak interactions), or by pair production from a sufficiently energetic photon. Positrons are common artificial sources of ionizing radiation in medical PET scans.As positrons are positively charged particles they can also directly ionize an atom through Coulomb interactions.

Indirectly Ionizing

Radiation interaction - gamma rays are represented by wavy lines, charged particles and neutrons by straight lines. The small circles show where ionization occurs. Indirect ionizing radiation is electrically neutral and therefore does not interact strongly with matter. The bulk of the ionization effects are due to secondary ionizations.

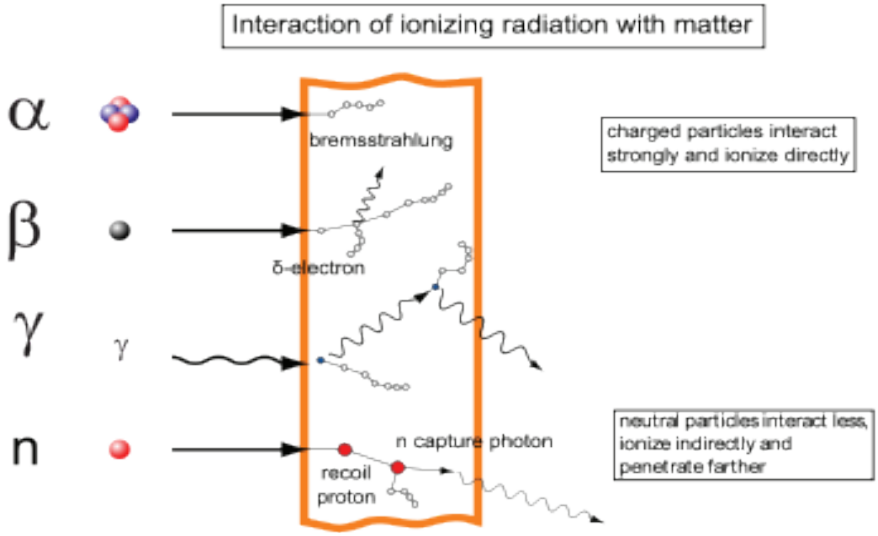


Figure 4.2. Different types of indirectly ionizing

3 Main Uses of Ionizing Radiation in Medicine

- Treatment
- Diagnosis
- Sterilization,

Cancer

Cancers are growths of cells (cancerous tumours) which are out of control. As a result of this, they do not perform their intended function.

Treatment of Cancer

Cancerous tumors can be treated using the following main methods:

- Chemotherapy (drugs).
- Radiation therapy (radiotherapy and brachytherapy).

Surgery

Factors which affect the choice of treatment for cancer.

The choice of treatment depends on a number of factors including:

- The size of the tumour.
- The position of the tumour.

4.2. DIAGNOSTIC X-RAY EQUIPMENTS

Three types of rays emits continuously from a radium material. These rays are known as alpha rays (a rays), Beta rays (p rays) and gamma rays (x rays). Gamma rays also known as x-rays. The frequency of x-rays as approximately 1020 Hz and its wave length is approximately 10"10 meter. X-rays are electromagnetic wave which are widely used in medical field and industries for inspection of human body or any other thing

The discovery of X-rays came from experimenting with Crookes tubes, an early experimental electrical discharge tube invented by English physicist William Crookes around 1869-1875. In 1895, Wilhelm Röntgen discovered X-rays emanating from Crookes tubes and the many uses for X-rays were immediately apparent. One of the first X-ray photographs was made of the hand of Röntgen's wife. The image displayed

both her wedding ring and bones. On January 18, 1896 an *X-ray machine* was formally displayed by H.L. Smith.

In the 1940s and 1950s, X-ray machines were used in stores to help sell footwear. These were known as fluoroscopes. However, as the harmful effects of X-ray radiation were properly considered, they finally fell out of use. Shoe-fitting use of the device was first banned by the state of Pennsylvania in 1957. (They were more a clever marketing tool to attract customers, rather than a fitting aid.)

An X-ray imaging system consists of an X-ray source or generator (X-ray tube), an image detection system which can be either a film (analog technology) or a digital capture system, and a PACS,

4.2.1. Production of X-Rays

X-rays can be produced with the help of high vacuum tube with a heater, cathode and anode. Vacuum tube is operate at very high voltage. A special electron tube (vacuum tube) is shown in Fig No 11 which is used for production of x-rays. Such a tube has a hot filament cathode an anode made a very heave metal. Electron flow from the cathode to anode as in any diode tube. However a large DC voltage is used between cathode and anode of x-rays tube.

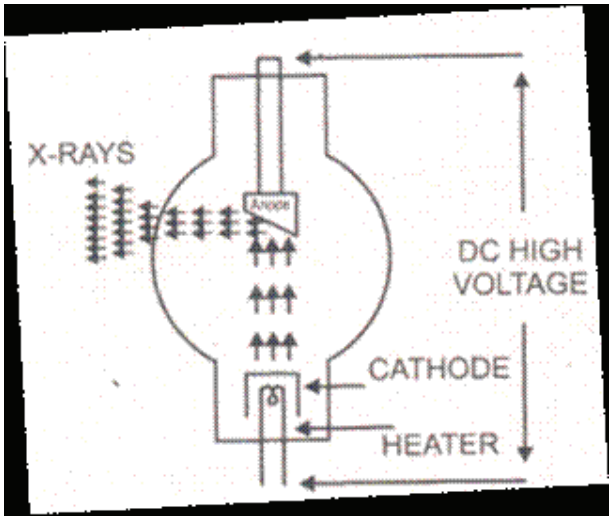


Figure 4.3. Production of x-rays

When heater is on and very high anode to cathode voltage is applied the electron emits from cathode and travel toward the anode with very high Velocity, as clear from fig No11, this beam of electron strike the metal anode such speed that new rays are made from the slanting surface of the anode these x-rays seem to bounce sideways ad out thought the well of the tube. As the DC voltage (anode-to-cathode of the x-rays tube) is increased, the wave length of x-rays decreases. Same tubes now operate at more than a million volts.

MECHANISM

The heart of an X-ray generator is the X-ray tube. Like any vacuum tube, the X-ray tube contains a cathode, which directs a stream of electrons into a vacuum, and an anode, which collects the electrons and is made of copper to evacuate the heat generated by the collision. When the electrons collide with the target, about 1% of the resulting energy is emitted as X-rays, with the remaining 99% released as heat. Due to the high energy of the electrons that reach relativistic speeds the target is usually made of tungsten even if other material can be used particularly in XRF applications. A cooling system is necessary to cool the anode; many X-ray generators use water or oil recirculating systems.

X ray machine has five different blocks

1. Power supply
2. X ray tube aluminum filter
3. Collimator
4. Bucky diaphragm
5. Lead shield

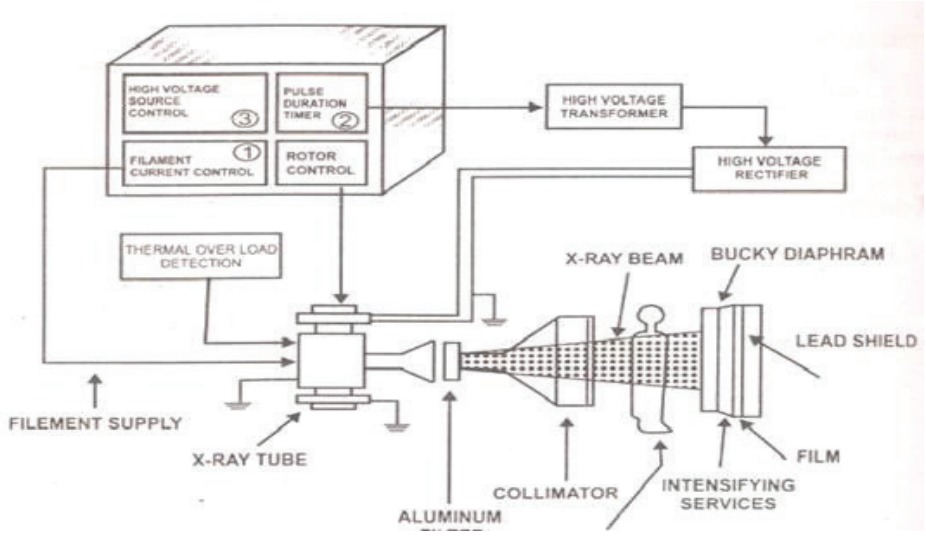


Figure 4.4. Block diagram of X ray machine

X ray output can be obtained when electrons heat the anode Density or darkness of the image is directly proportional to the amount of X rays that penetrate the film/ Contrast is measure of the darkness of desired image.

Power Supply

- X ray will have high voltage source and high voltage transformer and high voltage rectifier. The power supply arrangement will have the options for filament current control, rotor control, timer control and thermal overload production circuit.
- The various component in the X ray machine are used to improve the the quality of the image, increase the contrast, improve the resolution size and minimize the dose of X rays used on the patient.
- The density or darkness of the image is proportional to the amount of X rays that penetrate the film. Contrast is a measure of darkness of the desired image, compare to its surroundings.
- The good contrast in image will mainly depends on the mass attenuation coefficient.

Aluminum Filters

The emitted X rays wiil contain a broad range of frequency generally the aluminium filters will observe the lower X ray frequency and hence the intensity of low frequency X ray incident on the patient is reduced.

Collimator

Collimator is placed between the patient and aluminium filter. It is nothing but an aperture diaphragm which restricts the X ray beam falling on the patient. The necessary shape of X ray beam is obtained only by collimator. A lamp and reflecting mirror arrangement will makes a visible attern on the patient, so that the medical attendant can tell where the X ray will strike. And this arrangement is used to align or positioning the beam on the patient.

- Bucky grid
- It is used to reduce scattered radiation
- The Bucky grid is placed between the patient and the film cassette to improve the sharpness of image.

Radiography

- X ray images developed by photography or photosensitive film
- High resolution in images can be obtained
- Wide range of contrast can be obtained
- Patient is not exposed to X rays during the examination of the X ray image
- The patient dose is very low
- Permanent record is available
- The image can be obtained after developing the film and examination can be made before developing the film,
- Movement of organs cannot be observed
- Efficient is more,

Fluoroscopy

Fluoroscopy is the method that provides real-time X ray imaging that is especially useful for guiding a variety of diagnostic and interven-

tional procedures. The ability of fluoroscopy to display motion is provided by a continuous series of images produced at a maximum rate of 25-30 complete images per second. This is similar to the way conventional television or video transmits images. While the X ray exposure needed to produce one fluoroscopic image is low (compared to radiography), high exposures to patients can result from the large series of images that are encountered in fluoroscopic procedures. Therefore, the total fluoroscopic time is one of the major factors that determines the exposure to the patient from fluoroscopy.

Applications of X Ray

- X ray is used to visualize skeletal structure
- X ray is used to take chest radiograph
- Bronchography
- Heart examinations are performed by taking frontal and lateral X ray film images
- Gastro intestinal tract can be imaged by using X ray
- Urinary tract can be examined by using X rays,

Angiography

- Angiography is a special X ray imaging technique through which high contrasts can be obtained.
- The outline of the blood vessels are visible in angiogram
- **Angiocardiography**: It mean study of heart
- **Cerebral angiography**: It mean study of brain
- **Bronchography**: It maen study of lungs
- **Nephro angiography**: it mean study of kidney,

4.3. USE OF RADIO ISOTOPE IN DIAGNOSIS

One major use of radioisotopes is in nuclear medicine. Of the 30 million people who are hospitalized each year in the United States, 1/3 are treated with nuclear medicine. More than 10 million nuclear-medicine procedures are performed on patients and more than 100 million nuclear-medicine tests are performed each year in the United States alone. A

comparable number of such procedures are performed in the rest of the world.

There are nearly one hundred radioisotopes whose beta and/or gamma radiation is used in diagnosis, therapy, or investigations in nuclear medicine. The most used radioisotopes were discovered before World War II using the early cyclotrons of Ernest Lawrence, with the initial applications to medicine being developed by his brother John Lawrence. Some of the most well known radioisotopes, discovered by Glenn Seaborg and his coworkers, are ^{131}I (discovered in 1938), ^{60}Co (1937), ^{99m}Tc (1938), and ^{137}Cs (1941). By 1970, 90 percent of the 8 million administrations per year of radioisotopes in the United States utilized either ^{131}I, ^{60}Co, or ^{99m}Tc. Today, ^{99m}Tc, with a half-life of 6 hours, is the workhorse of nuclear medicine. It accounts for more than 10 million diagnostic procedures a year in the United States. It is used for brain, bone, liver, spleen, kidney, lung and thyroid imaging as well as for blood-flow studies.

^{131}I, with a half-life of 8 days, is used to diagnose and treat thyroid disorders. Seaborg's mother was one of the first to benefit from the use of this radioisotope that her son had discovered. Fatally ill from hyperthyroidism, (a related condition from which her sister died), diagnosis and treatment with ^{131}I led to her complete recovery and a long life. Former President George Bush and First Lady Barbara Bush are some notable people who were successfully treated for Graves' disease, a thyroid disease, with ^{131}I. Radioactive iodine treatment is so successful that it has virtually replaced thyroid surgery.

A very effective role for radioisotopes in nuclear medicine is the use of short-lived positron emitters such as ^{11}C, ^{13}N, ^{15}O, or ^{18}F in a process known as Positron Emission Tomography (PET). Incorporated in chemical compounds that selectively migrate to specific organs in the body, diagnosis is effected by detecting annihilation gamma rays–two gamma rays of identical energy emitted when a positron and an electron annihilate each other. These gamma rays have the very useful property that they are emitted in exactly opposite directions. When both are detected, a computer system may be used to reconstruct where the annihilation occurred. By attaching a positron emitter to a protein or a glucose molecule, and allowing the body to metabolize it, we can study the function-

al aspect of an organ such as the human brain. The PET image shows where the glucose has been absorbed (Fig. 13-3a).

PET imaging becomes even more valuable when we can observe the functional image compared to the anatomical image. Magnetic Resonance Imaging (MRI)–originally known as Nuclear Magnetic Resonance Imaging–can provide very detailed images of the anatomy as shown in the second image shown in Fig. 13-3b. These techniques provide researchers a better understanding of what is healthy tissue versus what is diseased.

The radioisotope ^{60}Co emits gamma rays that are used to destroy cancer cells. Hundreds of thousands of Americans who suffer from cancer have been treated in this way. Every year millions of cubic meters of medical products and equipment are sterilized by irradiation worldwide. ^{137}Cs has found substantial applications as a gamma-ray source in medical therapy, similar in its use to that of ^{60}Co.

Cancer treatment with beams of massive ions directly from an accelerator has gained increasing utilization in the last decade. Unlike gamma rays, which distribute their energy equally in healthy as well as cancerous cells, massive particles such as protons or alpha particles will deposit the bulk of their energy just before they stop. If the energy is well-chosen, most of the energy will be dumped into the tumor and not into the surrounding healthy tissue. Using three dimensional water degrader columns, the shape of the tumor can be mapped out and selectively irradiated. Dedicated accelerators are now being built to continue this work at medical centers. In the United States, the Loma Linda Medical Center in California is now operating a proton synchrotron for therapy, and a second facility is being built at Massachusetts General in Boston. Boron Neutron Capture Therapy (BNCT) is under development for the treatment of glioblastoma multiforma, a brain cancer which afflicts some 12,500 people a year in the US alone and is almost impossible to treat by currently available means.

4.3.1. Radioisotopes: Their Uses in Medical Diagnosis and Therapy

Radiation is used to both detect and treat abnormalities in the body. We've already discussed the use of iodine-131 therapy for hyperthyroid-

ism. Iodine-131 can also be used in a diagnostic procedure to monitor the function of the thyroid. The rate at which the thyroid rakes up the iodine-131 can be monitored with a scanning device to see if it is functioning properly.

What makes radioisotopes so useful in diagnostic procedures is that the body treats the tagged isotope in the same way that it treats the nonradioactive element. Therefore, the tagged isotope goes right to the area of the body where you want it to go. For example, iodine, whether it's radioactive or not, goes right to the thyroid, where it is incorporated into the amino acid thyroxine (the only molecule in the body that contains iodine). Therefore, iodine-131 is perfect for monitoring the thyroid gland.

Chromium, in the form of sodium chromate, attaches strongly to the hemoglobin of red blood cells. This makes radioactive chromium-151 an excellent isotope for determining the flow of blood through the heart. This isotope is also useful for determining the lifetime of red blood cells, which can be of great importance in the diagnoses of anemias.

Radioactive cobalt (cobalt-59 or cobalt-60) is used to study defects in vitamin B_{12} absorption. Cobalt is the metallic atom at the center of the B_{12} molecule. By injecting a patient with vitamin B_{12}, labeled with radioactive cobalt, the physician can study the path of the vitamin through the body and discover any irregularities.

We've already discussed how radiation therapy can be used to destroy cancer cells. Radiation can be delivered to a malignant area in three ways.

One method is tele therapy, in which a high-energy beam of radiation is aimed at the cancerous tissues. A second method is brachytherapy, in which a radioactive isotope is placed into the area to be treated. This is usually done by means of a seed, which could be a glass bead containing the isotope. In this way the isotope delivers a constant beam of radiation to the affected area.

The third method is called radio pharma ceutical therapy. This method involves oral or intravenous administration of the isotope. The isotope then uses the normal body pathway to seek its target. This is the method that is used to get iodine-131 to the thyroid gland.

4.3.2. Isotopes Used in Medicine

- Reactor Radioisotopes (half-life indicated)
- Molybdenum-99 (66 h): Used as the 'parent' in a generator to produce technetium-99m.
- Technetium-99m (6 h): Used in to image the skeleton and heart muscle in particular, but also for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney (structure and filtration rate), gall bladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection and numerous specialized medical studies.
- Bismuth-213 (46 min): Used for TAT.
- Chromium-51 (28 d): Used to label red blood cells and quantify gastro- intestinal protein loss.
- Cobalt-60 (10.5 MTh): Formerly used for external beam radiotherapy.
- Copper-64 (13 h): Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases.
- Dysprosium-165 (2 h): Used as an aggregated hydroxide for synovectomy treatment of arthritis.
- Erbium-169 (9.4 d): Use for relieving arthritis pain in synovial joints.
- Holmium-166 (26 h): Being developed for diagnosis and treatment of liver tumours.
- Iodine-125 (60 d): Used in cancer brachytherapy (prostate and brain), also diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmune- assays to show the presence of hormones in tiny quantities. Iodine-131 (8 d): Widely used in treating thyroid cancer and in imaging the thyroid; also in diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction. A strong gamma emitter, but used for beta therapy.
- Iridium-192 (74 d): Supplied in wire form for use as an internal radiotherapy source for cancer treatment (used then removed).
- Iron-59 (46 d): Used in studies of iron metabolism in the spleen.

- Lutetium-177 (6.7 d): Lu-177 is increasingly important as it emits just enough gamma for imaging while the beta radiation does the therapy on small (eg endocrine) tumours. Its half-life is long enough to allow sophisticated preparation for use.
- Palladium-103 (17 d): Used to make brachytherapy permanent implant seeds for early stage prostate cancer.
- Phosphorus-32 (14 d): Used in the treatment of polycythemia vera (excess red blood cells). Beta emitter.
- Potassium-42 (12 h): Used for the determination of exchangeable potassium in coronary blood flow.
- Rhenium-186 (3.8 d): Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.
- Rhenium-188 (17 h): Used to beta irradiate coronary arteries from an angioplasty balloon.
- Samarium-153 (47 h): Sm-153 is very effective in relieving the pain of secondary cancers lodged in the bone, sold as Quadramet. Also very effective for prostate and breast cancer. Beta emitter.
- Selenium-75 (120 d): Used in the form of seleno-methionine to study the production of digestive enzymes.
- Sodium-24 (15 h): For studies of electrolytes within the body.
- Strontium-89 (50 d): Very effective in reducing the pain of prostate and bone cancer. Beta emitter.
- Xenon-133 (5 d): Used for pulmonary (lung) ventilation studies.
- Ytterbium-169 (32 d): Used for cerebrospinal fluid studies in the brain.
- Yttrium-90 (64 h): Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter.
- Radioisotopes of caesium, gold and ruthenium are also used in brachytherapy.
- Cyclotron Radioisotopes
- Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18: These are positron emitters used in PET for studying brain physiology and pa-

thology, in particular for localising epileptic focus, and in dementia, psychiatry and neuropharmacology studies. They also have a significant role in cardiology. F-18 in FDG has become very important in detection of cancers and the monitoring of progress in their treatment, using PET.

- Cobalt-57 (272 d): Used as a marker to estimate organ size and for in-vitro diagnostic kits.
- Gallium-67 (78 h): Used for tumour imaging and localisation of inflammatory lesions (infections).
- Indium-111 (2.8 d): Used for specialist diagnostic studies, eg brain studies, infection and colon transit studies.
- Iodine-123 (13 h): Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.
- Krypton-81m (13 sec) from Rubidium-81 (4.6 h): Kr-81m gas can yield functional images of pulmonary ventilation, e.g. in asthmatic patients, and for the early diagnosis of lung diseases and function.

4.4. RADIATION THERAPY

Radiation therapy uses ionizing radiation to treat cancer i.e. to destroy cancerous cells.

There are two techniques in radiation therapy that are used to treat cancer using ionizing,

- Radiation:
- Radiotherapy
- Brachytherapy,

Radiation Therapy

Radiotherapy Treatment Planning

- Every treatment using radiotherapy has to be rigorously planned. The planning process consists of three phases:
- Planning
- Simulation
- Treatment,

Planning

- The cancerous tumour has to be located so that its size and position can be analyzed. This information can be obtained from:
- X-rays
- CT scans
- MRI scans
- Ultrasound images,

Simulation

Once the amount of radiation to be given has been accurately calculated, the patient then goes to the simulator to determine what settings are to be selected for the actual treatment using a

linear accelerator. The settings are determined by taking a series of x-rays to make sure that the tumour is in the correct position ready to receive the ionising radiation.

Treatment

Cancerous tumours can be treated using radiotherapy as follows:

- Irradiation using high energy gamma rays.
- Irradiation using high energy x-rays.

Irradiation Using High Energy Gamma Rays

- Gamma rays are emitted from a cobalt-60 source – a radioactive form of cobalt.
- The cobalt source is kept within a thick, heavy metal container.

This container has a slit in it to allow a narrow beam of gamma rays to emerge.

Brachytherapy

- This involves placing implants in the form of seeds, wires or pellets directly into the tumour.
- Such implants may be temporary or permenant depending on the implant and the tumour itself.

- The benefit of such a method is that the tumour receives nearly all of the dose whilst healthy tissue hardly receives any.

Brachytherapy is used to treat the following cancers

- Uterus
- Cervix
- Prostate
- Intraocular
- Skin
- Thyroid
- Bone

4.4.1. POSITRON EMISSION TOMOGRAPHY (PET SCAN)

A positron emission tomography (PET) scan is an imaging test that uses a radioactive substance called a tracer to look for disease in the body.

A PET scan shows how organs and tissues are working. This is different than magnetic resonance imaging (MRI) and computed tomography (CT), which show the structure of and blood flow to and from organs,

How the Test is Performed

A PET scan uses a small amount of radioactive material (tracer). The tracer is given through a vein (IV), most often on the inside of your elbow. The tracer travels through your blood and collects in organs and tissues. This helps the radiologist see certain areas of concern more clearly.

You will need to wait nearby as the tracer is absorbed by your body. This takes about 1 hour.

Then, you will lie on a narrow table that slides into a large tunnel-shaped scanner. The PET detects signals from the tracer. A computer changes the signals into 3-D pictures. The images are displayed on a monitor for your doctor to read.

You must lie still during test. Too much movement can blur images and cause errors. How long the test takes depends on what part of the body is being scanned.

How to Prepare for the Test

You may be asked not to eat anything for 4 - 6 hours before the scan. You will be able to drink water.

Why the Test is Performed

A PET scan can reveal the size, shape, position, and some function of organs.

This Test Can be Used to

- Check brain function
- Diagnose cancer, heart problems, and brain disorders
- See how far cancer has spread
- Show areas in which there is poor blood flow to the heart,
- Several PET scans may be taken over time to check how well you are responding to treatment for cancer or another illness.

Normal Results

A normal result means there were no problems seen in the size, shape, or position of an organ. There are no areas in which the tracer has abnormally collected.

What Abnormal Results Mean

Abnormal results depend on the part of the body being studied. Abnormal results may be due to:

- Change in the size, shape, or position of an organ
- Cancer
- Infection
- Problem with organ function

Risks

The amount of radiation used in a PET scan about the same amount as for most CT scans. Short-lived tracers are used so the radiation is gone from your body in about 2-10 hours. Tell your doctor before having this test if you are pregnant or breast feeding. Infants and babies developing in the womb are more sensitive to radiation because their organs are still growing. Rarely, people may have an allergic reaction to the tracer material. Some people have pain, redness, or swelling at the injection site.

Considerations

It is possible to have false results on a PET scan. Blood sugar or insulin levels may affect the test results in people with diabetes.

Most PET scans are now performed along with a CT scan. This combination scan is called a PET/CT.

4.4.2. COMPUTERISED TOMGRAPHY (CT SCAN)

A computerized tomography (CT) scan uses X-rays and a computer to create detailed images of the inside of the body.

CT scans are also sometimes known as CAT scans, which stands for computerised axial tomography.

During a CT scan, you'll usually lie on your back on a flat bed. The CT scanner consists of an X-ray tube that rotates around your body. You'll usually be moved continuously through this rotating beam.

The X-rays will be received by a detector on the opposite side of your body and an image of the scan will be produced by a computer.

Unlike an MRI scan, where you're placed inside a tunnel, you shouldn't feel claustrophobic.

The images produced by a CT scan are called tomograms and are more detailed than standard X-rays. A CT scan can produce images of structures inside the body, including the internal organs, blood vessels, bones and tumours. The scan is painless and will usually take between five and 10 minutes depending on the part of your body being scanned.

When CT Scans are Used

CT scans can be used to diagnose and monitor a variety of different health conditions, including brain tumours, certain bone conditions, and injuries to internal organs such as the kidneys, liver or spleen. They're also now being used to look at the heart.

They're also often used to look inside the body before another procedure takes place, such as radiotherapy treatment or a biopsy (where a small sample of tissue is taken so that it can be examined under a microscope).

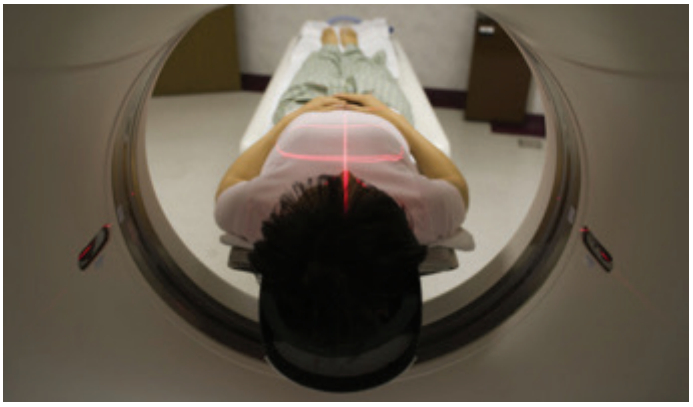


Figure 4.5. CT Scan Machine

The CT scanner is a large circular machine. You'll be asked to lie on your back on a motorized bed that can be moved in and out of the scanner. The radiographer will position the bed so that the part of your body being investigated is lined up with the scanner.

The radiographer will operate the scanner from an adjoining room. While the scan is taking place, you'll be able to hear and speak to them through an intercom. While each scan is being taken, you'll need to lie very still and breathe normally. This ensures that the scan images aren't blurred. You may be asked to breathe in, breathe out, or hold your breath at certain points.The X-ray unit inside the ring will rotate around you. Each time it goes round it creates a new X-ray scan. The bed will move forward slightly after each scan is completed.

4.4.3. MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging (MRI) is a type of scan that uses strong magnetic fields and radio waves to produce detailed images of the inside of the body. An MRI scanner is a large tube that contains powerful magnets. You lie inside the tube during the scan.

An MRI scan can be used to examine almost any part of the body, including the:

- Brain and spinal cord
- Bones and joints
- Breasts
- Heart and blood vessels
- Internal organs, such as the liver,
- Womb or prostate gland

The results of an MRI scan can be used to help diagnose conditions, plan treatments and assess how effective previous treatment has been.

What Happens During an MRI Scan?

During an MRI scan, you lie on a flatbed that is moved into the scanner. Depending on the part of your body being scanned, you will be moved into the scanner either head first or feet first.

The MRI scanner is operated by a radiographer, who is trained in carrying out X-rays and similar procedures. They control the scanner using a computer, which is in a different room to keep it away from the magnetic field generated by the scanner. You will be able to talk to the radiographer through an intercom and they will be able to see you on a television monitor throughout the scan.

At certain times during the scan, the scanner will make loud tapping noises. This is the electric current in the scanner coils being turned on and off. You will be given earplugs or headphones to wear. It is very important that you keep as still as possible during your MRI scan. The scan will last between 15 and 90 minutes, depending on the size of the area being scanned and how many images are taken.

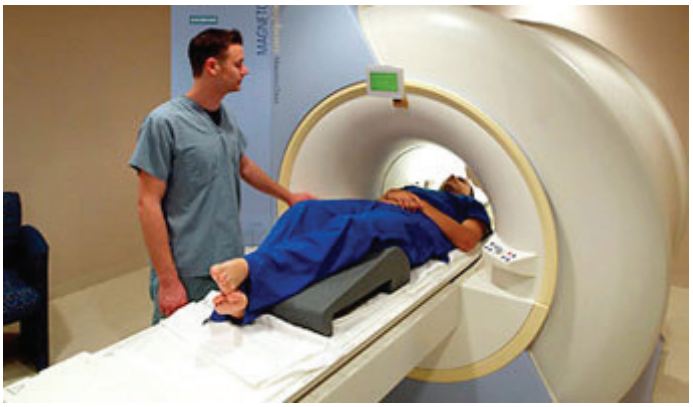


Figure 4.6. MRI scan machine

An MRI scanner is a short cylinder that is open at both ends. You will lie on a motorised bed that is moved inside the scanner. You will enter the scanner either head first or feet first, depending on the part of your body being scanned.In some cases, a frame may be placed over the body part being scanned, such as the head or chest. This frame contains receivers that pick up the signals sent out by your body during the scan and it can help to create a better quality image.

A computer is used to operate the MRI scanner, which is located in a different room to keep it away from the magnetic field generated by the scanner.

The radiographer operates the computer, so they will also be in a separate room to you. However, you will be able to talk to them, usually through an intercom, and they will be able to see you at all times on a television monitor.

The MRI scanner will make loud tapping noises at certain times during the procedure. This is the electric current in the scanner coils being turned on and off. You will be given earplugs or headphones to wear. You are usually able to listen to music through headphones during the scan if you want to, and in some cases you can bring your own CD of music you would like to listen to.

4.4.4. ULTRASOUND SCAN

An ultrasound scan, sometimes called a sonogram, is a procedure that uses high frequency sound waves to create an image of part of the inside of the body, such as the heart. As sound waves are used rather than radiation, the procedure is safe. Ultrasound scans are commonly used during pregnancy to produce images of the baby in the womb.

Ultrasound Scans Can Also be Used to

- Detect heart problems
- Examine other parts of the body such as the liver, kidneys and abdomen
- Help guide a surgeon performing some types of biopsy

Most ultrasound scans don't take long to perform, typically between 15 and 45 minutes. Your ultrasound scan will generally take place in an X-ray department in hospital and be performed either by a doctor, who will provide a diagnostic report, or by a sonographer.

A sonographer is a specialist trained in the use of ultrasound, who will provide a descriptive report for the doctor to make a diagnosis.

PREPARING FOR AN ULTRASOUND SCAN

Before having some types of ultrasound scan, you may be asked to follow certain instructions before the procedure, such as:

- **Drink water and not go to the toilet until after the test –** this is to fill your bladder and may be needed before a scan of your unborn baby or your pelvic area
- **Avoid eating for several hours before the scan –** this may be needed before a scan of your abdomen to lower the amount of air and gas in your stomach or bowel and enable your gallbladder to be better assessed

Depending on the area of your body being examined, the hospital may also ask you to remove some clothing and wear a hospital gown. You may choose to have a sedative, or it may be needed for some ultrasound procedures. If you have a sedative, you will need someone to take you home and stay with you for around 24 hours, until the effects wear off.

TYPES OF ULTRASOUND SCAN

There are different kinds of ultrasound scans depending on which part of the body is being scanned and why. The three main types are:

- External ultrasound
- Internal ultrasound
- Endoscopic ultrasound

UNIT V.
RECENT TRENDS IN MEDICAL INSRUMENTATION

5.1. THERMOGRAPHY

Thermograph, thermal imaging, or thermal video, is a type of infrared imaging. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 μm) and produce images of that radiation. Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermograph makes it possible to see one's environment with or without visible illumination.

The amount of radiation emitted by an object increases with temperature, therefore thermograph allows one to see variations in temperature (hence the name). When viewed by thermo graphic camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermograph's extensive use can historically be ascribed to the military and security services. Thermal imaging photography finds many other uses. For example, firefighters use it to see through smoke, find persons, and localize the base of a fire.

Figure 5.1. Thermogram of a cat

With thermal imaging, power lines maintenance technicians locate overheating joints and parts, a telltale sign of their failure, to eliminate potential hazards. Where thermal insulation becomes faulty, building construction technicians can see heat leaks to improve the efficiencies of cooling or heating air-conditioning.

Thermal imaging cameras are also installed in some luxury cars to aid the driver, the first being the 2000 Cadillac Deville. Some physiological activities, particularly responses, in human beings and other warm-blooded animals can also be monitored with thermo graphic imaging. The appearance and operation of a modern thermo graphic camera is often similar to a camcorder. Enabling the user to see in the infrared spectrum is a function so useful that ability to record their output is often optional. A recording module is therefore not always built-in. Instead of CCD sensors, most thermal imaging cameras use CMOS Focal Plane Array (FPA). The most common types are InSb, In GaAs, HgCdTe and QWIP FPA.

The newest technologies are using low cost and uncooled micro bolometers FPA sensors.

Their resolution is considerably lower than of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermos graphic cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often export restricted. Older bolometer or more sensitive models as require cryogenic cooling, usually by a miniature Stirling cycle refrigerator or liquid nitrogen.

Methods of Thermography

Infrared thermography

Liquid crystal thermography

Microwave thermography**.**

5.1.1. INFRARED THERMOGRAPHY

Infrared thermography is the science of acquisition and analysis of thermal information by using non-contact thermal imaging devices. Human skin emits infrared radiation as an exponential function of its absolute temperature and the emissive properties of the skin temperature. The maximum wavelength λmax = 10 μm and range from 4 to 40μm.The thermal picture is usually displayed on a TV tube may be photographed to provide a permanent record. Every thermo graphic equipment is provided with a special infrared camera that scales the object. The camera contains an optical system in the form of an oscillating plane mirror which scans the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiations onto chopper.

The chopper disc interrupts the infrared beam so that a.c signals are produced. Then they are given to detector. The detector is infrared radiation detector. The detected output by detector is amplified and led to phase sensitive. Infrared thermography (IRT), thermal imaging, and thermal video are examples of infrared imaging science. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers or 9–14 μm) and produce images of that radiation, called thermograms. Since infrared radiation is emitted by all objects above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted

by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography is particularly useful to the military and other users of surveillance cameras.

Every thermo graphic equipment is provided with a special infrared camera that scales the object. The camera contains an optical system in the form of an oscillating plane mirror which scans the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiations onto chopper. The chopper disc interrupts the infrared beam so that a.c signals are produced. Then they are given to detector. The detector is infrared radiation detector. The detected output by detector is amplified and led to phase sensitive.

Some physiological changes in human beings and other warm-blooded animals can also be monitored with thermal imaging during clinical diagnostics. Thermography is often used for breast screening, allergy detection, and in veterinary use. Government and airport personnel used thermography to detect suspected swine flu cases during the 2009 pandemic.

Figure 5.2. Thermal imaging camera and screen

Thermal imaging can detect elevated body temperature, one of the signs of the virus H1N1 (Swine influenza).

Thermography has a long history, although its use has increased dramatically with the commercial and industrial applications of the past fifty years. Firefighters use thermography to see through smoke, to find persons, and to localize the base of a fire. Maintenance technicians use thermography to locate overheating joints and sections of power lines, which are a sign of impending failure. Building construction technicians can see thermal signatures that indicate heat leaks in faulty thermal insulation and can use the results to improve the efficiency of heating and air-conditioning units.

Specialized thermal imaging cameras use focal plane arrays (FPAs) that respond to longer wavelengths (mid- and long-wavelength infrared). The most common types are InSb, InGaAs, HgCdTe and QWIP FPA. The newest technologies use low-cost, uncooled micro bolometers as FPA sensors. Their resolution is considerably lower than that of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermal imaging cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often export-restricted due to the military uses for this technology. Older bolometers or more sensitive models such as InSb require cryogenic cooling, usually by a miniature Stirling cycle refrigerator or liquid nitrogen.

Thermal images, or **thermograms** are actually visual displays of the amount of infrared energy emitted, transmitted, and reflected by an object. Because there are multiple sources of the infrared energy, it is difficult to get an accurate temperature of an object using this method. A thermal imaging camera is capable of performing algorithms to interpret that data and build an image. Although the image shows the viewer an approximation of the temperature at which the object is operating, the camera is actually using multiple sources of data based on the areas surrounding the object to determine that value rather than detecting the actual temperature

The appearance and operation of a modern thermographic camera is often similar to a camcorder. Often the live thermogram reveals

temperature variations so clearly that a photograph is not necessary for analysis. A recording module is therefore not always built-in.

Non-specialized CCD and CMOS sensors have most of their spectral sensitivity in the visible light wavelength range. However by utilizing the "trailing" area of their spectral sensitivity, namely the part of the infrared spectrum called *near-infrared* (NIR), and by using off-the-shelf CCTV camera it is possible under certain circumstances to obtain true thermal images of objects with temperatures at about 280 °C and higher. This phenomenon may become clearer upon consideration of the formula:

Incident Radiant Power = Emitted Radiant Power + Transmitted Radiant Power + Reflected

Radiant Power

Where: Incident Radiant Power is the radiant power profile when viewed through a thermal imaging camera.

Emitted Radiant Power is generally what is intended to be measured; **Transmitted,**

Radiant Power is the radiant power that passes through the subject from a remote thermal source, and; **Reflected Radiant Power** is the amount of radiant power that reflects off the surface of the object from a remote thermal source.

This phenomenon occurs everywhere, all the time. It is a process known as Radiant Heat Exchange, since Radiant Power x Time equals Radiant Energy. However, in the case of Infrared Thermography, the above equation is used to describe the radiant power within the spectral wavelength passband of the thermal imaging camera in use. The Radiant Heat exchange requirements described in the equation apply equally at every wavelength in the Electromagnetic Spectrum.

If the object is radiating at a higher temperature than its surroundings, then power transfer will be taking place and power will be radiating from warm to cold following the principle stated in the Second Law of Thermodynamics. So if there is a cool area in the thermogram, that object will be absorbing the radiation emitted by the warm object.

The ability of objects to emit is called *emissivity*, to absorb radiation is called *absorptivity*. Under outdoor environments, convective cooling from wind may also need to be considered when trying to get an accurate temperature reading.

5.1.2. LIQUID CRYSTAL THERMOGRAPHY

Liquid crystals are a class of compounds which exhibit colour temperature sensitivity in the cholestric phase. Scattering effects with the material give rise to iridescent colours, the 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 flim support into which encapsulated liquid crystals cemented to a pseudo solid powder (with particle sizes between 10 to 30) have been incorporated.

Thermal contact between the skin surface and plate produces a color change in the encapsulated liquid crystals; red for relatively low temperatures through the visual spectrum to violet for high temperatures. But in infrared thermograms, the violet colour is used to identify the low temperature regions and the bright colour or red is used to identify the temperature regions. If we want to study a breast's temperature distribution, several different plates are necessary to cover a breast temperature range from 280C to360C. Each plate covers a range of temperature 30C. A record of the liquid crystal image may be obtained by colour photography. The response time varies according to the thickness of plate (ranges from 0.06mm to 0.3 mm) and is 20 to 40 seconds.

5.1.3. MICROWAVE THERMOGRAPHY

Even though we get microwave emissions from the skin surface, that intensity is very small when we compare with Infra-red radiation intensity. (10 wavelength emission intensity is 108 times greater than 10 cm wavelength emission intensity). But using modern microwave radiometers one can detect temperature change of 0.1K. Since body tissues are partially transparent to microwave radiations which orginates from a tissue volume extending from the skin surface to a depth of several centimeters. Microwave radiometers consisting of matched antennae

placed in contact with the skin surface for use at 1.3 G Hz and 3.3 G Hz have been used to sense subcutaneous temperature.

The present day thermographic systems, using Infrared radiation, only give a temperature map of the skin due to low penetration depth of the short wavelength of the infrared component of the emitted radiation. Using a microwave receiver with a frequency response from 1.7 GHz to 2.5 GHz a penetration depth of 1 cm in tissue and 8 cm in fat and bone can be obtained. A severe problem is the unknown emissivity of the body surface for microwaves, as part of the radiation is reflected back into the body. In a conventional radiometer this gives rise to a measurement error proportional to the temperature difference between the body surface and the applied antenna. This error lies in the order of 1-2 K which is too high for medical applications. The problem has been solved iv an elegant way by adding artificial microwave noise from the antenna, thus providing a radiation balance between the receiver and body surface. With this a temperature sensitivity of 0.1 K could be obtained. Based on the transducer attachment on the skin surface, we can classify the thermography into contact thermography and telethermograph.

Advantages of Thermography

Get a visual picture so that you can compare temperatures over a large area It is real time capable of catching moving targets Able to find deteriorating components prior to failure Measurement in areas inaccessible or hazardous for other methods It is a non-destructive test method.

Limitations & Disadvantages of Thermography

Quality cameras are expensive and are easily damaged Images can be hard to interpret accurately even with experience Accurate temperature measurements are very hard to make because of emissivity's Most cameras have ±2% or worse accuracy (not as accurate as contact) Training and staying proficient in IR scanning is time consuming Ability to only measure surface areas.

APPLICATIONS

- Condition monitoring
- Low Slope and Flat Roofing Inspections

- Building diagnostics including building envelope inspections, moisture inspections, and energy losses in buildings[15]
- Thermal Mapping
- Digital infrared thermal imaging in health care
- Medical imaging
- Breast thermography: tele-thermography (medical), contact thermography and dynamic angiothermography
- Peripheral vascular disease screening.
- Neuromusculoskeletal disorders.
- Extracranial cerebral and facial vascular disease.
- Thyroid gland abnormalities.
- Various other neoplastic, metabolic, and inflammatory conditions.
- Archaeological Kite Aerial Thermography
- Thermology
- Veterinary Thermal Imaging
- Night vision
- UAV Surveillance
- Stereo vision
- Research
- Process control
- Nondestructive testing
- Surveillance in security, law enforcement and defence
- Chemical imaging
- Volcanology
- Building

5.2. ENDOSCOPY UNIT

The first endoscope was developed in 1806 by Philipp Bozzini in Mainz with his introduction of a "Lichtleiter" (light conductor) "for the examinations of the canals and cavities of the human body".[5] However, the Vienna Medical Society disapproved of such curiosity. The use of

electric light was a major step in the improvement of endoscopy. The first such lights were external although sufficiently capable of illumination to allow cystoscopy, hysteroscopy and sigmoidoscopy as well as examination of the nasal (and later thoracic) cavities as was being performed routinely in human patients by Sir Francis Cruise (using his own commercially available endoscope) by 1865 in the Mater Misericordiae Hospital in Dublin, Ireland Later, smaller bulbs became available making internal light possible, for instance in a hysteroscope by Charles David in 1908.

Endoscopy is a nonsurgical procedure used to examine a person's digestive tract. Using an endoscope, a flexible tube with a light and camera attached to it, your doctor can view pictures of your digestive tract on a color TV monitor.

During an upper endoscopy, an endoscope is easily passed through the mouth and throat and into the esophagus allowing the doctor to view the esophagus, stomach, and upper part of the small intestine.

Similarly, endoscopes can be passed into the large intestine (colon) through the rectum to examine this area of the intestine. This procedure is called sigmoidoscopy or colonoscopy depending on how far up the colon is examined.

A special form of endoscopy called endoscopic retrograde cholangiopancreaticography, or ERCP, allows pictures of the pancreas, gallbladder, and related structures to be taken.Endoscopic ultrasound or EUS combines upper endoscopy and ultrasound examination to obtain images and information about various parts of the digestive tract.

Doctors Will Often Recommend Endoscopy to Evaluate

- Stomach pain
- Ulcers, gastritis, or difficulty swallowing
- Digestive tract bleeding
- Changes in bowel habits (chronic constipation or diarrhea)
- Polyps or growths in the colon

In addition, your doctor may use an endoscope to take a biopsy (removal of tissue) to look for the presence of disease. Endoscopy may also be used to treat a digestive tract problem. For example, the endoscope

might not only detect active bleeding from an ulcer, but devices can be passed through the endoscope that can stop the bleeding. In the colon, polyps can be removed through the scope to prevent the development of colon cancer. Also, using ERCP, gallstones that have passed outside the gallbladder and into the bile duct can be removed.

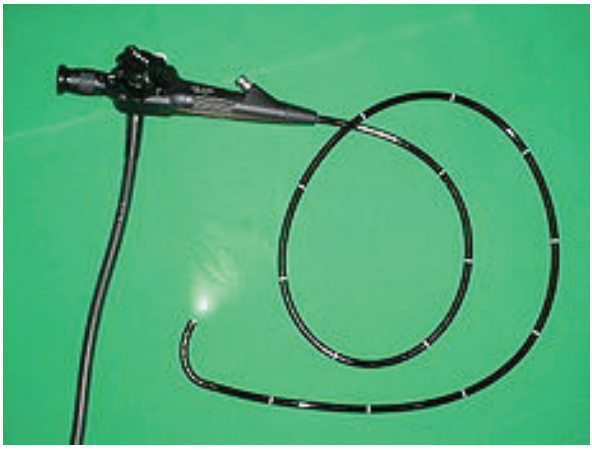


Figure 5.3. An example of a flexible endoscope

Endoscopy means *looking inside* and typically refers to looking inside the body for medical reasons using an **endoscope**, an instrument used to examine the interior of a hollow organ or cavity of the body. Unlike most other medical imaging devices, endoscopes are inserted directly into the organ. There are many different types of endoscope, and depending on the site in the body and the type of procedure, endoscopy may be performed by a doctor or a surgeon, and the patient may be fully conscious or under general anaesthetic. Endoscope can also refer to using a borescope in technical situations where direct line of-sight observation is not feasible.

Components

An endoscope can consist of:

- a rigid or flexible tube.
- 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 fiber optics in the case of a fiberscope.
- an eyepiece. Modern instruments may be video scopes, with no eyepiece, a camera transmits image to a screen for image capture.
- an additional channel to allow entry of medical instruments or manipulators.

The procedure requires sedation, which includes its own risks, including permanent cognitive impairments.

5.2.1. APPLICATIONS

Health care providers can use endoscopy to review any of the following body parts:

- The gastro intestinal tract (GI tract):
  - oesophagus, stomach and duodenum (esophagogastroduodenoscopy)
  - small intestine (enteroscopy)
  - large intestine/colon (colonoscopy, sigmoidoscopy)
  - Magnification endoscopy bile duct endoscopic retrograde cholangi opan creatography (ERCP), duo denoscope-assisted cholangi opan creatoscopy, intraoperative cholangioscopy
  - rectum (rectoscopy) and anus (anoscopy), both also referred to as (proctoscopy)
- The respiratory tract
  - The nose (rhinoscopy)
  - The lower respiratory tract (bronchoscopy)
- The ear (otoscope)
- The urinary tract (cystoscopy)
- The female reproductive system (gynoscopy)
  - The cervix (colposcopy)
  - The uterus (hysteroscopy)
  - The fallopian tubes (falloposcopy)
- Normally closed body cavities (through a small incision):

- The abdominal or pelvic cavity (laparoscopy)
- The interior of a joint (arthroscopy)
- Organs of the chest (thoracoscopy and mediastinoscopy)

Endoscopy is used for many procedures:

- During pregnancy
  - The amnion (amnioscopy)
  - The fetus (fetoscopy),
- Plastic surgery,
- Panendoscopy (or triple endoscopy)
  - Combines laryngoscopy, esophagoscopy, and bronchoscopy
- Orthopedic surgery
  - Hand surgery, such as endoscopic carpal tunnel release
  - Knee surgery, such as anterior cruciate ligament reconstruction
  - Epidural space (Epiduroscopy)
  - Bursae (Bursectomy),
- Endodontic surgery
  - Maxillary sinus surgery
  - Apicoectomy,
- Endoscopic endonasal surgery
- Non-medical uses for endoscopy
- The planning and architectural community have found the endoscope useful for previsualization of scale models of proposed buildings and cities (architectural endoscopy)

An Endoscopy is a simple procedure which allows a doctor to look inside human bodies using an instrument called an endoscope. A cutting tool can be attached to the end of the endoscope, and the apparatus can then be used to perform surgery. This type of surgery is called Key hole surgery, and usually leaves only a tiny scar externally.

Risks

Infection and Over-Sedation

The main risks are perforation, or a tear, of the stomach or esophagus lining and bleeding. Although perforation generally requires surgery, certain cases may be treated with antibiotics and intravenous fluids. Bleeding may occur at the site of a biopsy or polyp removal. Such typically minor bleeding may simply stop on its own or be controlled by cauterization. Seldom does surgery become necessary. Perforation and bleeding are rare during gastroscopy.

Other minor risks include drug reactions and complications related to other diseases the patient may have. Consequently, patients should inform their doctor of all allergic tendencies and medical problems.

Occasionally, the site of the sedative injection may become inflamed and tender for a short time. This is usually not serious and warm compresses for a few days are usually helpful.While any of these complications may possibly occur, it is good to remember that each of them occurs quite infrequently.

5.2.2. Recent Developments

With the application of robotic systems, tele surgery was introduced as the surgeon could be at a site far removed from the patient. The first transatlantic surgery has been called the Lindbergh Operation.

Wireless esophageal pH measuring devices can now be placed endoscopically, to record pH trends in an area remotely.

Disposable Endoscopy

Disposable endoscopy is an emerging category of endoscopic instruments. Recent developments[11] have allowed the manufacture of endoscopes inexpensive enough to be used on a single patient only. It is meeting a growing demand to lessen the risk of cross contamination and hospital acquired diseases. A European consortium of SME are working on the DUET project to build a disposable endoscope.[12]

Capsule Endoscopy

Main article: Capsule endoscopy A new endoscopy technology uses a Magnetically Guided Capsule Endoscope (MGCE) for wireless control, monitor and imaging.[13]

Augmented Reality

The endoscopic image can be combined with other image sources to provide the surgeon with additional information. For instance, the position of an anatomical structure or tumor might be shown in the endoscopic video.[14]

Measuring Endoscopy

Current research works on the endoscopic collection of dimensional 3D-data, such as using laser triangulation or the approach of structured light projection. Depending on the optics used, technical inner geometries can be measured with accuracies in the low µm-area.

5.3. LASERS IN MEDICINE

LASERS (Light Amplification by Stimulated Emission of Radiation)

Laser therapies are medical treatments that use focused light. Laser light is a very special kind of light. Unlike most light sources, it is tuned to very specific wavelengths. This allows it to be focused into powerful beams. Laser light is so intense it can be used to shape diamonds or cut steel.

In medicine, lasers offer surgeons the ability to work very precisely. They can focus on a small area and damage less of the surrounding tissue. Patients who have laser therapy may experience less pain, swelling, and scarring than with traditional surgery. However, laser therapy is expensive. It may also require repeated treatments.

Laser therapy is used in many procedures. It may be used to

- Shrink or destroy tumors, polyps, or precancerous growths
- Relieve symptoms of cancer
- Remove kidney stones
- Remove part of the prostate

- Repair a detached retina
- Improve vision ("laser eye surgery").

Lasers Can Have a Cauterizing (Sealing) Effect. They May be Used to Seal

- Nerve endings, to reduce pain after surgery
- Blood vessels, to help prevent blood loss
- Lymph vessels, to reduce swelling and limit spread of tumor cells.

According to the National Cancer Institute (NCI), lasers may be useful in treating the very early stages of cancers such as:

- Cervical cancer
- Penile cancer
- Vaginal cancer
- Vulvar cancer
- Non-small cell lung cancer
- Basal cell skin cancer

When used in cancer treatment, laser therapy is usually used alongside other treatments such as surgery, chemotherapy, or radiation.

Laser Therapy is Also Used Cosmetically

It can

- Remove warts, moles, birthmarks, and sun spots
- Remove hair
- Ressen the appearance of wrinkles, blemishes or scars
- Remove tattoos

Different Lasers are Used for Different Procedures

- **Carbon dioxide (CO2)** lasers make shallow cuts. They are often used for superficial cancers, such as skin cancer.
- **Argon lasers** also make shallow cuts. They can be used to activate **photosensitizing** (light activated) drugs during **Photodynamic**

therapy (PDT). This type of cancer treatment combines light with chemotherapy to kill more cancer cells.

- **Nd: YAG** lasers can travel along optical fibers. They are used in **Laser-induced interstitial thermotherapy (LITT),** a type of cancer treatment.

5.3.1. BENEFITS OF LASER THERAPY

There are many potential benefits of receiving laser therapy

- Lasers are more precise than traditional surgical instruments. Cuts can be made shorter and shallower. This causes less damage to tissue.
- Operations are generally shorter than traditional surgeries. They can often be done on an outpatient basis. Patients don't have to spend the night in the hospital. If **general anesthesia** is required, it is usually used for a shorter time..
- Patients usually heal faster. They may have less pain, swelling, and scarring than with traditional surgeries.

Lasers Used in Medicine Include in Principle any Type or Laser Design, but Especially

- CO_2 lasers, used to vaporize tissue
- Diode lasers
- Dye lasers
- Excimer lasers
- Fiber lasers
- Gas lasers
- Free electron lasers
- Semiconductor diode lasers

5.3.2. CARBON DIOXIDE LASER

A test target is vaporized and bursts into flame upon irradiation by a high power continuous wave carbon dioxide laser emitting tens of kilowatts of infrared light.

The **carbon dioxide laser** (**CO_2 laser**) was one of the earliest gas lasers to be developed (invented by Kumar Patel of Bell Labs in 1964[1]), and is still one of the most useful. Carbon dioxide lasers are the highest-power continuous wave lasers that are currently available. They are also quite efficient: the ratio of output power to pump power can be as large as 20%. The CO_2 laser produces a beam of infrared light with the principal wavelength bands centering around 9.4 and 10.6 micrometers.

The population inversion in the laser is achieved by the following sequence:

1. Electron impact excites vibrational motion of the nitrogen. Because nitrogen is a homonuclear molecule, it cannot lose this energy by photon emission, and its excited vibrational levels are therefore metastable and live for a long time.

2. Collisional energy transfer between the nitrogen and the carbon dioxide molecule causes vibrational excitation of the carbon dioxide, with sufficient efficiency to lead to the desired population inversion necessary for laser operation.

3. The nitrogen molecules are left in a lower excited state. Their transition to ground state takes place by collision with cold helium atoms.

The resulting hot helium atoms must be cooled in order to sustain the ability to produce a population inversion in the carbon dioxide molecules. In sealed lasers, this takes place as the helium atoms strike the walls of the container. In flow-through lasers, a continuous stream of CO_2 and nitrogen is excited by the plasma discharge and the hot gas mixture is exhausted from the resonator by pumps.

A **laser diode**, or **LD**, is an electrically pumped semiconductor laser in which the active laser medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode.

A laser diode is electrically a P-i-n diode. The active region of the laser diode is in the intrinsic (I) region, and the carriers, electrons and holes, are pumped into it from the N and P regions respectively. While initial diode laser research was conducted on simple P-N diodes, all modern lasers use the double-heterostructure implementation, where

the carriers and the photons are confined in order to maximize their chances for recombination and light generation. Unlike a regular diode used in electronics, the goal for a laser diode is that all carriers recombine in the I region, and produce light. Thus, laser diodes are fabricated using direct bandgap semiconductors. The laser diode epitaxial structure is grown using one of the crystal growth techniques, usually starting from an N doped substrate, and growing the I doped active layer, followed by the P doped cladding, and a contact layer. The active layer most often consists of quantum wells, which provide lower threshold current and higher efficiency.[1]

Laser diodes form a subset of the larger classification of semiconductor *p*-*n* junction diodes. Forward electrical bias across the laser diode causes the two species of charge carrier – holes and electrons – to be "injected" from opposite sides of the *p*-*n* junction into the depletion region. Holes are injected from the *p*-doped, and electrons from the *n*-doped, semiconductor. (A depletion region, devoid of any charge carriers, forms as a result of the difference in electrical potential between *n*- and *p*-type semiconductors wherever they are in physical contact.) Due to the use of charge injection in powering most diode lasers, this class of lasers is sometimes termed "injection lasers," or "injection laser diode" (ILD). As diode lasers are semiconductor devices, they may also be classified as semiconductor lasers. Either designation distinguishes diode lasers from solid-state lasers.

5.4. DIATHERMY UNITS

Diathermy is used in physical therapy to deliver moderate heat directly to pathologic lesions in the deeper tissues of the body. Surgically, the extreme heat that can be produced by diathermy may be used to destroy neoplasms, warts, and infected tissues, and to cauterize blood vessels to prevent excessive bleeding. The technique is particularly valuable in neurosurgery and surgery of the eye. The three forms of diathermy employed by physical therapists are short wave, ultrasound, and microwave. The application of moderate heat by diathermy increases blood flow and speeds up metabolism and the rate of ion diffusion across cellular membranes. The fibrous tissues in tendons, joint capsules, and scars are more easily stretched when subjected to heat, thus facilitating

the relief of stiffness of joints and promoting relaxation of the muscles and decrease of muscle spasms.

Diathermy is the treatment process by which cutting, coagulation of tissues are obtained.

- Application of high-frequency electromagnetic energy
- Used to generate heat in body tissues
- Heat produced by resistance of tissues
- Also used for non-thermal effects

Advantages

- Treatment can be controlled easily.
- Use of appropriate electrodes permit the heat to be localized only in the region to be treated.
- Amount of heat that is to be delivered can be adjusted accurately.
- Inter lying tissues, muscles, bones, internal organs, etc, can be provided with heat by using high frequency.

Basis of Diathermy

1. Electrical current converted to thermal energy
2. Amount of heat is proportional to volume of tissue traversed by current (need for broad contact with diathermy pad).

Types of Diarthermy

1. Monopolar

Circuit: plate, cable, patient

Cut (most effective when electrode placed a small distance away from tissue): continous current discharges across air gap, high temperature sparks generated, cause's cellular water to explode

Coagulate: intermittent current released: tissue damage occurs by "fulguration", intermittent bursts of energy generated smaller effects

2. Bipolar

Current transferred between two electrodes (tips)

Safer but only able to coagulate

Physiologic Effects Are Those of Heat In General

- Tissue temperature increase
- Increased blood flow (vasodilation)
- Increased venous and lymphatic flow
- Increased metabolism
- Changes in physical properties of tissues
- Muscle relaxation
- Analgesia.

Types of Diathermy

- Shortwave diathermy
- Ultrasonic diathermy
- Microwave diathermy
- Surgical diathermy.

5.4.1. SHORTWAVE DIATHERMY

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

The frequency allowed for short wave diathermy operations is under the control of the Federal Communications Commission. The frequencies assigned for short wave diathermy operations are 13.66, 27.33, and 40.98 megahertz. Most commercial machines operate at a frequency of 27.33 megahertz and a wavelength of 11 meters. Short wave diathermy usually is prescribed for treatment of deep muscles and joints that are covered with a heavy soft-tissue mass, for example, the hip. In some instances short wave diathermy may be applied to localize deep inflammatory processes, as in pelvic inflammatory disease.

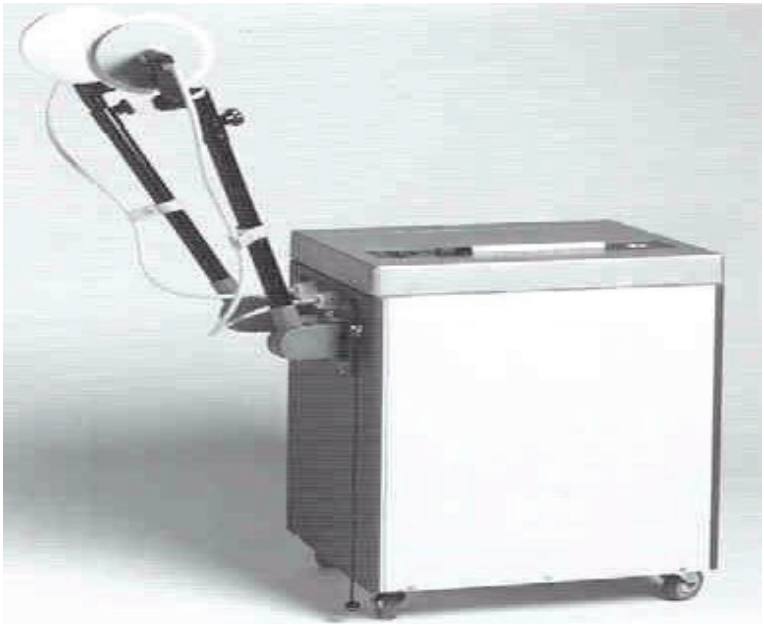


Figure 5.4. Short wave diathermy unit

SWD Electrodes

- Capacitor electrodes
- Inductor electrodes
- Selection of appropriate electrodes can influence the treatment.

5.4.2. ULTRASONIC DIATHERMY

Ultrasound diathermy employs high-frequency acoustic vibrations which, when propelled through the tissues, are converted into heat. This type of diathermy is especially useful in the delivery of heat to selected musculatures and structures because there is a difference in the sensitivity of various fibers to the acoustic vibrations; some are more absorptive and some are more reflective. For example, in subcutaneous fat, relatively little energy is converted into heat, but in muscle tissues there is a much higher rate of conversion to heat.

The therapeutic ultrasound apparatus generates a high-frequency alternating current, which is then converted into acoustic vibrations. The

apparatus is moved slowly across the surface of the part being treated. Ultrasound is a very effective agent for the application of heat, but it should be used only by a therapist who is fully aware of its potential hazards and the contraindications for its use. It is used for curing the diseases of peripheral nervous system, skeletal muscle system and skin ulcers.

- It is adopted when the short wave treatment has failed and it helps to achieve the localization of heart to the affected part.
- The heating effect is produced in the tissues by the absorption of ultrasonic energy. The absorption effect is similar to that of a micro massage.
- It is better than the manual massage because the micro massage provides a greater depth of massage without causing any pain to the patient.
- Piezo-electric transducer is excited by the high frequency alternating current produced by the Rf oscillator.
- Ultrasonic wave from the piezo electric transducer is used for the purpose of treatment.
- It can be applied in continuous mode or pulse mode.
- Frequency range of 800 KHz to 1MHz is suitable for the ultrasonic method of treatment.

5.4.3. MICROWAVE DIATHERMY

Microwave diathermy uses radar waves, which are of higher frequency and shorter wavelength than radio waves. Most, if not all, of the therapeutic effects of microwave therapy are related to the conversion of energy into heat and its distribution throughout the body tissues. This mode of diathermy is considered to be the easiest to use, but the microwaves have a relatively poor depth of penetration.

Microwaves cannot be used in high dosage on edematous tissue, over wet dressings, or near metallic implants in the body because of the danger of local burns. Microwaves and short waves cannot be used on or near persons with implanted electronic cardiac pacemakers.

In this method the tissues are heated by the absorption of microwave energy. The frequency used is about 2450 MHz.

- Better results are obtained by the microwave method and it is more advantageous than the short wave method.
- There is no pad electrodes and flexible cable.
- Microwave is transmitted into body and treat directly from the direction of unit.
- Microwaves are produced with the help of magnetron
- Proper cooling arrangements are made for the purpose of cooling the magnetron

Precautions

- Necessary precautions should be taken during this method of treatment
- Excessive dosage causes skin burns and the skin should be dry as the waves are rapidly absorbed by water.

5.4.4. SURGICAL DIATHERMY

High frequency currents apart from their usefulness for therapeutic applications can also be used in the operating rooms for surgical purposes involving cutting and coagulation. The frequency of currents used in surgical diathermy units is in the range of 1-3MHz in contrast with much higher frequencies employed in shortwave therapeutic diathermy machines. The evolving steam bubbles in the tissues at the cutting action is obtained. Similarly during the passage of the high frequency current through the tissue, the tissue is heated locally. so that the tissue is melted instantaneously and sealing of the capillary and other blood vessels is taking place. Then the coagulation of the tissues takes place. The use of high frequency current is to avoid the intense muscle activity and the electrocution hazard occurs if low frequencies are used.

Surgical diathermy machines depend for their action, the heating effect of electric current. When high frequency current flows through the sharp edge of a wire loop or point of a needle into the tissue. There is a high contraction of current at this point. The tissue is heated to such an extent that cells immediately under the electrode are torn apart by the boiling of the cell fluid. The indifferent electrode establishes a large area contact with the patient and the RF current is therefore dispersed so that

very little cheat is developed at this electrode. This type of tissue separation forms the basis of electrosurgical cutting. These parameters are of great value in micro surgery since localization of electrosurgical effects would also be accompanied by Coagulation and homeostasis.

Coagulation

Electrosurgical coagulation of the tissue is caused by the high frequency current flowing through the tissue and heating it locally so that it coagulates from inside. The coagulation process is accompanied by a grayish-white discoloration of the tissue that the edge of the electrode. In contrast to a thermocautery, better coagulation can be achieved by high frequency currents because it does not cause superficial burning.

Fulguration

The term fulguration refers to a superficial tissue destruction without affecting deep-seated tissues. This is obtained by passing sparks from the needle or ball electrode of small diameter to the tissue. When electrode is held near the tissue without toughing it, spark is produced. This spark is capable of burning the unwanted portions.

Desiccation

The needle point electrodes are stack into the tissue and kept steadily while passing electric current. This creates a high local increase in heat and drying of tissues is taking place. This is called desiccation.

Blending

When the electrode is kept above the skin, an electrical arc is sent. The developed heat produces wedge shaped narrow cutting of the tissue on the surface. By increasing the current level, deeper level cutting of the tissues takes place. Normally continuous RF current is used for cutting.

Hemostasis

The concurrent use of continuous RF current for cutting and a RF wave burst for coagulation is called Hemostasis mode.

5.5. ELECTRICAL SAFETY IN MEDICAL EQUIPMENT

Electrical safety is a very important element in hospital safety. Electric shock is a traumatic state caused by the passage of electric current can flow through the human body either accidentally or intentionally. The kind and amount of damage depends on the intensity, type and duration of the current, the point where the electricity first touched the body and the path it took through the body. Burns may be superficial or very deep with widespread tissue death. Severe shock may cause muscle contractions, respiratory paralysis, unconsciousness and cardiac arrest. A high voltage electric shock may cause sudden muscle spasm that may through the victim away from the power source with extreme force, resulting in further injuries, such as fracture. Lightening causes injuries similar to those sustained from a high voltage electric shock.

Electrical currents are administered intentionally in the following case.

1. For measurement of respiration rate by impedance method, a small current at high frequency is made to flow between the electrodes applied on the surface of the body.
2. High currents are also passed through the body for therapeutic and surgical purposes.
3. When recording signals like ECG, and EEG, the amplifiers used in the preamplifier stage may deliver small currents themselves to the patient. These are due to bias currents.
4. Accidental transmission of electrical current takes place because of defect in the equipment; excessive leakage and simultaneous use of other equipment on the patient which may produce potentials on the patient circuit.

5.5.1. Electric Shock Hazards

It is a common experience that the hazards due to electric shock are also associated with The electrical safety of the Medical equipment in hospital is the most important of it. Equipment other than that used in hospitals. However, the equipment's used in medical practice have to operate in special environments. Which differ I certain respects from others. Some such special situations are as follows:

A patient may not be usually able to react in the normal way. He/she is either ill, unconscious anaesthetized or strapped on the operating table. He/she may not be able to withdraw him/herself from the electrified object, when feeling tingling in his/her skin, before any danger of electrocution occurs.

The patient or the operator may not realize that a potential hazard exists. This is because potential differences are small and high frequency and ionizing radiations are not directly indicated.

Considerable neutral protection and barrier to electric current is provided by human skin. In certain applications of electro medical equipment, the natural resistance of the skin may be passed. Such situations arise when the tests are carried out on the subject with a catheter in his/her heart or an large blood vessels.

Electro medical equipment, example: pacemakers may be used either temporarily or permanently to support or replace functions of some organs of the human body. The interruption in the power supply or failure of the permanent injuries or even prove fatal for the patient.

Medical instruments are quite often used in conjunction with several other instruments and equipment. These combinations of high power equipment and extremely sensitive low signal equipment. Each of these devices may be safe in itself, but can become dangerous when used in conjunction with others.

Environmental conditions in the hospitals particularly in the operating theatres cause explosion or fire hazards due to the presence of anesthetic agents, humidity and cleaning agents.

5.5.2. Two Kinds of Grounding / Earthing

Grounding of Electrical Systems

Connecting N-line of the service side to earth due to technical reason and for protection of systems and plants (removing the floating high voltage in the secondary (service) side of the distribution transformer).

Protective Grounding

Connecting conducting parts, which are not intended for carrying current in normal circumstances (enclosures; switch-, fuse-, outlet- met-

al boxes; etc.) via 3rd conductor (which, in normal situations, does not carry current) to earth.

Leakage Current & Fault Current

Due to the relatively low values of the stray capacitances and frequency, the resulting el. Pathway is very high resistive, and hence, the resulting leakage currents are very low. Distinguishing between leakage and fault current depends on the internal resistance of the source in relation to the load in a given circuit.

MACRO-SHOCK

External or touch - current shock (voltage applied externally, current pass through the skin in and out

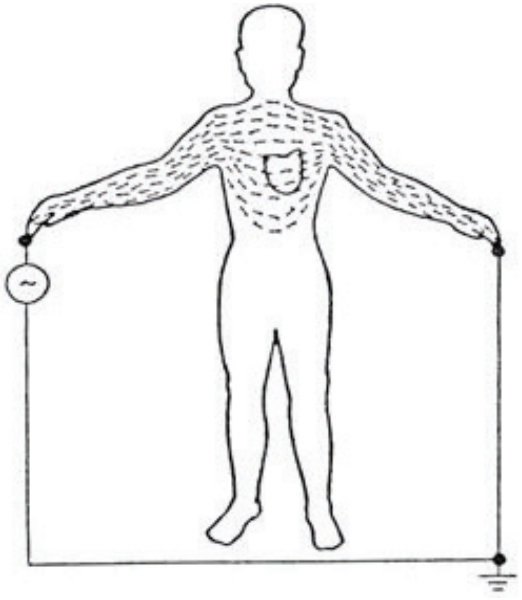


Figure 5.5. Macro shock

MICRO-SHOCK

Current affect heart directly (through pacemaker leads or catheter) Currents less than (100) micro-Ampere have the potential to cause VF (it is possible from (25) micro-Ampere up).

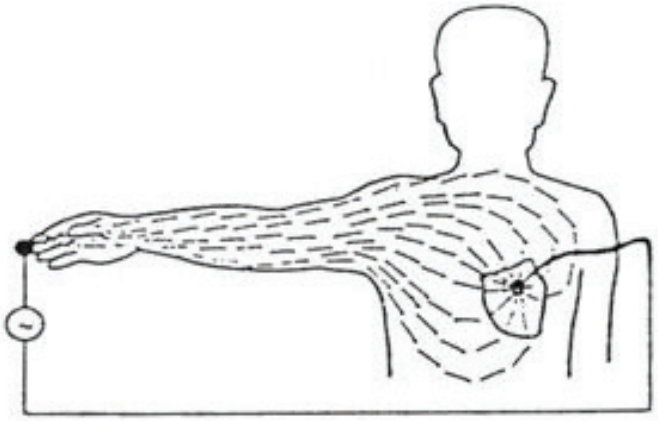


Figure 5.6. Micro shock

Methods of Protection Against El. Shock

- Over-current protection (indirect protection).
- Protective earthing (grounding).
- Double insulation.
- Low voltage power supply.
- Differential circuit breaker (Ground Fault Circuit Interrupter GFCI) .
- Isolated power system (IPS).

Protective Earthing

Simple, efficient, and inexpensive, but it is not "fail-safe" (i.e. if it fails, equipment does not go in a safe mode (alarm, power interruption for example)).

Double Insulation

All surfaces which can be contacted are made of non- conductive materials, or all voltage carrying parts are double insulated. Equipment protected this way are referred to as class II, and need not to be earthed.

Low Voltage Supply

- Referred to as class III.

- Supply voltage less than 50 Volt.
- Equipment need not to be earthed.
- For wet areas: voltage less than 25 Volt.
- If skin immersed in water: voltage less than 12 Volt.
- If supply is via transformer, then primary and secondary must be galvanically separated.

Differential Circuit Breaker &GFCI

If difference between currents in "hot" and neutral wires is more than 6 mA, the circuit breaker is activated within 5 ms.

Isolated Power System (IPS) & Isolation Transformer

Isolation transformer is used to omit the ground connection so that the el. System on service side is no more "ground seeking IPS & Line Isolation Monitor (LIM).

- IPS are not 100% isolated. It has certain "resistance" to earth (caused by stray capacitances).
- LIM measure this resistance. The monitored value in LIM represent a virtual current which would flow if a short-circuit occurred between a power carrying line and earth (prognostic value, worst case condition).
- LIM gives audio-visual alarm if the a.m. prognostic value exceeds 5 mA (USA standard).
- The 5 mA could be annoying, but it is normally not dangerous.
- Grounding of the equipment is independent of the power system (isolated or not).

IPS Applications

- IPS is a protection against macro-shock. It is not (and has never been) a protection against micro-shock (even if it makes the related safety level higher).
- IPS is necessary for operation theatres (OT), but is not necessary (and not required) for ICU.

5.5.3. Rules for Med. Equipment Electrical Safety

- Equipment connected to a patient to be powered from one socket, or a block of sockets having the same protective grounding point.
- All metal subjects in the vicinity of the patient to be grounded one at a time with the same protective ground point.
- Patient to be connected to the common ground through only one grounding pole.
- Isolation amplifiers to be used for measurements if possible.
- If possible, avoid using material which can be charged electro-statically.
- Deal carefully with electric wires and sockets and let it be checked periodically. Do not use extension cables. Do not use faulty cables / plugs and ask for replacement.
- If an equipment has a failure, which can cause electric shock, it has to be taken out of service immediately. Reversing the plug (this "advice" is heard often) , which might lead to eliminate the shock, is a wrong action / behavior.
- If, by touching the metallic surface of an equipment, you sensed an electric prickle (even a light one), then plug off the equipment immediately and ask for check. This equipment is either badly earthed or not earthed at all.
- Do not use any medical equipment you do not know the basics of its operation and did not read its instruction manual carefully.

REFERENCES

1. Ader. C., (1897). "Sur un nouvel appareil enregistreur pour cables sousmarins", *Compt. rend. Acad. Sci. (Paris)* 124: 1440-2.
2. Durrer. D., Van. Dam. RT., Freud. G.E., Janse. M.J., Meijler. F.L., Arzbaecher. R.C., (1970): "Total excitation of the isolated human heart". *Circulation* 41:(6) 899-912.
3. Einthoven. W., (1908): "Weiteres ber das Elektrokardiogram". *Pflger Arch. ges. Physiol.* 122: 517-48.
4. Einthoven .W., Fahr. G., De. Waart. AÇ, (1913): "Ber Die Richtung Und Die Manifeste Grsse Der Potential Schwankungen Im Mennschlichen Herzen Und Ber Den Einfluss Der Herzlage Auf Die Form Des Elektro Kardio Gramms". *Pflger Arch. ges. Physiol.* 150: 275-315.
5. Einthoven. W., Fahr. G., De Waart. A., (1950): "On the Direction and Manifest Size of the Variations Of Potential In The Human Heart and On The Influence Of the Position Of The Heart On The Form Of the Electrocardiogram". *Am. Heart J.* 40:(2) 163-211. (Reprint 1913, translated by HE Hoff, P Sekelj).
6. Geselowitz. D.B., (1964): "Dipole Theory In Electrocardiography". *Am. J. Cardiol.*14:(9) 301-6.
7. Goldberger. E., (1942a): "The aVL, aVR, and aVF leads; A simplification of standard lead electrocardiography". *Am. Heart J.* 24: 378-96.
8. Goldberger. E., (1942b): "A simple indifferent electrocardiographic electrode of zero potential and a technique of obtaining augmented, unipolar extremity leads". *Am. Heart J.* 23: 483-92.
9. Mason. R., Likar. L., (1966): "A New System Of Multiple Leads Exercise Electrocardiography". *Am. Heart J.* 71:(2) 196-205.
10. Netter. F.H., (1971): "The Ciba Collection of Medical Illustrations", Ciba Pharmaceutical Company, Summit, N.J. *Heart,* Vol. 5, 293 pp.
11. Scher.A.M., Young. A.C., (1957): "Ventricular Depolarization and the Genesis Of The QRS". *Ann. N.Y. Acad. Sci.* 65: 768-78.

12. Waller. A.D., (1887): "A Demonstration On Man Of Electromotive Changes Accompanying The Heart's Beat". *J. Physiol. (Lond.)* 8: 229-34.

13. Waller. A.D., (1889): "On The Electromotive Changes Connected With The Beat Of The Mammalian Heart, And On The Human Heart In Particular". *Phil. Trans. R. Soc. (Lond.)* 180: 169-94.

14. Wilson. F.N., Johnston.F.D., Macleod. A.G., Barker. P.S., (1934): "Electrocardiograms That Represent The Potential Variations Of A Single Electrode". *Am. Heart J.* 9: 447-71.

15. Berger. H., (1929): "Ber das Elektro enkephalogram des Menschen". *Arch. f. Psychiat.* 87: 527-70.

16. Blumhardt. L.D., Barrett. G., Halliday. A.M., Kriss. A., (1977): "The Asymmetrical Visual Evoked Potential To Pattern Reversal In One Half Field And Its Significance For The Analysis Of Visual Field Effects". *Br. J. Ophthalmol.* 61: 454-61.

17.Cooper R, Osselton JW, Shaw JC (1969): *EEG Technology,* 2nd ed., 275 pp. Butterworths, London.

18.Gilmore RL (1994): J. Clin. Neurophysiol RL Gilmore (ed.): "American Electroencephalographic Society guidelines in electroencephalography, evoked potentials, and polysomnography", *J. Clin. Neurophysiol.* 11:(1, January) 147 pp.

19.Jasper HH (1958): "Report of the Committee on Methods of Clinical Examination in Electroencephalography". *Electroenceph. Clin. Neurophysiol.* 10: 370-1.

20.Nunez PL (1981): "*Electric Fields of the Brain: The Neurophysics of EEG",* 484 pp. Oxford University Press, New York.

21.Puikkonen J, Malmivuo JA (1987): "Theoretical investigation of the sensitivity distribution of point EEG-electrodes on the three concentric spheres model of a human head - An application of the reciprocity theorem". *Tampere Univ. Techn., Inst. Biomed. Eng., Reports* 1:(5) 71.

22.Rush S, Driscoll DA (1969): "EEG-electrode sensitivity - An application of reciprocity". *IEEE Trans. Biomed. Eng.* BME-16:(1) 15-22.

23.Sharbrough F, Chatrian G-E, Lesser RP, Lders H, Nuwer M, Picton TW (1991): "American Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature". *J. Clin. Neurophysiol* 8: 200-2.

24.Suihko V, Malmivuo JA, Eskola H (1993): "Distribution of sensitivity of electric leads in an inhomogeneous spherical head model". *Tampere Univ. Techn., Ragnar Granit Inst.*, Rep. 7:(2) .

25.Bernstein D. "Evaluation of the cardiovascular system: history and physical evaluation". In: Kliegman RM, Stanton BF, St. Geme JW III, et al, eds. *Nelson Textbook of Pediatrics*. 19th ed. Philadelphia, PA: Elsevier Saunders; 2011:chap 416.

26.Simel DL. "Approach to the patient: history and physical examination". In: Goldman L, Schafer AI, eds. *Goldman's Cecil Medicine.* 24th ed. Philadelphia, PA: Elsevier Saunders; 2011:chap 6

27."Basic Hemocytometer usage".

28.Han, J.W., Breckon, T.P., Randell, D.A., Landini, G. (2012). "The Application of Support Vector Machine Classification to Detect Cell Nuclei for Automated Microscopy". *Machine Vision and Applications* (Springer) **23** (1): 15–24. doi:10.1007/s00138-010-0275-y. Retrieved 8 April 2013.

29.Han, J.W., Breckon, T.P., Randell, D.A., Landini, G. (July 2008). "Radicular cysts and odontogenic keratocysts epithelia classification using cascaded Haar classifiers". *Proc. 12th Annual Conference on Medical Image Understanding and Analysis*. pp. 54–58. Retrieved 8 April 2013.

30.Mayo Clinic staff (2012). "Upper endoscopy". *mayoclinic.com*. Retrieved 24 September 2012.

31.American Gastroenterological Association, "Five Things Physicians and Patients Should Question", *Choosing Wisely: an initiative of the ABIM Foundation* (American Gastroenterological Association), retrieved August 17, 2012

32.Spechler SJ, Sharma P, Souza RF, Inadomi JM, Shaheen NJ; Spechler; Sharma; Souza; Inadomi; Shaheen (2011). "American Gastroenterological Association Medical Position Statement on the Management of Barrett's Esophagus". *Gastroenterology* **140** (3): 1084–1091. doi:10.1053/j.gastro.2011.01.030. PMID 21376940.

33.Wang KK, Sampliner RE; Sampliner; Practice Parameters Committee of the American College of Gastroenterology (2008). "Updated Guidelines 2008 for the Diagnosis, Surveillance and Therapy of Barrett's Esophagus". *The American Journal of Gastroenterology* **103** (3): 788–797. doi:10.1111/j.1572-0241.2008.01835.x. PMID 18341497.

34.Bozzini (1806) "Lichtleiter, eine Erfindung zur Anschauung innerer Teile und Krankheiten, nebst der Abbildung" (Light conductor, an invention for examining internal parts and diseases, together with illustrations), *Journal der practischen Arzneykunde und Wundarzneykunst* (Journal of Practical Medicine and Surgery), **24** : 107-124.

35. "The utility of the endoscope as an aid in the diagnosis and treatment of disease". By Francis Richard Cruise. The Dublin Quarterly Journal of Medical Science. February 1. 1865.

36. "Clinical Reports of Rare Cases, occurring in the Whitworth and Harwicke Hospitals". By Samuel Gordon. Dublin Quarterly Journal of Medical Science Feb 1, 1866

37.Edmonson JM (1991). "History of the instruments for gastrointestinal endoscopy". *Gastrointestinal endoscopy* **37** (2 Supply): S27–S56. doi:10.1016/S0016-5107(91)70910-3. PMID 2044933.

38.Woodside, Gayle (1997). "*Environmental, Safety, and Health Engineering*". US: John Wiley & Sons. p. 476. ISBN 0471109320.

39.Stallcup, James G. (2006). "*OSHA: Stallcup's High-voltage Telecommunications Regulations Simplified*". US: Jones & Bartlett Learning. p. 133. ISBN 076374347X.

40."Beta Decay". *Lbl.gov*. 9 August 2000.

41.European Centre of Technological Safety. "Interaction of Radiation with Matter". *Radiation Hazard*. Retrieved 5 November 2012.

42.Feynman, Richard; Robert Leighton; Matthew Sands (1963). "*The Feynman Lectures on Physics", Vol.1*. USA: Addison-Wesley. pp. 2–5. ISBN 0-201-02116-1.

43.L'Annunziata, Michael; Mohammad Baradei (2003). "*Handbook of Radioactivity Analysis*". Academic Press. p. 58. ISBN 0-12-436603-1.

44.Grupen, Claus; G. Cowan; S. D. Eidelman; T. Stroh (2005). "*Astroparticle Physics*". Springer. p. 109. ISBN 3-540-25312-2.

45.Charles Hodgman, Ed. (1961). "*CRC Handbook of Chemistry and Physics", 44th Ed*. USA: Chemical Rubber Co. p. 2850.

46. "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields". OET Office of Engineering and Technology BULLETIN 56 Fourth Edition August 1999.

47. "Ettinger DS. Lung cancer and other pulmonary neoplasms". In: Goldman L, Ausiello D, eds. *Cecil Medicine*. 24th ed. Philadelphia, Pa: Saunders Elsevier; 2011:chap 197.

48.Griggs RC, Jozefowicz RF, Aminoff MJ. "Approach to the patient with neurologic disease". In: Goldman L, Ausiello D, eds. *Cecil Medicine*. 24th ed. Philadelphia, Pa: Saunders Elsevier; 2011: chap 403.

49.Kramer CM, Beller GA. Noninvasive cardiac imaging. In: Goldman L, Ausiello D, eds. *Cecil Medicine*. 24th ed. Philadelphia, Pa: Saunders Elsevier; 2011: chap 56.

50. Segerman D, Miles KA. "Radionuclide imaging: general principles". In: Adam A, Dixon AK, eds. *Grainger & Allison's Diagnostic Radiology: A Textbook of Medical Imaging*. 5th ed. New York, NY: Churchill Livingstone; 2008: chap 7.