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Original Research Paper

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WHY MEASUREMENT OF RADIATION DOSE BY MEDICAL PHYSICIST AND RADIATION ONCOLOGIST BOTH?

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ABSTRACT Many years after the discovery of X-ray's and gamma rays. They have been used empirically in medicine, later on realized that this approach was dangerous mainly in radiotherapy and up to some extent in diagnostic radiology. Thus Means of measuring x-ray/γ-rays had to be found in terms of unit of x-rays quantity defined and accepted. The magnitude of the biological effect desirable in case therapy and undesirable in case of diagnosis. It depends upon how much radiation energy is absorbed by irradiated material. X-ray dosimetry is the measurement of energy absorbed in any material particularly in different tissues of the body.

KEYWORDS : X-ray Dosimetry, γ Gamma Rays.

DISCUSSION-

The Biological Effects—Depends Upon

- Quantity of absorbed energy.
- Volume of tissue irradiated.
- Pattern of absorbed energy distribution.
- Length of time over which radiation is given.
- Type of Tissue.
- Quality of the radiation.

— — Direct Measurement in the irradiated person is impracticable thus a material to be taken, which nearly as possible simulate the material of interest.

Any Measuring System must have certain Criteria-
System should be

- Reproducible: Obtainable in constant from any were any time.
- Repeatable: Repeated. measurement of same amount of radiation should given same reading.
- Sensitive: Small amount should be enough to obtain acceptable reading.
- Objective: As far as possible personal subjective.
- Linear: Judgment should not be involved in obtaining an answer. Response should be simply proportional to the quantity being measurement.

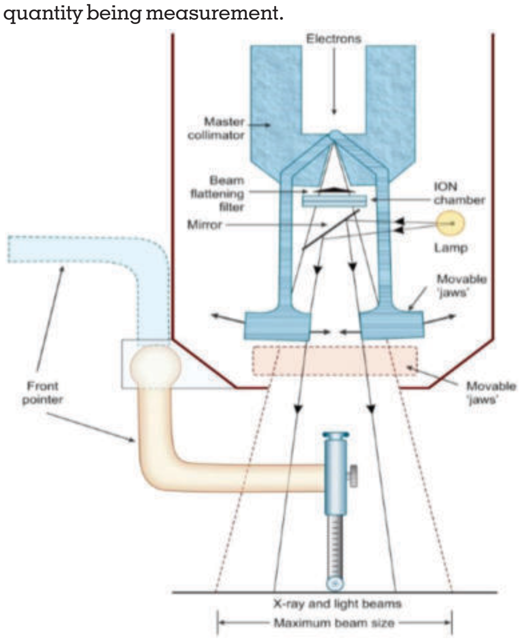

Fig. 1: X-RAY PRODUCTION

- Requirements of X-ray Dosimeter-
- It should be capable of measuring from very small to very large amount of radiation.
- It is important that the variation of absorption with radiation energy in the test material should be nearly as possible the same as for the material of interest. This can be achieved if two substances have same atomic number and electron density at any energy they will absorbed amount of energy per gram.
- The ionization of air internationally accepted basis of standard x-ray dosimetry.

— — Ionization of Air: We know ionization is a major product of the energy absorption process and therefore to measure ionization is essentially to measure energy absorption.

Air-Is-Chosen?

- Atomic No. of AIR (Average of Several Component) is 7.64 so and muscle is 7.42So that energy absorbed/gram of muscle tissue will be same as per gram ofAIR.
- Readily Available and its composition is universally almost constant thus is reproducible & Repeatable
- It is sensitive.
- Answer can be read of a meter dial thus no personal judgment (Objective)
- Electron Density of AIR and soft tissue is $3x10^{23}$/gm. Ionization of AIR dose not run parallel at all type of radiation qualities with the ionization and absorption per gram in materials of different atomic number..Example: Radiation energy absorption in bone (Z≫13) on basis of AIR ionization is more complex matter.
- Roentgen: This definition came in 1937. Roentgen is that amount of X-ray/γray radiation such that the associated corpuscular emission per .001293 gram of AIR, (weighted ICC of air at 0^{0}C & 760 mm) produces in AIR ions carrying 1 Esu of charge of either sign. Here corpuscular emission refers to the photo electron, Compton election, pair production electrons set in motion by primary interaction between radiation photons and the AIR. If total charge librated by electrons originating in ICC of AIR amounts to IS then the AIR has been exposed to 1 Roentgen (Applicable only for x-ray/□-ray energy upto 3 MeV)

Thus roentgen is the amount of radiation but it does not measure the energy taken from that amount of radiation which is what we really want hence forth in 1962. Roentgen shall be unit of exposure and RAD is the unit of absorbed dose.

Limitation of roentgen are:

- It does not indicate directly absorbed dose in bone (due to higher atomic no. of bone Z≫B in compression to that of AIR & soft tissue (7.64 & 7.42).

- It cannot be use for beta rays/or neutron only can be used for only x-rays/gamma rays Exposure (X) is defined by $X=\Delta Q/\Delta M$
- Where is ΔQ is sum of all electrical charges of all the ions of one sign produced in AIR ΔM is the mass of volume of AIR (in which all the electron librated by photon are completely stopped in AIRIR = $2.58x10^{4}$coulomb/kg of AIR
- RAD : Since exposure dose not fulfil the purpose of measuring absorbed energy., But we want to measure absorbed dose, Thus unit of absorbed dose is RAD, 1 RAD = 100 ergs/gm 1 ion pair = 33.7 eV, So the roentgen measures amount of radiation incident upon material and the RAD is the amount of energy absorbed as a result of this exposure. To measure the RAD we measure the exposure in roentgens and then calculate the rads. Through known factors which depends of the material irradiated and the radiation energy. This easy for soft tissue but complex for material like bone., Gray is the unit of absorbed dose, 1 Gray =100 rad. 1 Gy = 1J/Kg. = 10^{7} Erg/ 10^{3}gram = 100 ray, Now we know the methods of dosimetry are generally indirect so measure exposure by ionization in AIR and from this calculate absorbed dose in any other material.

Other Measuring Methods -

We know standard measurement is ionization of AIR. But many effects of radiation can be use as detectors of radiation and up to some extent as measuring methods.

Biological Methods

Earliest attempt of x-ray measurement were based on erythema production. The threshold Erythema dose (TED) was amount of radiation which would produce reddening of skin in 80% those expose. But this effect has lots of variation person to person. Thus repeatability was not good .

Chemical Methods

Here oxidation of ferrous sulphate to ferric sulphate use as a dosimeter (called Frike dosimeter). It can be use for very large amount of radiation but not small amount of radiation. Thus was not sensitive. Purity of chemical was important for the precise effect.

Physicochemical Methods

Photographic effect of x-ray on film, because use blackening produced in proportional to the radiation energy absorbed, but blackening also depends upon development condition and type of radiation quality other fact is that film contains element of high atomic number than that of low atomic number soft tissue.

Physical Methods

Fluorescence -

- Intensity of visible light emitted by a fluorescent material depends primarily on the amount of energy absorbed by it therefore also on the intensity of x-ray falling upon it. Thus fluorescence would therefore to offer method of measuring radiation dosage since measurement of visible light is quite straight forward.
- But material use in radiology (zinc sulphide or calcium tungstate) contains elements of high atomic number so that the variation with radiation energy of this absorption will be very different from that of soft tissue.
- So we can use such as Anthracene or one of the number of transparent plastics. Florence do occurs when irradiated with x-ray and also have atomic number close to AIR and soft tissue using a photo multiplier tube to amplify effect of tiny amount of light
- This method is sensitive, repeatability is good but dose not have high reproducibility.
- hermo Luminescence -
- A very wide range of dose can be measure by using the thermoluminescent material, Phenomenon lithium fluoride use for this because it has got atomic number close to that of soft tissue therefore the variation with radiation energy absorption. Both material will be very similar tiny capsules can readily be inserted into body cavities sites not normally accessible to more conventional measuring method. Relative values of doses at a number of site can be readily obtained like fluorescence thermo luminescence depends on tiny amount of impurities in the crystalline material thus it is not possible to produce a universally constant material.

Calorimetry-

Energy deposited in any material is to measure the heat generated due to slowing down of the primary electrons and product of many of the radiation induced chemical reactions. But amount of heat generated are extremely small thus requirement is most careful and sensitive techniques.

Standard free AIR Chamber–

In free AIR chamber the ionization produced in AIR by the irradiation of a known amount of AIR must be measured. This free AIR chamber is principally confined to National Standard Laboratory. ,X-ray from the focal spot of an X-ray tube is collimated by circular diagram of area A. The collimated beam inters the ionization chamber. Here interaction of x-ray with AIR produces ion pair. These ion pair travels in all directions. Electrons produced by the photon beam in specified volume must spend all their energy by ionization of AIR between the plates. This can occur only when rage of electron librated by the incident photon is less than the distance between each plate and specified volume. Lead line box ions produced in EFGH volume collected by Electrodes C of length Connected to positive potential. Guarding arrangement is placed to keep field parallel at the edge of electrodes Plate spacing

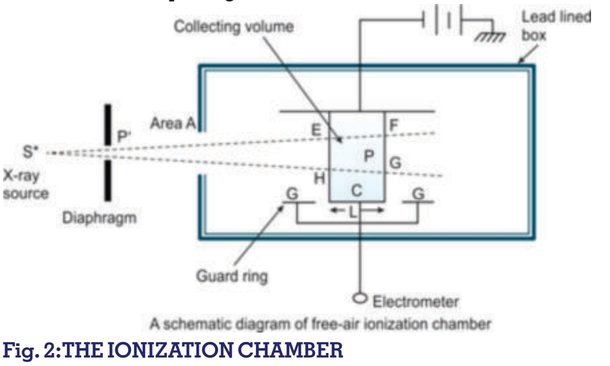

Fig. 2:THE IONIZATION CHAMBER

X – Ray voltage	Photoelectron	Compton electron	Plate used	Separation
100kV	12 cm	10%	.5 cm	90 (12 ~ SM)
200kV	37 cm	.4%	4.5 cm	99.6
100kV	290 cm	0	220 cm	100 (4 meter

Requirement is that the distance of each plate form the beam should be greater than the fastest electron generated, thus every electron expends all its energy in AIR and produces all the ionization of which it is capable rather than colliding with the plate whilst still having some energy.

Voltage Applied between the Plates

With voltage application +ve& -ve ions combine thus voltage applied and electric field generated by voltage, in the amount of librated charge collected since in voltage more it prevent its recombination but a state will come when if you increase voltage there would be no increase in collection because every ion being formed collected. So it is require that free ion chamber applied voltage should be such that is should produced saturation condition

The Charge Produced in Collected and Measure by Electro Meter -

Exposure at P (P)X
DQ total charge collected
P is density of the AIR
A is the area of diaphragm aperture
L is the length of electrode Collector plate

CD is the uniform field so any ions from in section ABCD no other will be attracted to plate CD and measured by E. When matter these electron produce hundreds of ionization before being brought to rest. For example 100 KeV photo electron travel 12 cm in AIR and produce 3000 in ionization (100 Kev) Compton electron set in motion and travel 1 cm in AIR and produce nearly 500 ionization. Ions collected from zone ABCD may be produced by primary electron originating outside ABCD called g electron. Electron entering ABCD but produce effect outside the collecting zone

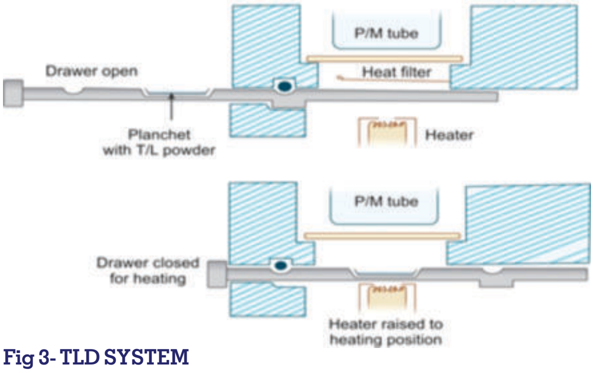

Fig 3- TLD SYSTEM

some of their effect will be lost. Such tracks called lost (L) electron. In practice gain and lost described will be equal thus ions collectedby plate CD measure by electrometer, as being the ionization produced by the electron arising from the irradiation of volume representedby A,B,C,D. For Equal Lost and gain electronin the zone of interest provided that before arriving at collecting volume the beam hastraversed a thickness of AIR which is least equal to the range of most energetic electronthe beam can produce.

Temperature and Pressure Taking into Account –

Practically ionization chambers that are an open chamber thus temperature and pressure must be taken into account and their difference from normal temperature and pressure NTP (760 mm and 0^0C). Thus if reading M found then true reading (X) is given by Departmental Chamber The free AIR chamber exit in small number. Henceforth it is being used as standard and a standardizing instrument but it is not suitable for use in X-ray Department (Due to large size). It cannot measure dose within patient. It can not measure dose of radiation received by radiographer during his or her work for so for that purpose we use TLD system to monitor exposure of radiography, The Physicist, radiation oncologist during working in the close proximity of radiotherapy equipments.

Thimble chamber must standardize at intervals against the standard free AIR ion chamber. The volume of thimble chamber (.33 to 3 cc) here in thimble chamber ionization taken in small circumscribed volume. Large majority of electron tracks start inside will produce much of their ionization beyond its confines while tracks majority in number, will originate outside the volume of interest. Lost and gain electron can be compensated provided that AIR volume being considered is surrounded by AIR to a maximum thickness R to the maximum range of electron. If all ionization in little volume collected and

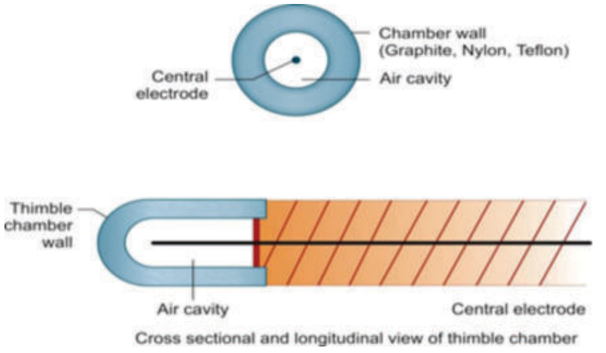

Fig. 4 : THIMBLE CHAMBER

measure we can get exposure. Since maximum bulk of ionization produce in the volume arises from electron which is liberated inits surrounding AIR. Now the situation with in the volume would not be altering surrounding AIR out to the range R were solidified to give wall to the air volume.Due to low atomic no. of graphite (z=6)thus thee wall materials tends to contribute less ionization than would have occurred in AIR wall. This can be compensated by using central electrode aluminium (Z=13).

Chamber Size

Large volume = larger charge amount can measure ANY way. But for small volume requirement of sensitive electrometer required like AIR 1 R (exposure) gives in 1 Esu 1 cc air charge1R IN 1000 CC OF AIR
GIVES 1000 Esu.

Measuring System

- Exposure Meter (Dose Meter)
- Exposure Rate Meter (Dose Rate Meter)
- Voltage supplied by:
- Battery must be high enough to saturate the ionization chamber and about 200 volt per cm of gap between central electrode and wall are usually provided In exposure meter reading increase continuously As long as the irradiation Continues because that instrument adding up the charges liberated However this not in case exposure rate meter. Here reading comes instantly up to appropriate value assuming the radiation rate is constants and stays at the value no. matter, how long the exposure continues.

Practically:-- Exposure meter & exposure rate meter present in same instrument. Both the instrument connected to ionization chamber with long leads so that ionization chamber can be expose to radiation chamber reading can be take from outside the zone of radiation.

Wall Thickness -

Condition is that has to be fulfilled before an ionization chamber measures roentgens is that its wall thickness must be at least equal to max. Range of electrons produced by the radiation that is being measured. Now that thickness will

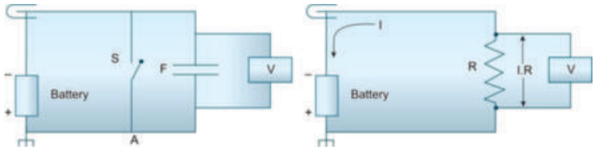

Fig. -5 : EXPOSURE RATE METER

be different for radiation energies. It is usual tohave wall which is about 1 mm thick since thehandling is easy and it can be use for radiationup to about 300 KV.

Perspex or other plastic caps are use to supplement the wall thicknessfor higher energy radiations.

Effect of wall thickness on measured ionization:

Wall thinner than E contributestoo few electrons. Whilst if the thickness isgreater than E, then measured effect is reducedbecause of attenuation of beam in the wall.Wall attenuation effect will be marked at low energies.

Calibration

The response of a radiation meter to give exposure or exposure rate depending on a factor:

- AIR Volume
- Wall Thickness
- Material of Wall and Central Electrode
- Sensitivity of Electrical Measuring System

In calibration the instrument readings compared with free AIR standard chamber and reading multiplied with calibration factor to give roentgens these calibrations should be use different for different radiation quality at which the instrument is likely to be used. It should be repeated at 2 yearly intervals to check the constancy of equipment. Side by side meter should be check at local level at monthly /2 monthly interval. Such check is carried out by placing the ionization chamber to some radioactive source of a known radiation exposure rate. Above stated factors given by Standardizing Laboratory for departmental meter. For higher energy Compton Effect produced and we know Compton Effect in dependent of material used in chamber wall and central electrode thus instrument will be more incentive. It will give reading slightly increased value.

At Low Energy: Photo electric effect produced max. Effect since we photo electric effect varies with a Z^3 (A.N.) atomic number thus wall material and central electrode becomes very important in correction factor indicating that the instrument become more sensitive for low energy radiation. Other factor is wall attenuation of x-ray beam factor reduction is reversed because of compromise wall thickness greater than needed at low energy at lower energy grater this effect hence greater the value of correction. For very low energy Grenz rays – special chamber (ionization) use for < 10 KV.

Generating Voltage 300 KV 200 KV 175 KV 150 KV 100 KV 75 KV 50 KV 40 KV 30 KV
Multiplying Factor 1.02 1.02 1.01 1 1.02 1.06 1.13 1 . 1 8 1.27

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