PHYSICS OF RADIATION THERAPY

Currently three major methods are used alone or in combination to treat cancer:

1-Surgery

2-Radation

3-Drugus (chemotherapy)

The success of radiation therapy depends on:

1-The type and extent of cancer

2-The skill of the radiotherapist

3-The kind of radiation used in treatment

4- The accuracy with which the radiation is administered to the tumor

There is evidence that an error of 5% to 10% in the radiation dose to the tumor can have a significant effect of the results of the therapy.

Too little radiation does not kill all the tumor.

Too much can produce serious complications in normal tissue.

Figure 1 shows how local cure and sever complications depend on the dose in the treatment of with radiation

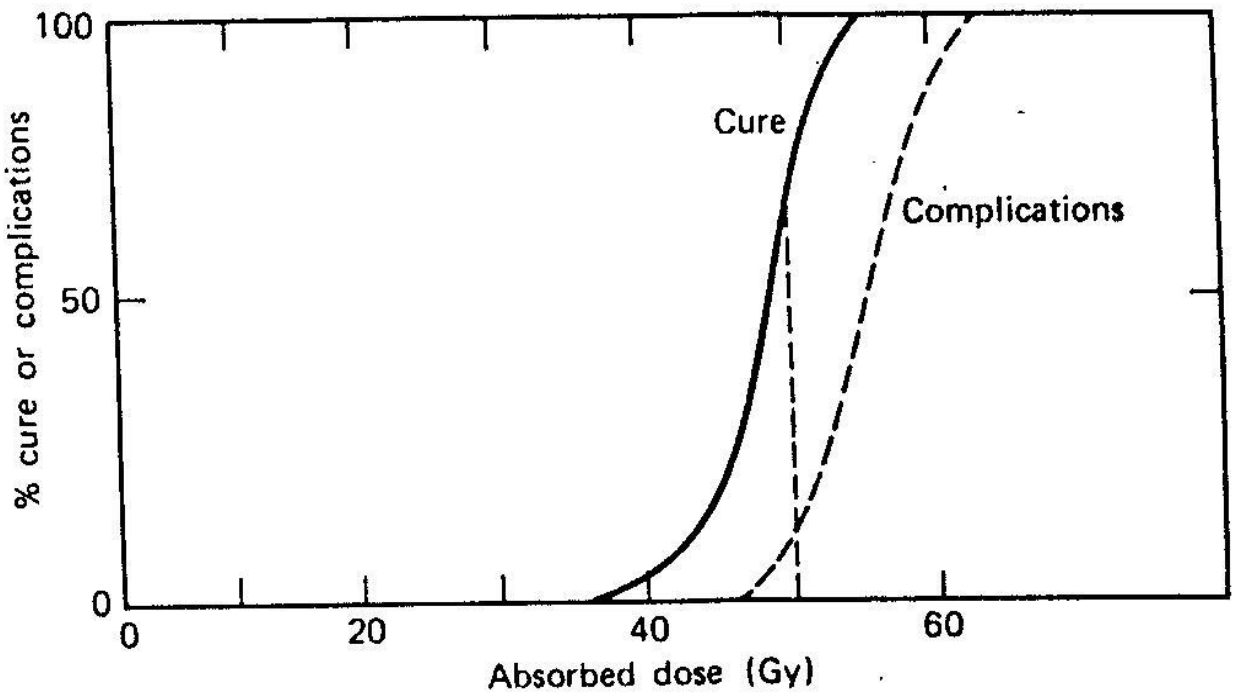

Figure 1: For many tumors treated with radiation, the dose needed to give a reasonable chance of cure (control of the local tumor) is only slightly lower than the dose that will cause severe complications. This graph does not represent data for a particular tumor but shows the general trend.

The solid line shows the percent of cure of a local tumor as a function of dose for a large number of patients with the same type of tumor. The dashed line shows the percent of severe complications as a function of dose.

That giving a dose just 5% lowers than 50Gy reduces the chance of local cure by a factor of nearly 2.

While the giving a dose 5% higher does not greatly increase the cure rate but does greatly increase the number of major complications.

These curves, which differ from tumor to tumor, demonstrate why accurate physical measurements by radiological physicists are important in radiation therapy.

THE DOSE UNITS USED IN RADIOTHERAPY

Roentgen (R). a unit based on ionization in air, a measure of amount of electric charge produced by ionization in air

$$1\ R = 2.5 \times 10^{-4}\ c/kg \text{ of air}$$

It was an inappropriate unit to use for radiation absorbed by a part of the body.

Rad is defined as 100 ergs/g. That is the radiation beam gives 100 ergs to 1 g of tissue gives the tissue an absorbed dose of rad.

The Rad can be used for any type of radiation in any material: The roentgen (R) is defined only for x-rays and gamma rays in air.

The rad can be related to exposure in roentgens.

The rad was defined so that for x-rays and gamma rays an exposure of 1 R would result in nearly 1 rad of absorbed dose in soft tissue (water).

In bone the ratio of rads to roentgens depends on the energy of x-ray photons. At the energies used in diagnostic radiology the ratio of rads to roentgens in bone is about 4: That is 1R exposure results in about 4 rads of absorbed dose. At the high energies used in modern radio therapy the ratio of rads to roentgens is nearly 1 for both bone and soft tissue (fig 2)

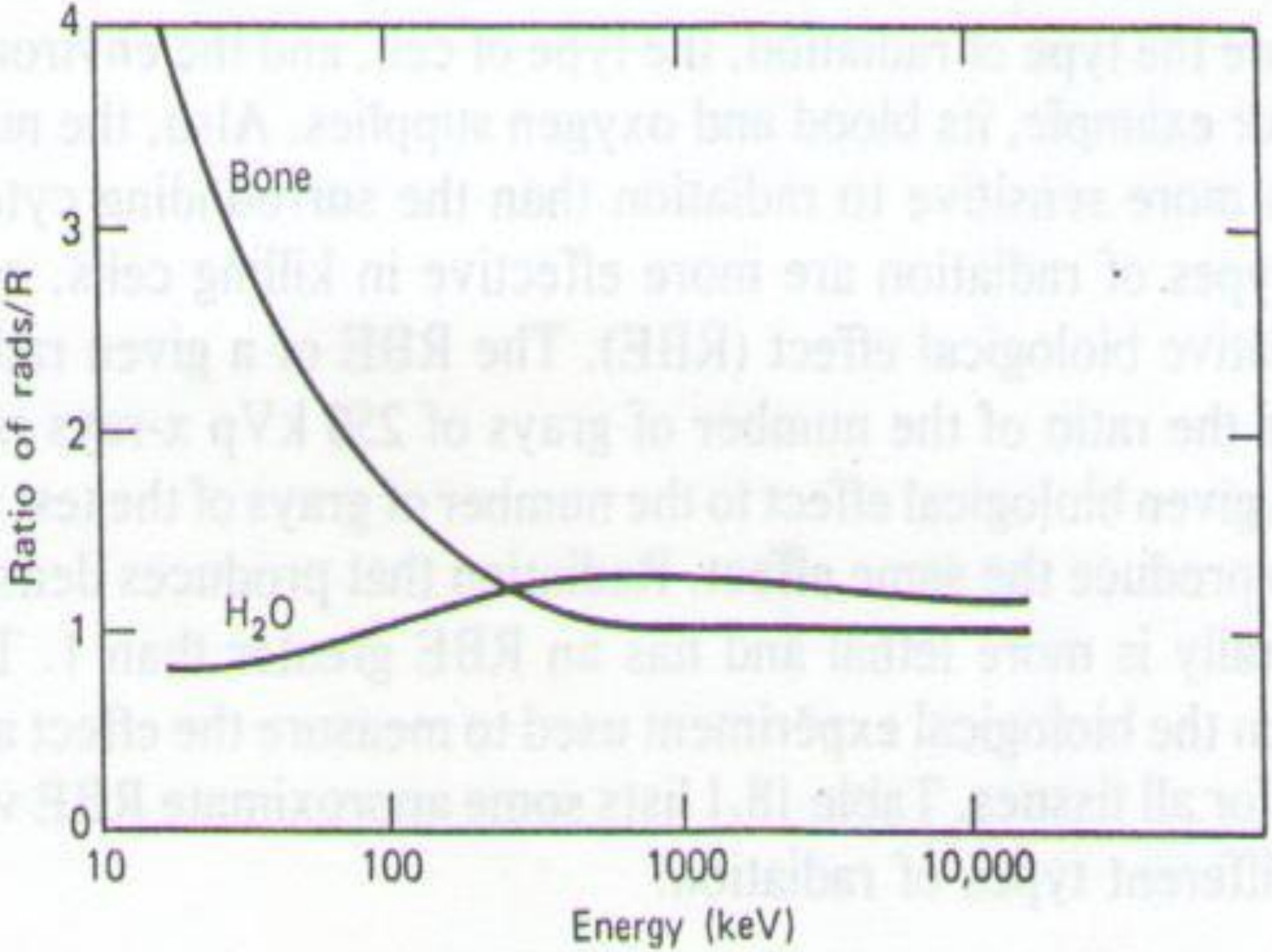

Figure .2. The energy absorbed in tissue depends on the tissue composition and the photon energy. High Z materials such as calcium absorb more energy per roentgen than water for x-ray and gamma ray energies below 200 keV.

The energy absorb in tissue depends on tissue composition and the photon energy. High Z materials such as calcium absorb more energy per roentgen than water for x-ray and gamma ray energies below 200 Kev.

GRAY (Gy) as international (SI) UNIT OF DOSE

1 GY = 1 J/Kg

GY = 100rads

PRINCIPLES OF RADIATION THERAPY

The basic principle of radiation therapy is to maximize damage to the tumor while minimizing damage to normal tissue.

Ionizing radiation, such as x-rays and gamma rays, tears electrons off atoms to produce

1-Positive and negative ions

2-It also breaks up molecules

The new chemicals formed are no use to the body and can be considered a form of poison.

Toxic chemicals formed in the cell by the breakup of the normal molecules kill the cell.

How much radiation does it take to kill cell? This is analogous to question: How many bullets does it take to kill a person? One bullet may do job, but a person may survive an onslaught of 10 if the bullets do not strike a critical organ. Factors that determine how much radiation is required are the type of radiation, the type of cell, and the environment of the cell, for example, its blood and oxygen supplies. Also the nucleus of the cell is more sensitive to radiation than the surrounding cytoplasm.

Some types of radiation are more effective in killing cells or have a higher relative biological effect (RBE). The RBE of a given radiation is defined as the ratio of the number of grays of 250KVp x-rays needed to produce a given biological effect to number of grays of the test radiation needed to produce the same effect.

Radiation that produces dense ionization generally is more lethal and has an RBE greater than 1. The RBE is not the same for all tissues.

Table (1) Lists some approximate RBE values for

Several different types of radiation

Particle	RBE
Electron or beta rays	1
X-rays or gamma rays	1
Fast neutron	5
Alpha particles	> 10

<u>Figure 3</u> shows the percent of surviving Hela cells for various doses of radiation. Note that at low doses the curve for x-rays and gamma rays has a shoulder that is not present when alpha particles are used, but it only takes about 1.0 Gy to kill half of those remaining. The quantity that will kill half organisms in a population (cells, mice, people, etc) is called the lethal dose for 50% or LD_{50}, the amount of radiation that will kill 50% of organisms in 30 days is called the LD $_{50(30)}$. The $LD_{50(30)}$ For humans is about 4.5 Gy.

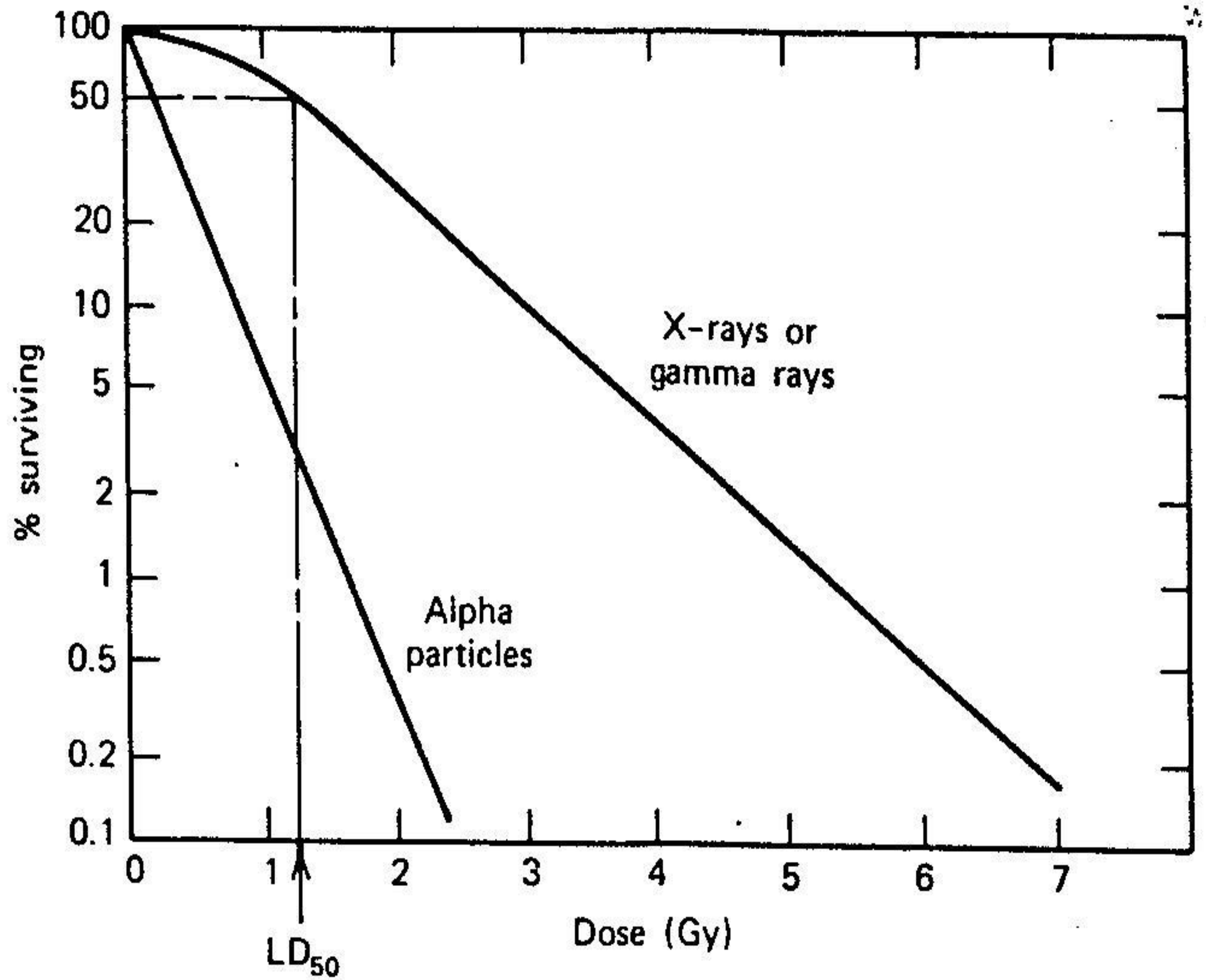

Figure 3. The percent of surviving Hela cells as a function of the dose of x-rays or gamma rays and alpha particles. Note that the first grays of x-rays are not very lethal. The alpha particles have a greater biological effect per gray.

OXYGEN EFFECT

Cell irradiated in the presence of oxygen were much easier to kill than cells of the same type irradiated without oxygen. The oxygen effect may play a role in the recurrence of cancer. The cells near the center of a large tumor have a poor blood supply_and thus a poor oxygen supply.

When the tumor is irradiated the healthy cancer cells with a good blood supply are killed and many of the more poorly oxygenated, radio resistant tumor cells remain alive. These cells may later divide and permit the tumor to re grow.

It was suggested that radio resistance of the poorly oxygenated cells in the center of a large tumors could possibly be overcome by increasing the oxygen supply to the entire body.

RADIATION PROTECTION IN MEDICINE

1-BIOLOGICAL EFFECTS ON IONIZING RADIATION

The biological effects of ionizing radiation are two general types somatic and genetic

Somatic effects an individual directly (loss of hair, reddening of the skin, ete).

Depend on

1-Amount of radiation

2-The part of the body irradiated

3-Age of the patient

In general, the younger the person, the more hazardous the radiation. In fact, the most dangerous period to receive radiation is before birth. At certain periods in the development of the fetus, radiation can produce deformities.

Some of the common somatic effects of radiation are stiffening (fibrosis) of the lung, formation of holes (fistulas) in tissues, reduction of white blood cells (leucopenia) and cataracts in the eyes.

Perhaps the most feared somatic effect of radiation is carcinogenesis, the induction of cancer. It has found that radiation can induce many types of cancer besides skin cancer. Radiation to the thyroid has caused thyroid cancer, and radiation to the blood – forming organ (bone marrow) has caused blood cancer, or leukemia.

Genetic effects

Consist of mutations in reproductive cells that effect later generations, since genetic effects occur only when reproductive cells are irradiated. The gonads shielded are during x-ray studies.