



Second lecture

Radiation in the Treatment of Cancer

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Radiotherapy:

Also called radiation therapy, is the branch of medicine that deals with the treatment of some medical conditions especially cancer disease by delivering high-energy radiation beams directly to a tumor, or intended target to destroy or weaken particular cells.

The interaction of radiation with a cell is a matter of chance [probability]. If an interaction occurs, the damage may not be expressed, in fact damage is more frequently repaired. The initial deposition of energy occurs very quickly, The radiation is deposited in the cell randomly and expression of damage occurs after a latent period, ranging from hours to years or even generations. The DNA is the sensitive target in the cell

The goal is to achieve high dose conformity and homogeneity within the target volume (PTV) while ensuring the absorbed dose in the surrounding Organs at Risk (OARs) remains below critical Tolerance Doses. This balance is a primary function of the Treatment Planning System (TPS), informed by the machine physics.

Principles of radiation therapy:

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

Factors that determine how much radiation is required:

1. The type of radiation used.
2. The type of cells.
3. The environment of the cells for example, its blood and oxygen supplies also the nucleus of the cell is more sensitive to the radiation than the surrounding cytoplasm.
4. The relative biological effect (RBE) of radiation.

Lethal Dose (LD₅₀)

The quantity of radiation that will kill half of the organisms in population is called lethal dose for 50% or LD₅₀, figure (2)

shows the surviving percentage for X-rays, gamma rays and Alpha particles.

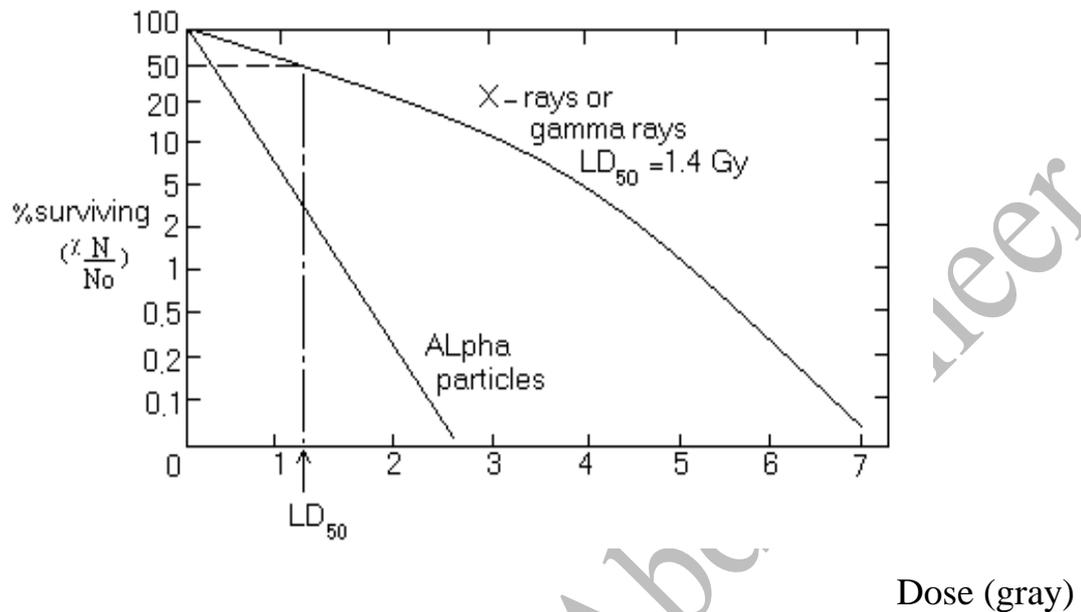


Figure 2 . The percent of surviving heal cells as a function of the dose X-ray or gamma rays and alpha particles.

Where:

$$N/N_0 = e^{-KD}$$

No: original number of survival cells prior Dose.

N: number of survival cells posterior Dose.

D: dose.

K: constant depend on cells type.

Note:

* That the first grays of X-rays are not very lethal.

* The alpha particles have a greater biological effect per Gray.

Requirement for Radiotherapy:

1. Determination of the tumor by accurate diagnosis.
2. Determination the quantity and quality of radiation required for radiotherapy.
3. Linear energy transfer of radiation.
4. Dose fractionating.

5. Dose diving.
6. Oxygen enhancement (or other sensitizers) to increase killing of tumor cells.
7. Prohibitive to reduce killing in the healthy cells.
8. Bragg peak calculation.

Factors affecting radiosensitivity:

1. Biological factors:

1. Proliferate state of the cells.
2. The phase of the cell cycle at irradiation.
3. The presence of biological repair capacity (some type of cells have greater capacity for repair than other).
4. The sex of the biological target (females, therefore are less radiosensitive).
5. The age (humans are most sensitivity before birth then decreases until maturity, in old age humans again become more radiosensitive).
6. The species differences (if the patient suffering from malignant disease or other type of tumor).

2. Chemical Factors:

1. **Rediosensitizers:** are agents that makes tumor cells more sensitive to radiation therapy for example, Halogenated pyrimidine and Oxygen.
2. **Radioprotectores:** are compounds used to protect against harmful effects of radiation in normal tissues for example Sulphdry1 group (sulfur and hydrogen bound together) such as cysteine and cysteamine.

Chemical radiation protective agents:

The addition of the chemical protective agents reduces the effectiveness of subsequent radiation effects, to be effective all protective agents need to be present at the time of radiation and

they must be close to the critical site of radiation damage, post – irradiation treatment protection agents are ineffective. The protective agents normally combine with the damaging free radicals i.e. they act as a radical scavengers. These protective are sulphur – containing aminothids & their disulphide.

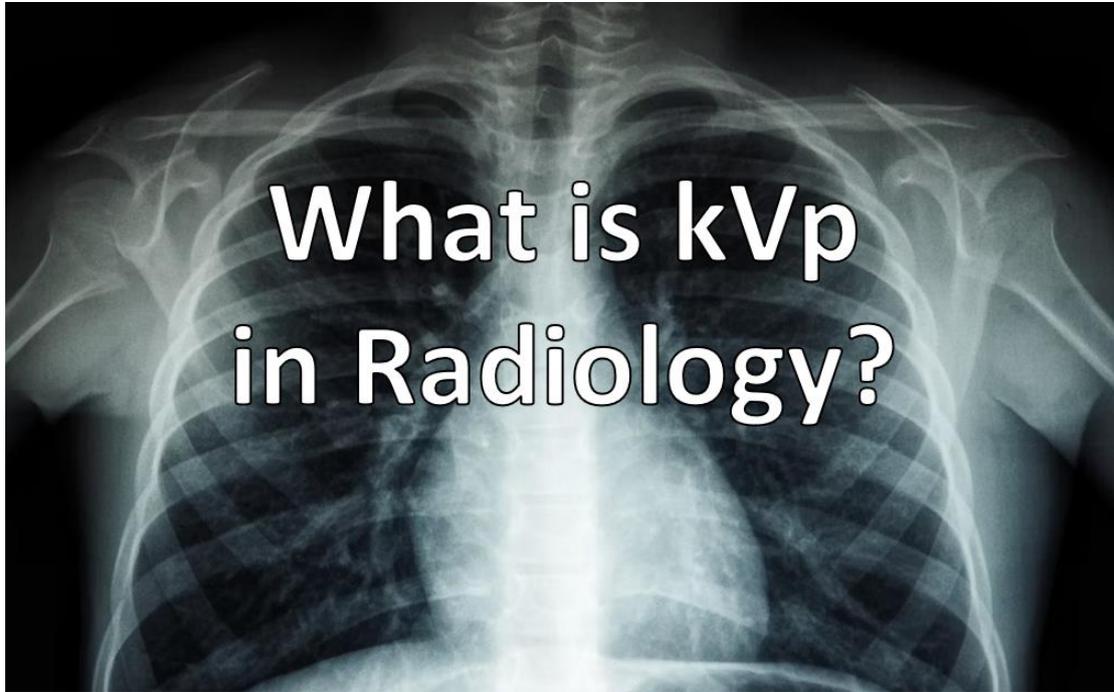
3. Physical Factors:

1. Dose and dose rate of radiation, if a dose of radiation is delivered over a long period of time rather than quickly, the effect of the dose will be less.
2. Dose fractionating, is less effective because tissue repair and recovery occur between the given doses.
3. Linear energy transfer of radiation. LET.

LET, is the most acceptable index to describe the average rate of energy an incident ionizing radiation transfers to soft tissue. It has units of keV of energy transferred per unit path length at micrometer level in soft tissue (keV/ μm). The ability of ionizing radiation to produce a biologic response increases as the LET of radiation increases.

<u>Type of radiation</u>	<u>LET(keV/μm)</u>
25 MeV X-rays	0.2
^{60}Co rays	0.25
1 MeV electrons	0.3
Diagnostic X-rays	3.0
10 MeV protons	4.0
Fast neutrons	50.0
5 MeV alpha particles	100.0
Heavy nuclei	1000.0

Since the biological effectiveness of particle is related to amount of ionization, thus particle of high LET will be more damage than low LET.



To obtain X-ray or CT images, the X-ray machine or CT-system needs power to generate the X-rays. This power is measured in kilovolts and it determines how strong or “fast” particles (electrons) in the machine are accelerated to generate X-rays. Therefore, the kVp determines how (bright) the images will be. The kilovolts always come in a “group” from lesser to more powerful ones. The kVp (kilovoltage peak) gives information on “how strong” the strongest parts of this power are.

This is important for the radiologist as it determines what can be looked at in your body. For example, soft tissue (such as chest X-rays) need higher kVp (120-130 kVp). But to differentiate bones, less power is needed (70-80 kVp).

The Linear Accelerator (LINAC)

A medical linear accelerator (LINAC) is a machine used in radiation therapy to produce high-energy X-ray or electron beams. It is primarily utilized for external-beam radiation therapy, targeting tumors while minimizing damage to surrounding healthy tissue. LINACs are designed to custo

mize radiation doses to conform to the shape of the tumor, ensuring effective treatment. They are essential in oncology, providing precise and controlled radiation delivery to destroy cancer cells.

Treatment process with a linac

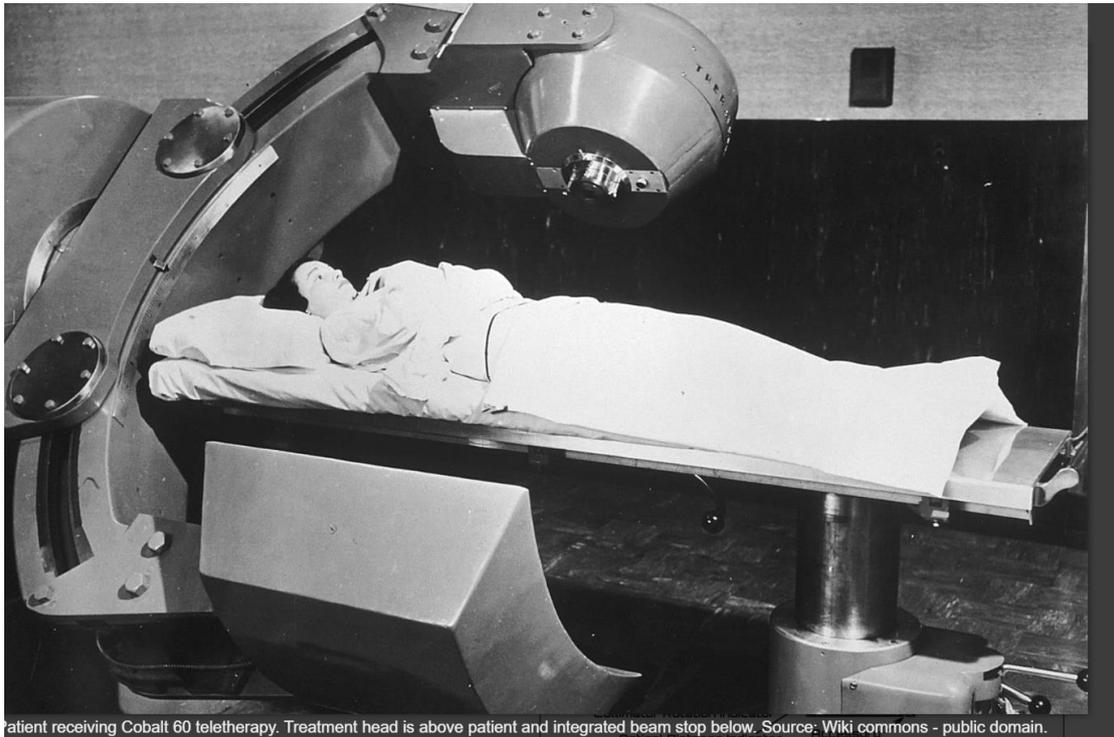
In the majority of cases, linacs are used to deliver a computerized treatment plan which is prepared in advance. After a medical doctor (radiation oncologist) prescribes a course of radiation treatment, a dosimetrist or medical physicist creates a plan on a computer to meet the prescription. The radiation oncologist then examines and approves the plan, and a medical physicist reviews and performs safety checks for the plan. Once the plan is deemed satisfactory it is transferred to the linac through a computer network. The patient is set up on the treatment table by radiation technology therapists (RTTs) and, using marks on the patient's body and/or x-ray imaging devices, moved into a position that corresponds to the computerized treatment plan. When the patient is in the correct position, the RTTs can direct the linac to deliver the programmed treatment plan.

The number of treatment sessions (which can be referred to as "fractions") and total radiation dose that a patient receives depends on the tumor type, the amount of dose tolerated by organs surrounding the tumor nearby, and the goal of treatment. The radiation for a single treatment session can often be delivered within a few minutes, but the total time for each treatment will vary depending on the time needed for patient set-up, the treatment method, and the total radiation dose delivered.

Cobalt Machines

Cobalt 60 teletherapy units appear similar to early generation clinical linear accelerators. Most feature a rotating gantry and variable jaw collimation located in the treatment head. A light field and optical distance indicator is incorporated into the treatment head to facilitate patient alignment. The machine may also include a primary beam stop and/or a means of portal imaging. Most Co^{60} units use a source-to-axis-distance

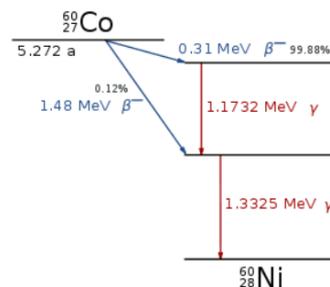
of 80cm which compensates for the lower output as compared with a linear accelerator.



patient receiving Cobalt 60 teletherapy. Treatment head is above patient and integrated beam stop below. Source: Wiki commons - public domain.

Cobalt 60 Properties

- Half life: 5.2714 years
- Decay Mode: β^-
 - ${}_{27}^{60}\text{Co} \rightarrow {}_{28}^{60}\text{Ni} + e^- + \bar{\nu}_e + \text{gamma rays}$
- Mean gamma energy: 1.25MeV (1.17MeV and 1.33MeV)
 - ~10% of the beam is resultant of scattered photons.
- Lead HVL: 11.0mm
- Exposure rate constant:
 - $\Gamma_{\delta} = 13.07 \frac{\text{R cm}^2}{\text{mCi hr}}$
- External beam source size: 1-2cm²



Dedicated CT scanners for use in radiotherapy treatment simulation and planning are known as CT simulators. The components of a CT simulator include: a large bore CT scanner (with an opening of up to 85 cm to allow for a larger variety of patient positions and the placement of treatment accessories during CT scanning); room lasers, including a movable sagittal laser, allowing for patient positioning and marking; a flat table top to more closely match radiotherapy treatment positions; and a powerful graphics workstation, allowing for image manipulation and formation



CT simulator. Note the flat table top and the large bore (85 cm diameter). The machine was manufactured by Marconi, now Philips

Examples

-is The most radiosensitive target in the cell.
A. Cytoplasm B.Mitochondria C. Nucleus (DNA)
D. Cell membrane E. Golgi apparatus
- The unit of Linear Energy Transfer (LET) is.....
A. Gray B. Sievert C. keV/ μm D. Joule/kg E. Becquerel
- Which of the following does not affect the required radiation dose?
A. Type of radiation used B. Type of target cells C. Cell environment (oxygen and blood supply) D. Ambient temperature E. Relative Biological Effectiveness (RBE)
- The lethal dose (LD50) is defined as.....
A. Dose that kills all cancer cells B. Dose that kills 25% of organisms C. Dose that kills 50% of organisms D. Safe dose for normal tissue E. Exactly 1 Gray
- A.....Which type of radiation has the greatest biological effect per Gray?
A. X-rays B. Gamma rays C. Alpha particles D. Radio waves E. Infrared