Lec:4

Physics of radiation therapy

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Radiotherapy:

Radiotherapy is used alone or in combination to treat some medical conditions especially the cancer by using radiation to weaken or destroy particular cells.

Radiation dose: It is the change in the amount of radiation energy delivered per unit mass.

$$D\ (Gy) = \Delta E\ (joul)/\ \Delta m\ (Kg)$$

$$D(Rad) = \Delta E\ (erg)/\ \Delta m\ (g)$$

Where:

- 1Gy= 100 Rad
- 1R= 8.7 mGy (D in air)

Interaction of radiation with bio-molecules:

1- **Direct Interaction:** This kind constitutes 5% of the total radiation interaction, where the ionizing radiation interacts with macromolecules of the body like protein and DNA

2- **Indirect Interaction:** which constitutes 95% of the total radiation interaction, where the ionizing radiation interacts with water molecules

1- Direct Interaction of Radiation:

Effect of Ionizing Radiation on Proteins:

The protein molecule composes of C, NH_2^+, $CooH^-$ and the side chain (R). The amino group represents the radiosensitive portion of the protein, while the acidic group is the radio resistive portion. When radiation incident on the radiosensitive part, this will lead to a series changes in the entire structure of the protein due to the breakage of the chemical bonds that held the protein in its structure.

Effect of Ionizing Radiation on DNA:

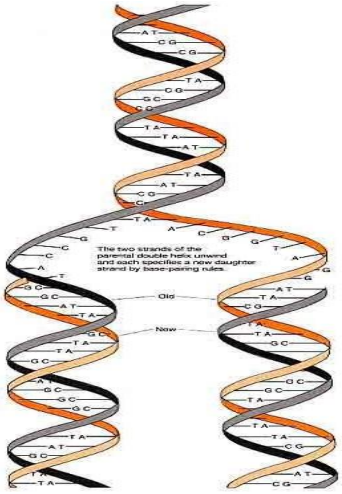
DNA is two spiral strands twisted around each other to form the double helix, it is found in the nucleus of the cell, it is responsible for ***Protein synthesis, controlling of cell division, Carrying genetic information.***

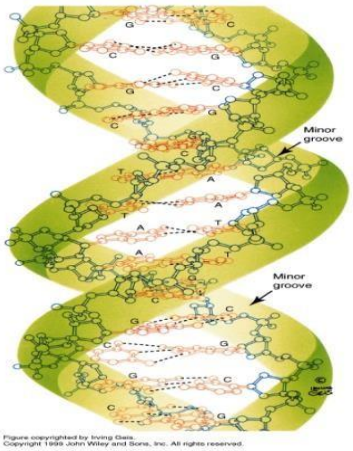
The chemical composition of the ***DNA*** molecule:

$$H_3Po_4 + C_5H_{12}\mathbf{O_4} \text{ + four nitrogenous bases (A, G, } \mathbf{T}\text{, C)}$$

The chemical composition of the ***RNA***:

$$H_3Po_4 + C_5H_{12}\mathbf{O_5} \text{ + four nitrogenous bases (A, G, } \mathbf{U}\text{, C)}$$





Incident radiation on the DNA molecule leads to the followings:

1- ***Single strand break***
2- ***Double strand break.***
3- ***DNA bases delay***
4- ***Delay in DNA synthesis and cell division.***
5- ***chromosomal damage and changes in the genetic material which leads to mutation.***

2- Indirect Interaction of Radiation:

This kind is represented by the interaction of ionizing radiation with water molecule, where radiation breaks the covalent bonds that held the water molecule in its structure and leading to the release of free radicals (H• & OH•). The free radicals are highly reactive species, they have a short life span (10-9 to 10-14).

This reaction depends on the linear energy transfer (***LET)*** of the ionizing radiation. ***LET*** is the average energy loses per unit of path traveled by the incident radiation, it is the energy deposited in each segment of tissue.

For low LET, the probability of recombination between $H^{\bullet}$ & $OH^{\bullet}$ to form water increased.

$$H^{\bullet} + OH^{\bullet} \text{ ---------} H_2O$$

For high LET, the probability of $H^{\bullet}$ combination and $OH^{\bullet}$ combination increased

$$H^{\bullet} + H^{\bullet} \text{ ------- } H_2 \text{ , } OH\bullet + OH\bullet \text{ ---------} H_2O_2$$

(toxic)

Effect of radiation on cancer:

Cancer (tumor): is a group of cells that divide to give a rather loosely organized mass of cells. The cancer cells are relatively independent on the normal control mechanism of the body. Tumors are often ***hypoxic and radio resistive*** that makes them more difficult to cure

Cells can be divided into two types according to their response to radiation:

1- ***radiosensitive cells***: like skin, bone marrow and gonads.

2- radioresistive cells: like brain, kidney, muscle and liver

The cure of cancer depends on:

1. The type of radiation used.
2. The type of cells to be irradiated
3. The environment of the cells (blood &O_2).
4. The relative biological effect (RBE) of radiation

RBE = Dose (Gy) to produce some effect with X or ∂ rad/ Dose (Gy) to produce the same effect with tested rad.

Particle	RBE
Electron	1
X or gamma ray	1
Fast neutrons	10
Alpha particles	> 20

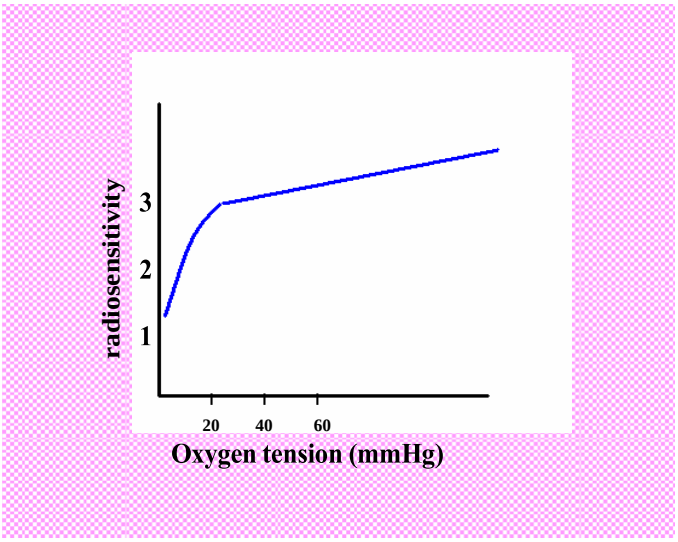
Requirement for radiotherapy:

1. Determination of the tumor by accurate diagnosis.
2. Determination the quantity and quality of radiation required for radiotherapy
3. Dose and dose rate of radiation
4. Linear energy transfer of radiation.
5. Dose fractionating
6. Dose dividing.
7. Oxygen enhancement
8. Bragg peak calculation

Bragg peak: It is the region of increased ionization seen near the end of a particle beam. It is possible to put the Bragg peak at the depth of lesion being treated while the superficial tissues traversed by particles with low LET values. The electron loses most of its energy at the end of its track when its energy <100eV

The Oxygen Enhancement of Radiation Effect (OER):

Dose of rad. needed to give an effect under anoxic conditions/ Dose of rad. needed to give the same effect under oxygenated conditions



- In the presence of molecular oxygen, cells are more sensitive to X and gamma rays than when they are irradiated at very low levels.

- Oxygen modifies the quantitative amount of radiation damage. It merely reduces the dose of radiation required to give certain biological effect.

OER is between 2 and 3 for most biological systems