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Paper: Radiation protection

Qus:1
Law of Bergonie and Tribondeau:
Introduction:

- One of the Radiology's most important discoveries was made the law of bergonie and Tribondeau.
- In 1906 ,two French scientist, bergonie and Tribondeau observed the radiosensitivity of biological tissue is directly proportional to the mitotic activity and inversely proportional to the degree of differentiation of its cells.
- Basically law states that the radiosensitivity of living tissue varies with maturation and metabolic.

Main points of law:

1. Stem cells are radiosensitive while mature cells are radioresistnant.
2. Tissues having high metabolic activity are radiosensitive.
3. Younger tissues and organs are radiosensitive.
4. High proliferation rate for cells and high growth rate for tissues results in increased radiosensitivity.

Radioresistant cells:

- Bone
- Liver
- Cartilage
- Muscles
- Nervous system
- Kidney

Radiosensitive cells:

- Lymphoid tissues
- Basal cells
- Germinal cell
- Hematopoietic tissues
- Epithelium of the GI tract
    - *low radiosensitive cell;* Nerve cell and muscle
    - *Intermediate*;
      ,osteoblast, endothelial cells, fibroblasts.
    - *High radiosensitive*; lymphocytes , stem cells, mucosal cells nad erythroblast.
- Children are more radiosensitive than adults.
- Fetuses more radiosensitive than children .
- Radiosensitivity of Female gonads;
    - Temporary sterility 1.5Gy (150 rad)
    - Permanent sterility 5Gy (500 rad).

- Radio sensitivity of male gonads;
    - Temporary sterility 2.5Gy (250 rad)
    - Permanent sterility 6Gy (600rad).

Physical factors that affects Radiosensitivity:

1. LET
2. RBT
3. Protection and fractionation

1. **LET:** Linear energy transfer is measure of the rate at which energy is transferred from a beam of radiation to the tissue through which it travels .
    a. It is the other method of expressing Radiation quality and determining the value the value of radiation weighting factor (**WŔ)**.
    b. ***Unit of LET :***LET is expressed in units of kiloelectron volt of energy transferred per micrometer of track length in soft tissue (**KeV/um).**
    c. LET of diagnostic x-ray: approximately 3keV/um.
    d. Higher LET ,ionization occurs frequently which increasing the probability of interaction with the target molecule.
    e. Increased LET means more biological damage.

Classification of LET :

- Low LET radiation
- High LET radiation

Low LET Radiation:

- This type if ionizing radiation that deposit less amount of energy along the track .
- Range;0.2_3KeV/um
- Examples;
  X-rays ,Gamma rays, Positrons,electons.

High LET Radiation:

- This type of ionizing radiation deposit large amount of energy in a small distance.
    - Range;3 _200KeV/um
    - Example;
      Alpha Particles,neutrons, protons.

2. **RBE:** The national Bureau of standards in 1954 define Relative Biological Effectiveness as ;the ratio D250/D where D250 and Dr are respectively the dose of x-ray and the test radiation required for equal biologic effect.
    - Whereas radiation with kower LET than diagnostic x ray have an RBE less then 1.
    - Radiation with higher LET have higher RBE.
    - ***RBE for diagnostic x _ray;***
      is 1.

- **Example:** to achieve 50%survival fraction 250 kV xray needs 2 Gy but the tested particle needs 0.66 Gy.

3 . Protraction:

Definition: the time ar which total dose is to be delivered.

- The dose is delivered continuously but at lower dose rate until all of the dose given .

Example:

- If give an exposure of 600 rads at 300 rads/ minute the effects will be less than if the same exposure is given at 600 rads / minute, This is called protection.

4.Fractionation:

Definition:

- when high dose is breaks in smaller doses.
- The extension of dose over a long periods of time in order to minimize unwanted radiation effects.
- Fractionation reduces effect because cells undergo repair and recovery between doses.

Example:

- Lethal _ 600 rad given in 3 min
- Non-lethal _ 600 rad given at the rate of 200 rad per min in 12 fractions of 50 rad separated by 24 hours.

Qus:2

1. **Effect of irradiation of macromolecules:** when macromolecules are irradiated in solution in vitro three main effects occurs.
    - **Main _chain Scission:**
        - it is the breakage of backbone of long chain macromolecules.
        - This results in the reduction of long,single molecule into many small**er** molecules.
        - Main chain scission reduces not only size of the macromoleciles but also viscosity of solution.
        - Measurement of viscosity determines the degree of main chain scission.
    - **Cross _linking:**
        - Some macromolecules are small have spur like structure that extend off the main chain.
        - Thes sides structures can behave as through they had sticky substance on end and attach to nearby molecules. This process us called cross linking.
    - **Point lesions:**
        - Radiation interaction with macromolecules are also can result in disruption of single chemical points producing point lesion.
        - It is not detectable .
        - Point lesions can result in the stochastic radiation effects observed at the whole body level.

- **Note:** all of above types of radiation effects on macromolecules are reversible through intracellular repair and recovery.

2. **Radiolysis of water:**

Definition: when water is irradiated it dissociate into other molecular products this action is called radiolysis of water.

- Human body is contain 80% of water .
- When H^2O is irradiated it is ionized and dissociate into an ion pair.
- At initial ionization,first the ion piar may be rejoin a stable water molecule.
- Second,if these ions do not rejoin it has possibility for negative ion to attach to another water molecule.
- HOH+ and HOH- ions are unstable.
- Finally the radiolysis of water is the formation of ion pair H+and OH- and also two free redicals have no biological damage occurs.
- OH*free redical join with similar molecule to form hydrogen peroxide which is poisonous to cell as a toxic agent.
- H* free redical can interact with Oxygen yo form hydroperoxyl redical.
- Hydrogenperoxyl radical with hydrogen peroxide be the principle damaging product after the radiolysis of water.
- Free redical are energetic molecule because of their unique structure.

3. **Effect of radiation on cell:**
    - Cell death may be apostotic or mitotic
    - Radiation damage of cells can either occur directly or indirectly.
    - Most of damage occurs to cell DNA may be of it's double or single strand breaks ,but cell have repair mechanism to fix the damage but these mechanism are not perfect.
    - Chromosome inside DNA can also be damaged.
    - *Direct radiation damage;*
        - In direct radiation damage DNA hit by radiation directly.
        - When DNA molecules are exposed directly to UV,energy absorbed by the light makes the molecules more reactive.
    - *Indirect radiation damage;*
        - *In* indirect damage radiation hits water and other organic molecules generating free radicals.
        - Free radicals can react with DNA and cause structural damage, this damage is common.
        - It is proved by study that up to 50,000 DNA lesions occurs daily.
    - It is lucky that DNA has the power of repairing damage.
    - However not all sites are repaired which cause mutation.
    - This mutation passed onto daughter cells as DNA replicates during mitosis.
    - Cancer cells whose DNA is damaged beyond repair die, they are broken down and eliminate by body.
4. **Protraction and Fractionation:**
    - If the dose is delivered continuously but at lower dose rate it is called protracted.

- When radiation dose deliverd at the same dose in equal portions at regular intervals is said to be fractionated.
- Dose protracted and fractionation cause less effect because time is allowed for intracellular repair and tissue recovery.
- Dose fractionation used regularly in radiation oncology.
- **Example:**

Protection:

- 600 rad delivered in 3 min at dose of 2Gy/mint the mouse die.
- But when 600 rad is delivered at 10 mGy/hr for time 600 hours , mouse will survive.

Fractionation:

- ***6***_Gy dose delivered at same dose rate but in 12 hours fractions of 500 mGy all separated by 24 hr ,mouse will survive***.**

***Qus*:3**

Early *effects of radiation on human:*

After exposure to a high radiation dose ,human can experience response within few days to few weeks ,this response is called deterministic effect. Such early effects is dose related.

1. **Acute radiation syndrome:**
    1. The sequence of events that follow high level radiation exposure leading to death witnin days or weeks is called acute radiation syndrome.
    2. These Syndromes are hematologic death , gastrointestinal death , and central nervous system***.***

Hematologic syndrome*:* Radiation Dose is the range of approximately 2 to 10 Gy produces hematologic syndromes***.***

- Initially experiences mild symptoms of the predomal syndrome appears in few hours***.***
- Latent period follows can extend as long as 4 weeks .
- Period of manifest illness is characterized by possible vomiting***,*** mild diarrhea ,lethargy ,malaise and fever.

Gastrointestinal syndrome*:*

Radiation dose is 10 to 50 Gy results ***in*** gastrointestinal syndrome***.***

- The predomal symptoms of vomiting and diarrhea occurs within hours of exposure***.***
- *Latent period**:*** 3 to 5 days but no symptoms.
- *Manifest illness; begins with second wave of nausea* and vomiting with diarrhea.

Central nervous systems syndrome:

After radiation dose in excess 50 Gy or higher received then a series of symptoms occurs that lead to death within matter to hours to days.

- During *Initially onset;* period may be highly nervous and confused.
- *Latent period;*burning sensation in skin ,may lose vision and consciousness within first hours this may be followed by latent period.
- *Manifest illness;* during which symptoms of prodromal stage return but are more severe.

2. Local tissue damage:

Every organ and tissue of the body can be affected by partial body irradiation. This effect is cell death which results in shrinkage of organ this effect can lead to total lack of function for that organ or tissue.

Example of local tissues damage that effect quickly are *Skin & Gonads.*

- ***Effects on skin;***
  - Skin having three layers,dermis ,epidermis and subcutaneous layer , all responses to radiation exposure.
  - Earlier mnifest; damage to basal cells.
  - Skin damage was seen as erythema (perhaps the first biologic response to radiation)sunburm like redding of skin along with desquamation .
  - Single dose of 3 to 10 Gy mild erythema occurs within first or second day.
  - At higher doses second wave erythema followed by moist desquamation.
- **Effects on gonads:** Human gonads are critically important target organ.Radiation to dose as low as 100 Gy (10 rad)have been observed .Male ,female gonads respond differently to radiation.
  - *Female gonads:* irradiation to ovaries early life reduce their size .
  - After puberty irradiation causes suppresion and delay menstruation.
  - At fatel life ovaries are radiosensitive.
  - Temporary sterility _ 2Gy (200 rad).
  - Permanent sterility _ 5Gy (500rad).

    Male gonads :
  - Testes Are similar to ovaries atropy occurs after high radiation doses.
    - The spermatogonia stem cells signify the most sensitive phase in gameyogenesi of spermatozoa.
    - Dose as low as 100 Gy can reduce the spermatozoa number.
    - *Temporary sterility* _ 2 gray (200 rad)
    - Permanent sterility _ Five gray (500rad).

3.Hematologic effects:

Hematopoietic systems consist of bone marrow,circulatory blood, lymphoid tissue.

- Hematopoietic system is another example of cell renewal system.
- Nomal cell growth and development determine the effect of radiation on this system.
- Principal response of hemopoietic system to radiation exposure is decrease in the number of cell types of blood cells in the circulatory blood.
- After exposure the first cells to become affected are lymphocytes and these cells reduce in number called lymphopenia.
- Radiation effect on granulocytes experience rapid increase jn number called granulocytosis.
- Depletion of platelets called thrombocytosis after radiation develop slowly.

4.Cytogenic effects:

The study of chromosome damage from radiation exposure is called cytogenetics. Chromosome damage takes on following different forms.

- *Chromosome aberration:*
    - *The* chromosome aberration visualized at metaphase consist of chromosome with material missing from the ends of two chromatids and two acentric fragments called isochromatids.
- *Chromatids deletion:*
    - The breakage of a chromatid is called chromatid deletion.
    - During S_ phase both remaining chromosome and deletion are replicated.
- *Reciprocal translocation:*
    - Reciprocal translocation are multi_ hit chromosome aberration that requires karyotypic analysis for detection.
    - Radiation induced reciprocal translocation results in no loss of genetic material simple a rearrangement of the genes.