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Biological Radiation hazards

second Lecture

Third Stage

By
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Radiation biology is the study of the action of ionizing radiation on living organisms

- **Different types of ionizing radiation**

- energy absorption at the atomic and molecular level leads to biological damage
- Repair of damage in living organisms
- Basic principles are used in radiation therapy with the objective to treat cancer with minimal damage to the normal tissues

Types of ionizing radiations

• Radiation is classified into two main categories:

1- Non-ionizing radiation (cannot ionize matter)
2- Ionizing radiation (can ionize matter)

Two major categories of ionizing radiation:

- Directly ionizing radiation (charged particles) electrons, protons, alpha particles, heavy ions. Deposits dose right away
- Indirectly ionizing radiation (neutral particles) photons (x-rays, gamma rays), neutrons. Interact with charged particles that deposit dose

Fundamental Principles of Radiobiology

Some tissues are more sensitive than others to radiation exposure. Such tissues usually respond more rapidly and to lower doses of radiation.

Reproductive cell are more sensitive than nerve cells.

This and other radiobiologic concepts were detailed in 1906 by two French scientists.

physical factors and biologic factors affect the radio biologic response of the tissue. Knowledge of these radio biologic factors is essential for understanding the positive effects of radiation oncology and the potentially harmful effects of low-dose radiation exposure.

the principal aim of the study of radiobiology is to understand radiation dose-response relationships. A dose-response relationship is a mathematical and graphic function that relates radiation dose to observed response.

LAW OF BERGONIE AND TRIBONDEAU

In 1906, two French scientists, Bergonie and Tribondeau, theorized and observed that radiosensitivity was a function of the metabolic state of the tissue being irradiated.

This has come to be known as the law of Bergonie and Tribondeau and has been verified many times. Basically, the law states that the radiosensitivity of living tissue varies with maturation and metabolism as follows

- Stem cells are radiosensitive; mature cells are radioresistant.
- Younger tissues and organs are radiosensitive.
- Tissues with high metabolic activity are radiosensitive.
- A high proliferation rate for cells and a high growth rate for tissues result in increased radiosensitivity.

This law is principally interesting as a historical note in the development of radiobiology. It has found some application in radiation oncology. In diagnostic imaging, the law serves to remind us that fetuses are considerably more sensitive to radiation exposure as are children compared with mature adults.

PHYSICAL FACTORS THAT AFFECT

RADIOSENSITIVITY

When one irradiates tissue, the response of the tissue is determined principally by the amount of energy deposited per unit mass—the radiation dose in Gyt (rad). Even under controlled experimental conditions, however, when equal doses are delivered to equal specimens, the response may not be the same because of other modifying factors. A number of physical factors affect the degree of radiation response.

 Linear Energy Transfer

Linear energy transfer (LET) is a measure of the rate at which energy is transferred from ionizing radiation to soft tissue. It is another method of expressing radiation quality and determining the value of the radiation weighting factor (WR) used in radiation protection. LET is expressed in units of kiloelectron volt of energy transferred per micrometer of track length in soft tissue (keV/µm).

- The LET of diagnostic x-rays is approximately 3 keV/µm.

The ability of ionizing radiation to produce a biologic response increases as the LET of radiation increases.When LET is high, ionizations occur frequently, increasing the probability of interaction with the target molecule.

 Relative Biologic Effectiveness

As the LET of radiation increases, the ability to produce biologic damage also increases. This effect is quantitatively described by the relative biologic effectiveness (RBE).

$$\text{RBE} = \frac{\text{dose of standard radiation necessary to produce a given effect}}{\text{dose of test radiation necessary to produce the same effect}}$$

Diagnostic x-rays have an RBE of 1. Whereas radiations with lower LET than diagnostic x-rays have an RBE less than 1, radiations with higher LET have a higher RBE.

Type of Radiation	LET (keV/μm)	RBE
25 MV x-rays	0.2	0.8
^{60}Co gamma rays	0.3	0.9
1 MeV electrons	0.3	0.9
Diagnostic x-rays	3.0	1.0
10 MeV protons	4.0	5.0
Fast neutrons	50.0	10
5 MeV alpha particles	100.0	20
Heavy nuclei	1000.0	30

Table 1: Linear Energy Transfer and Relative Biologic Effectiveness of Various Radiation Doses

 Protraction and Fractionation

If a dose of radiation is delivered over a long period of time rather than quickly, the effect of that dose is less.

Stated differently, if the time of irradiation is lengthened, a higher dose is required to produce the same effect.

This lengthening of time can be accomplished in two ways.

 If the dose is delivered continuously but at a lower dose rate, it is said to be **protracted**. Six gray (600 rad) delivered in 3 -minutes at a dose of 2 Gyt/min is lethal for a mouse. However, when 6 Gyt is delivered at the rate of 10 mGyt/hr for a total time of 600 hours, the mouse will survive.

- Dose protraction and fractionation cause less effect because time is allowed for intracellular repair and tissue recovery.

 If the 6-Gyt dose is delivered at the same dose rate, but in 12 equal fractions of 500 mGyt, all separated by 24 hours, the mouse will survive. In this situation, the dose is said to be **fractionated**.

Radiation dose fractionation reduces effect because cells undergo repair and recovery between doses. Dose fractionation is used routinely in radiation oncology.