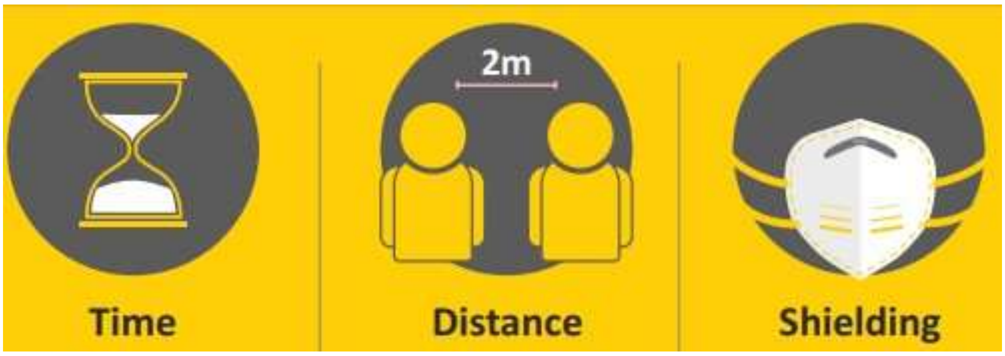

Principles of Radiological Protection

Second Lecture (2)

First semester / Second year

By

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Principles of Radiological Protection

Radiation safety principles aim to limit exposure to ionizing radiation for radiation therapy, people affected by cancer and the general public. The new system of dose limitation introduced the three principles of radiation protection:

1. No practice shall be adopted unless its introduction produces a positive net benefit.
2. All exposures shall be kept as low as reasonably achievable.
3. The doses given to individuals shall not exceed the limits recommended in the appropriate circumstances.

In order to keep the risk of stochastic damage from ionizing radiation low, there are three general principles for dealing with ionizing radiation. These principles are based on recommendations from the International Commission on Radiological Protection (ICRP):

- Justification of a practice
- Optimization of protection
- Dose limitation.

Justification of a Practice:

Justification is a process that requires that before any new class or type of practice involving ionizing radiation can be introduced in any country, the government must first assess it to determine whether the individual or societal benefit outweighs the health detriment it may cause. It means any exposure to ionizing radiation is only permitted when it is associated with a reasonable benefit to individuals or to society.

In medicine, where ionizing radiation is used, the requirement for justification takes a very specific form; with medical applications, a physician with expertise in the field of radiation protection has to declare the so-called ***"justifying indication"***. The justifying indication requires that the health benefits of exposure to ionizing radiation outweigh the risk in this special application to a specific person.

Optimization of Protection:

Even if the radiation exposure is justified, the overriding requirement of optimization requires that any unnecessary radiation exposure and contamination be avoided. Optimization aims to keep the risks low, which is:

- The likelihood of exposure
- The number of exposed persons
- The individual dose to which a person is exposed

The guiding principle of radiation safety is **"ALARA"** which stands for ***"as low as reasonably achievable***". It means avoiding exposure to radiation that does not have a direct benefit to you, even if the dose is small. To do this, you can use three basic protective measures in radiation safety: time, distance, and shielding, as shown in figure 1.

Figure (1): Shows the three basic protective measures in radiation safety.

1. **Time:** simply refers to the amount of time you spend near a radioactive source. Minimize your time near a radioactive source to only what it takes to get the job done. If you are in an area where radiation levels are elevated, complete your work as quickly as possible, and then leave the area.

   (Why?) The less time spent near a radiation source, the less radiation is absorbed, as shown in figure 2. This is especially important for personnel such as radiation therapists and physicists preparing radioactive sources and for nursing staff when caring for individuals who have a radioactive source in body tissue.

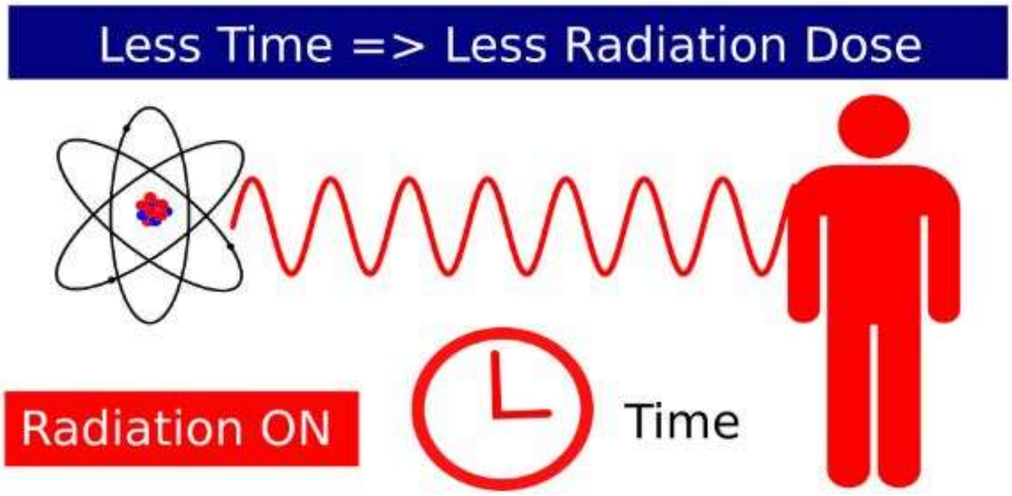

Figure (2): Shows the effect of time on radiation exposure.

2. **Distance:** refers to how close you are to a radioactive source. Maximize your distance from a radioactive source as much as you can.

   (Why?) If you increase your distance, you decrease your dose, as shown in figure 3. The inverse-square law states that radiation exposure and distance are inversely related. That means that as the distance from the source increases, the intensity of the radiation decreases.

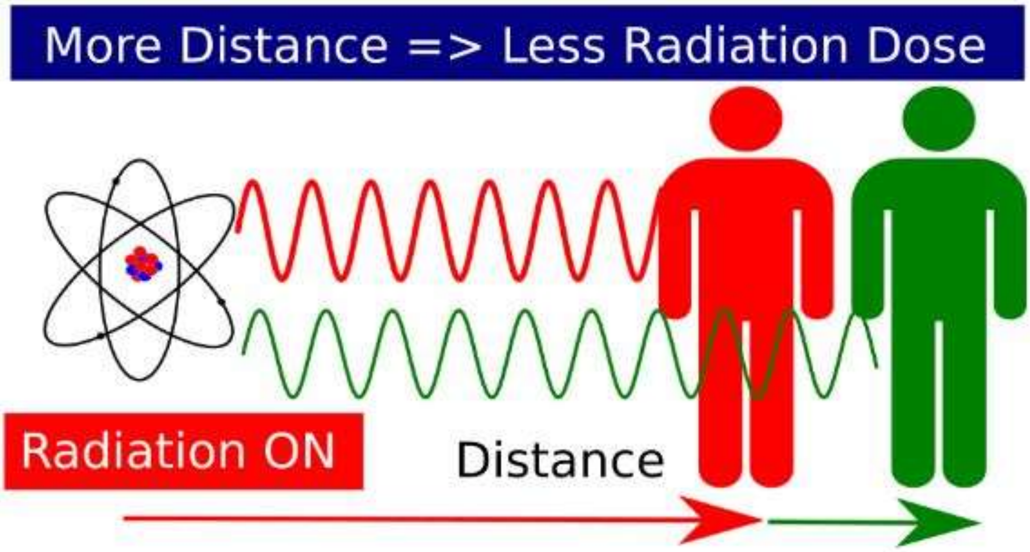

Figure (3): Shows the effect of distance on radiation exposure.

3. **Shielding:** To shield yourself from a radiation source, you need to put something between you and the radiation source. The most effective shielding will depend on what kind of radiation the source is emitting. Some radionuclides emit more than one kind of radiation. Standard shielding devices include lead aprons, thyroid, and eye shields.

   Radioactive sources are transported by licensed personnel in lead containers. Brachytherapy procedures are undertaken in a specialized unit or ward with appropriate facilities, and individuals are generally isolated in a single room. Departments are designed with radiation protection and shielding at the forefront of planning. Radiation therapy workers are required to wear thermo luminescent dosimetry **(TLD)** badges to measure radiation exposure, which is monitored by regulatory authorities.

   Other radiation measurement devices, such as Geiger counters, are used to monitor areas where radioactive sources are used. Appropriate signage must be in place in the presence of any radioactive substance, and education and information must be provided to all individuals who may be impacted. Appropriate procedures and notifications must be followed. These should be clearly outlined in the clinical environment as part of radiation safety and hospital policy.

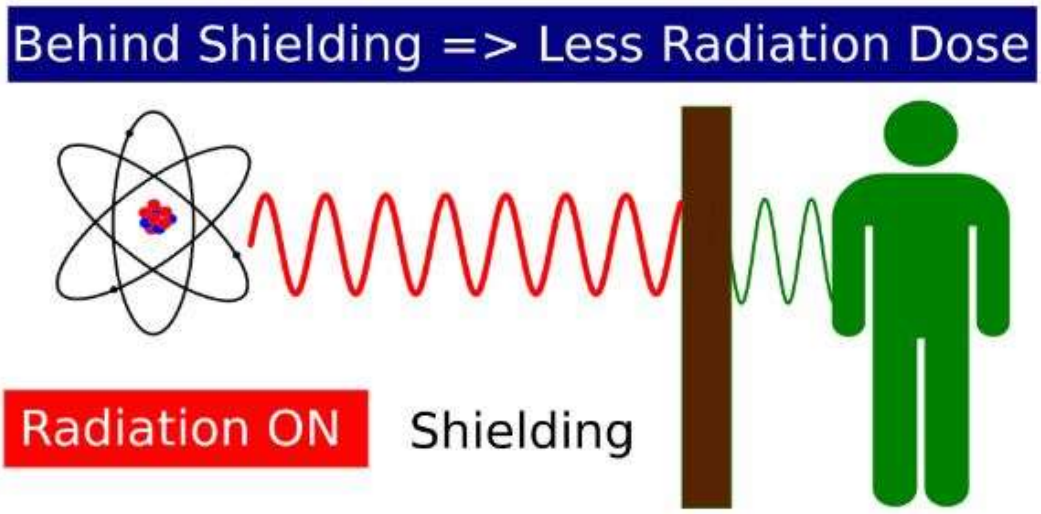

Figure (4): Shows the effect of shielding on radiation exposure.

Dose Limitation:

Radiation from planned exposures must not exceed certain dose limits; it's called the ***"dose limitation"***. Different limit values apply to the general population and people occupationally exposed to radiation. The limit values determine the maximum total radiation an individual person may receive from justified activities (for example, due to the operation of nuclear power plants). The ways in which people can be exposed to ionizing radiation are:

- By breathing (Inhalation).
- Intake through food (Ingestion).
- Externally, through ambient radiation.

Limit values for certain exposures ensure that the effective dose and organ doses are strictly committed to, and that no single way determines the entire exposure. For occupational radiation exposure, there are different limit values for:

1. The whole body or for body organs.
2. Different periods (month, year, working life).
3. Different groups of people (adolescents, adults, women of childbearing age, pregnant women).

However, there are no limit values for medical radiation exposure, i.e., for diagnostics or radiotherapy. Here, the justifying indication and the requirement for optimization apply by specialist physician to the individual patient’s condition.

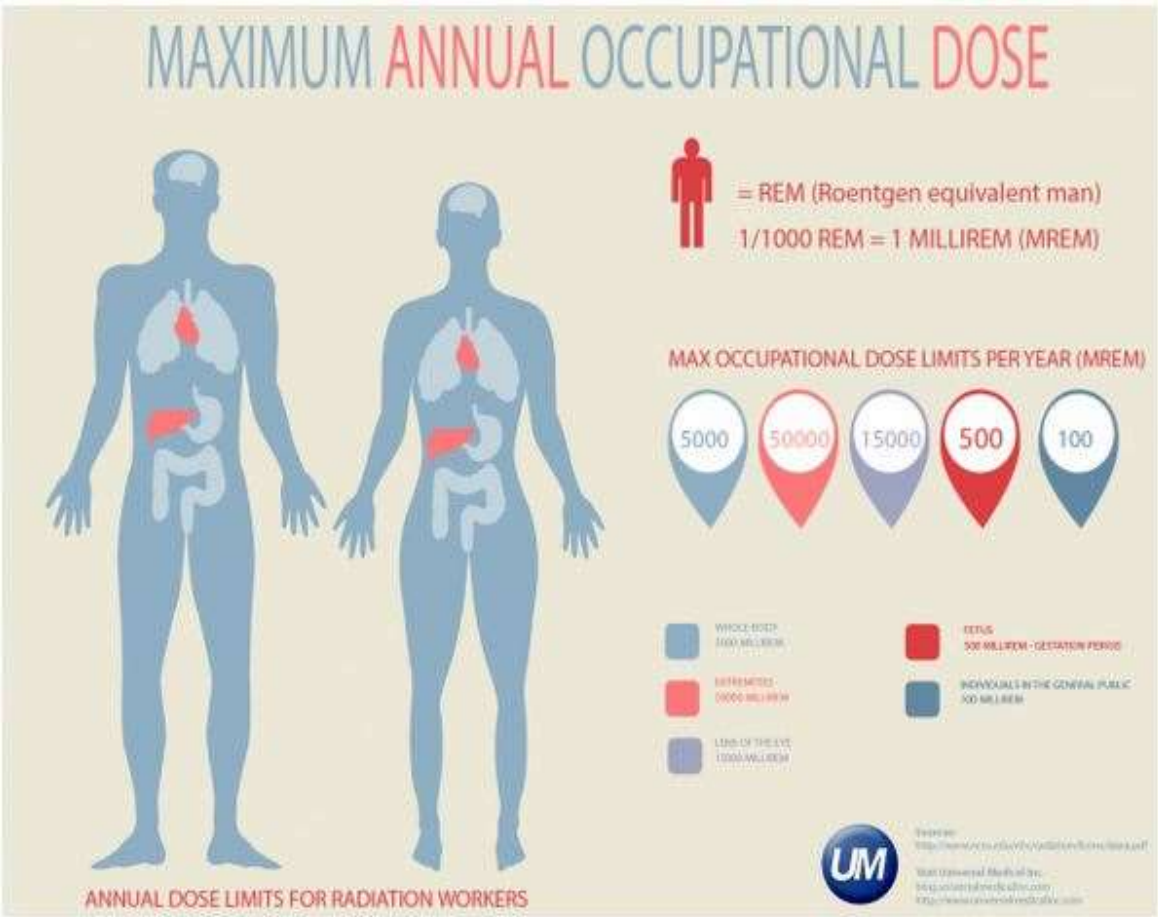

Figure (5): Shows the dose limits.

1. Maximum Permissible Occupational Doses:

The limit value for the effective dose to protect occupationally exposed people is 20 mSv in a year. ***"The maximum permissible dose"*** **(MPD)** is the upper limit of allowed radiation dose that one may receive without the risk of significant side effects, while the annual whole-body dose limit for physicians is 50 mSv. The scattered radiation dose to the patient and the medical personnel should be less than the above radiation doses. Reduction of the amount of radiation implies proper selection of the type of examination and imaging modality in order to minimize the exposure to the patient and personnel.

2. Maximum Permissible Public Doses:

The dose limit for non-occupational workers and public is set at two percent of the annual occupational dose limit. Therefore, it must not exceed 100 mrem in a year; it's equal to 1 mSv in a year. This exposure would be in addition to the annual background radiation. A single high-level radiation exposure (i.e., greater than 100 mSv) delivered to the whole body over a very short period of time may have potential health risks. From the follow-up of the atomic bomb survivors, we know acutely delivered, very high radiation doses can increase the occurrence of certain kinds of disease (e.g., cancer) and possibly negative genetic effects.

These calculated risks are compared to other known occupational and environmental hazards, and appropriate safety standards and policies have been established by international and national radiation protection organizations (e.g., the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements) to control and limit potential harmful radiation effects.

3. Maximum Permissible Patient Doses:

Doses to inaccessible organs can be measured using body-equivalent phantoms. Radiological imaging methods (X-Ray diagnostics, nuclear medicine, scintigraphy, NMRI magnetic resonance imaging, and ultrasonography) examine the structures and processes hidden inside the organism. Surface doses can also be conveniently measured using TLDs.

Table (1): Shows typical organ doses from various radiological examinations.

Device	Relevant Organ	Dose (mSv)
Dental X-Ray	Brain	0.01
Chest X-Ray	Lung	0.1
Screening Mammography	Breast	3
Adult Abdominal CT	Stomach	10
Neonatal Abdominal CT	Stomach	20

4. Whole-Body Dose Limits:

The whole-body dose limit is assumed to be ***"the deep-dose equivalent"*** **(DDE)**, is the dose equivalent at a tissue depth of 1 cm. It's applied to external exposure. ***"The lens dose equivalent"*** **(LDE)** is the dose equivalent to the lens of the eye from an external source of ionizing radiation at a tissue depth of 0.3 cm. ***"The shallow-dose equivalent"*** **(SDE)** is the external dose to the skin of the whole-body or extremities from an external source of ionizing radiation at a tissue depth of 0.007 cm averaged over an area of 10 cm^2. It's applied to external whole-body or extremity exposure.

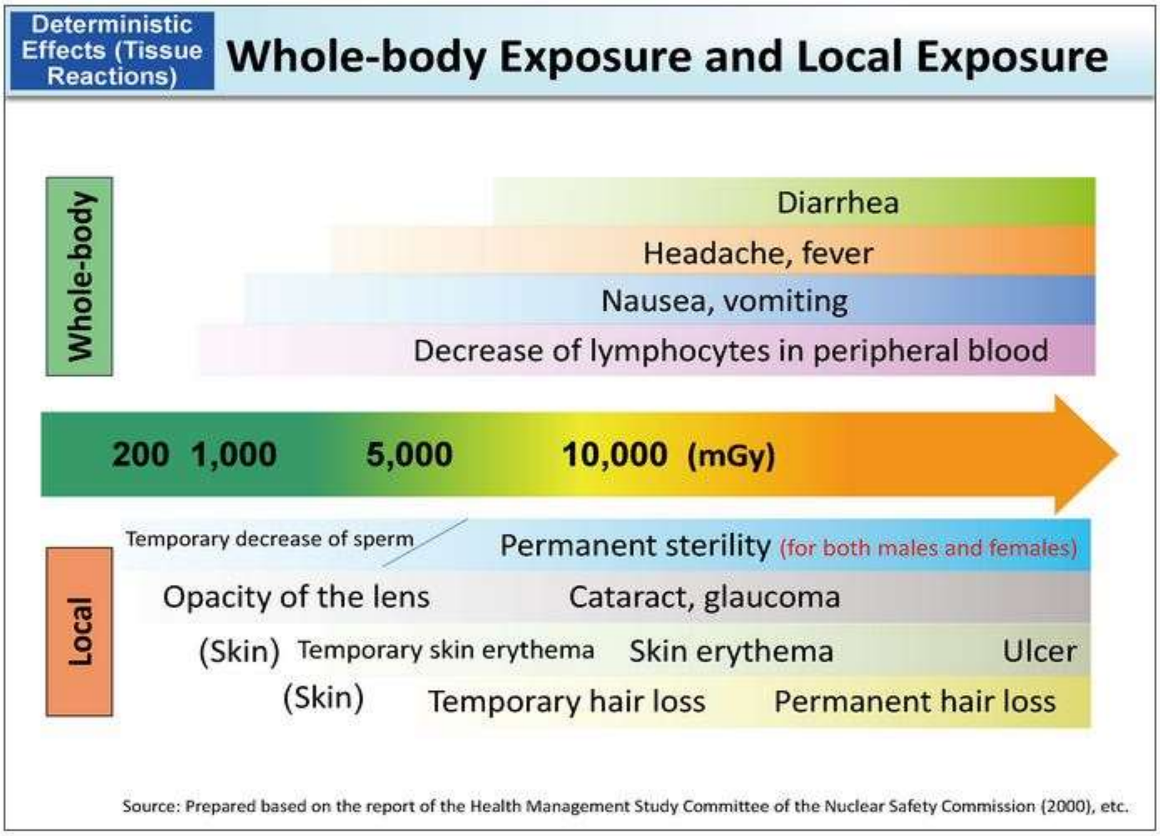

Figure (6): Shows the Whole-Body dose limits.

5. Dose Limits for Tissue and Organs:

"The maximum or total organ dose equivalent" **(TODE)** is the sum of the deep dose equivalent and the committed dose equivalent to the organ receiving the highest dose, while ***"the committed dose equivalent"*** **(CDE)** is the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following intake. Table 2 shows the annual maximum permissible dose.

Table (2): Shows the annual maximum permissible dose.

Effective Dose		**Occupational Dose Limit**	**Public Dose Limit**
		20 mSv per year, average over defined periods of 5 years	1 mSv per year
Annual equivalent dose	**The lens of the eye**	150 mSv	15 mSv
	The skin	500 mSv	50 mSv
	The hands and feet	500 mSv	No Recommendation
	For emergency Workers	Effective Dose 100 mSv Lens of eyes 300 mSv Skin 1000 mSv (1 Sv)	