Radiobiology I

FOR RADIOGRAPHER STUDENT

prepared by

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Content:

Course description

This course include all what the radiographer student should know about the radiobiology in this educational level m including the mean of radiation, its sources and types, what is mean by nuclear reactors as well as its types and indication, this course give bereave data about radiation quality and protection finally we try to give enough data about the radiation effect on the different body tissue and organs try to help the student to be effective member on his team work

Course knowledge

By the end of this course, the student will be able to

- Identify the radiation definition, its types and sources
- Has enough data about the nuclear reactors as its definition, structure, types and indications
- Recognize the meaning and methods of radiation protection
- Has enough data about radiation quality.
- Has enough data about the effect of therapeutic and diagnostic radiation on different body organs.
- Finally has enough data about measurement units of radiation.

Course skills

By the end of this course, the student will be able to

- How to protect the worker and the patient from the hazard of radiation by the use of the protective barrier.
- How to deal with patient with radioisotope material

Course overview

topics	Interactive lecture
Radiation(definition, types & sources)	2 hours
Nuclear reactors	2 hours
radioisotopes	2 hours
Radiation protection	2 hours
Radiation quality	2 hours
Effect of radiation	2 hours
Effect of radiation	2 hours
Effect of radiation	2 hours
Effect of radiation	2 hours
Units of measurement	1 hours
Revision	3 hours
Total course hours	22 hours

Chapter 1

Radiation

Objectives:

At the end of this chapter the student will be able to:

- Defied the definition of radiation
- Identify the types of radiation
- Recognize the sources of radiation
- Satisfied information about the factor determined the effect of radiation
- Recognize the methods to identify the radiation dose

Definition of radiation:

In physics, radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium This includes:

Electromagnetic radiation, such as radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma radiation (γ)

Particle radiation, such as alpha radiation (α), beta radiation (β), and neutron radiation (particles of non-zero rest energy)

Acoustic radiation, such as ultrasound, sound, and seismic waves (dependent on a physical transmission medium)

Gravitational radiation, radiation that takes the form of gravitational waves, or ripples in the curvature of space-time

Radiation is often categorized as either ionizing or non-ionizing depending on the energy of the radiated particles. Ionizing radiation carries more than 10 eV, which is enough to ionize atoms and molecules, and break chemical bonds. This is an important distinction due to the large difference in harmfulness to living organisms. A common source of ionizing radiation is radioactive materials that emit α, β, or γ radiation,

consisting of helium nuclei, electrons or positrons, and photons, respectively. Other sources include X-rays from medical radiography examinations and muons, mesons, positrons, neutrons and other particles that constitute the secondary cosmic rays that are produced after primary cosmic rays interact with Earth's atmosphere

Types of radiation:

Non-ionizing radiation

Ionizing radiation

1-Non-Ionizing Radiation:

Any type of electromagnetic radiation that does not carry enough energy to ionize an atom is called non-ionizing radiation.

An atom becomes ionized when it loses or gains an electron.

Ionizing radiation causes a chemical change and thus causes more damage than non-ionizing radiation. Still, observable effects can be tracked from non-ionizing radiation.

Visible light, infrared light, microwaves, and radio waves are some examples of non-ionizing radiation.

The light from the sun that reaches Earth is largely non-ionizing radiation, yet some ultraviolet rays (which have the ability to ionize) do reach the surface of Earth as well.

Infrared or laser light can cause burns to skin and damage to eyes, depending on the levels of energy they carry.

Laser light energy levels can also be controlled to avoid skin and eye damage.

Typical household laser pointers are designed to do no damage to skin. Microwaves carry enough energy to heat surfaces, which is why they are used in microwave ovens.

Some sources say that the energy levels found near low-frequency ectrical fields by power lines can cause nerves and muscles to respond erratically

2- Ionizing Radiation

The nucleus of an atom can decay or transform releasing energy in the form of either particles or waves.

Alpha decay occurs when the nucleus of a radioactive element, such as uranium, uses the strong nuclear force to release an alpha particle.

Alpha particles occur naturally, yet have enough energy to participate in nuclear reactions.

Alpha particles are exactly the same as helium nuclei, containing two protons and two neutrons each.

When an unstable atom spontaneously decays or transforms, its nucleus releases a beta particle and a neutrino.

The beta particle can be either a positively charged particle (positron) or a negatively charged beta particle similar to an electron.

The neutrino released is electrically neutral.

This process of beta decay occurs when the nucleus of an atom has either too many protons or too many neutrons. The weak nuclear force then causes a neutron to be converted into a proton (or vice versa) in order to become stable.

In general, beta particles are a form of ionizing radiation. There are some low-energy beta particles that do not cause ionization, however. Gamma radiation is a form of ionizing radiation, and thus produces a chemical change in the substance through which it passes.

Elements with high atomic numbers such as lead have the density to be able to absorb gamma rays and prevent them from penetrating. Note, however, that attenuation coefficients can vary with atomic number. Researchers need to take into account more than just atomic number to determine whether an element will block gamma rays.

All forms of ionizing radiation can destroy or cause damage to DNA in cells. Large doses of ionizing radiation have been shown to cause mutations in radiation victims' descendants

Sources of radiation

There are two types of radiation sources:

A) Natural source

B) Artificial source

A - NATURAL SOURCES OF IONIZATION RADIATION

Biosphere is situated in the field of radiation that has existed for millions years.

This field consists basically of two sources - extraterrestrial (cosmic) and terrestrial.

The components of the natural radioactive background are the natural radioactivity of ground, natural activity of atmosphere, natural radioactivity of water, and cosmic radiation.

A typical value of the effective dose obtained by an individual from the natural radioactive background is about 2.5 mSv annually.

Generally the most significant impact on the radiation exposure comes from natural sources of gaseous radon and its daughter products. This radioactive gas that occurs in nature together with uranium and thorium ores, decays by alpha decay and is dangerous in breathing as it causes internal irradiation.

Radon has the largest impact on the exposure of inhabitants in such houses and flats that are built on improper soils

So the natural sources of radiation are:

- Cosmic radiation
- Radiation with terrestrial origin
- Internal contamination
- Radon and its daughter products

ARTIFICIAL SOURCES OF IONIZATION RADIATION

The radiation background has been increased artificially due to the evolution of civilization.

The artificial sources of radiation that have currently the highest impact on the environment and population are as follows:

- medicine sources of ionization radiation
- nuclear explosions
- consumer products
- Nuclear power plants and their fuel cycle

Among the medicine sources of ionization radiation, medicine radio-diagnostic (roentgen) has a dominant position.

Patients from a major part of the population are irradiated by relatively high doses. The average whole-body radiation exposure of an individual, which he obtains from medicine sources of ionization radiation, can be estimated in our conditions as 0, 6 mSv/annually

The tests of nuclear weapons (mainly in the atmosphere) resulted in a radioactive fall that spread practically around the whole globe.

It peaked at the end of 1962 when nuclear powers USSR and USA carried out a lot of test explosions of thermonuclear weapons. Since that time the amount of nuclear arm tests has decreased, however, unfortunately, even these days tests are carried out in certain countries (India, Pakistan, and China).

The radiation exposure resulting from nuclear explosions is higher by factor of more than two than the exposure from natural sources

The mostly distributed household appliance that produces roentgen radiation is color TV apparatus. The annual total radiation exposure from consumer products represents about a hundredth of the exposure from natural sources

The contribution of the operation of nuclear power plants including the whole fuel cycle is less significant than the medicine use of the ionization radiation or from nuclear explosions.

The limit for the effective dose for individual from the population is 1 mSv/annually. However, the actual values achieved in our conditions are lower by the factor of hundreds to thousands.

The peaceful utilization of nuclear power sources thus has a relatively small contribution to the artificial sources of ionization radiation. The public opinions and concerns often do not correspond to these facts

Factors that determine the effect of radiation on the body:

1-The amount of radiation: The greater the amount of radiation that is exposed to the body whenever the impact of harmful biological one on the body.

2-Exposure duration: The shorter the duration of the exposure of the body to radiation, the less harmful biological effect on the body.

3 - Exposure rate: The higher the time spent between the radiation exposure of the body and the less harmful biological effects on exposed

4-Part of the exposed part of the body of radiation: The more the part of the section show the body of radiation whenever the harmful biological effect on the exposed body and the risk is less if the whole body exposure to radiation.

5- Position of exposure: The sensitivity of the body to radiation varies according to the nature of its composition and the rate of division of its cells. The bone marrow, the lens of the eye and the genital glands are more sensitive to radiation.

6 - Age of the exposed body: The biological changes resulting from radiation exposure in fetal age are more pronounced than in puberty or post-puberty. This means that infants and children are more sensitive to radiation than adults

The method of controlling the doses of radiation:

The method of control of doses of radiation depends on the principle of Alarra A-L-A-R-A and know the principle of Alarra: which is the preventive style is followed to control the arrival of the lowest possible dose of the body exhibit.

The method of control in doses of radiation depends on: -

1-Exposure time: Exposure time of radiation as less harmful biological effect and control of exposure time should be done through:

1-Planning work at first.

The use of devices and sources of radiation suitable for speed of termination of work

2- The distance between the exposed source and the exposed body is the simplest way to reduce the dose of exposure where the final dose that reaches the body decreases by the distance between the radioactive source and the exposed body according to the reverse quadratic law

Control of the distance depends on:

A -planning the work to ensure the fares of the body of the radioactive source.

B - The selection of the most appropriate devices that produce radiation ionized sentenced with specifications and factors determine the distance.

3-Preventive barriers:

Any material that intercepts the path of radiation absorbs part of it and times decreasing its intensity and the more thickness of the barriers whenever the amount of radiation absorbed

Examples of protective barriers:.

1-Protective cover of the tube - reinforced concrete and thick walls or.

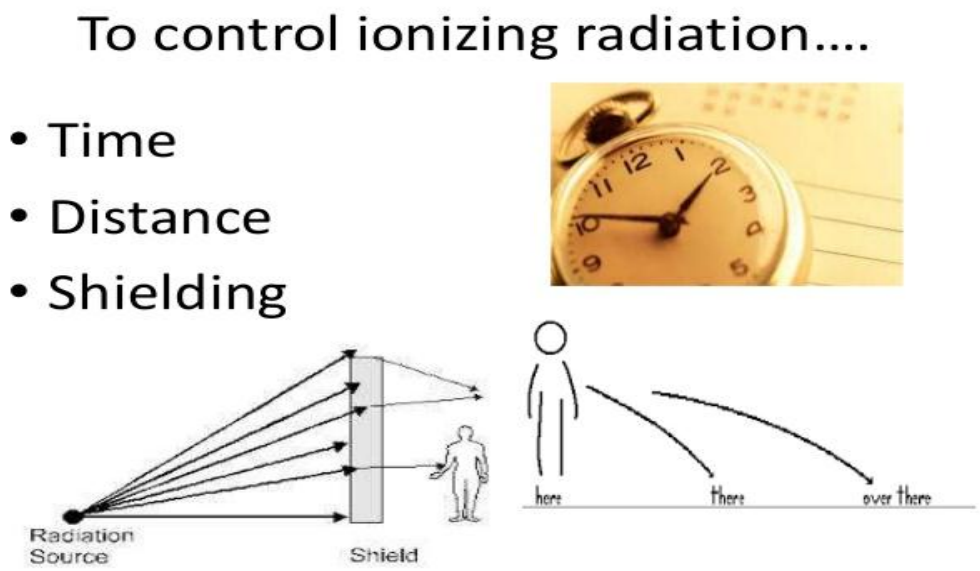
2-Personal protective barriers for sensitive devices of the body. –

4- Ensure before work began:

Providing work, employment and prevention services that provide information about:

- Levels of radiation scanning in the workplace.
- Levels of radiation contamination at the workplace.
- Employees receive training programs.

- Commitment to follow multiple prevention programs.



Total exposure limits for the whole body:

mSv (50 yrs) for radiologists + 18 year

mSv (15 yrs) for trainees

mSvR (5 for the public as a whole)

• Limits of eye exposure dose: mSvert (150 years) for workers

+18

mSvert (45 yrs) for trainees - 18

For the public (15 mSv)

Limitations of exposure dose for women of fertile age: -

- It is required to be in the abdominal area and is estimated to equal 13 millisever.

Limits of the dose of exposure to women during pregnancy: -

It is required to be in the abdominal area of the workers in the field of radiation and estimated by the equivalent of 10 millisever when the discovery of pregnancy

Chapter 2

Nuclear reactor

Objective:

By the end of this chapter, the student will be able to:

- Defined what is nuclear reactors
- Identify the types of reactors
- Have enough data about the isotopes
- Recognize the requirement and the especial requirement for protection when dealing with isotope material
- Recognize the international bodies mean with radiation protection

Nuclear Reactor:

Definition:

A device in which a controlled serial fission process is carried out.

It consists of:

1-The heart of the reactor, the part where nuclear fuel is found in the form of rods of uranium.

2-An inverter: is a substance placed around the fuel to prevent neutrons from moving out of the heart of the reactor.

3-The reactor cooling system: and its purpose is to pull the heat generated by the process of fission from the heart

4-The control system: which is a system to control the rate of reaction and therefore in the reaction of reactor.

5-Nuclear fuel is made in the form of rods or strips of small thickness and are used uranium.

6-Soothing substance: Natural uranium 234 is used to soothing used to slow the neutrons

Working theory:

Thermal energy and radiation particles are generated in the reactor as a result of fissionable of fissionable material in the heart of the reactor such as uranium. This energy is used to obtain energy to generate electricity.

Types of Reactor:

1. Gas-cooled reactor and graphite.
2. Normal compressed water cooling reactor.
3. Ordinary boiling water cooling reactor.
4. Heavy water reactors.
5. Research reactors.

Radioisotopes

Requirements for prevention of nuclear medicine departments or the method of securing and safety department of nuclear medicine and worker inside it:

1- Choosing the right place that does not allow exposure to the public and pollution of the environment by radiation.
2- Provide the appropriate equipment to measure the radiation of these sections.
3- . There should be restricted procedures to protect patients, and repeaters on these sections of the risk of radiation.
4- Provide personal measuring devices for radiation doses Provision of means of measuring personal dose
5- Provide suitable storage places for radiators under use
6- Provide suitable storage places for used radioactive substance
7- Provide suitable places for the conservation of radioactive waste as well as provide a safe means of disposal
8- The Nuclear Medicine Department must have a local license to deal with radioisotopes
9- When using open radioactive isotopes in the treatment of patients should be provided places to patients stay, which meet the requirements of prevention as well as private toilets have a private drainage, unlike drainage on special reservoirs.

10-The working team of the radioisotopes department is composed of :

- A physician specializing in nuclear medicine who holds a personal license for using ionizing radiation.
- A physicist or expert on a guard with a personal license
- A trained radiographer and has a personal license to deal with open isotopes.

Requirements and special requirements for the protection of radioactive isotopic trading.

1- All radioisotopes shall be kept in a continuously covered and labeled type and their radiation.
2- When transferring radioactive materials from one place to another, they must be placed inside containers of lead to prevent leakage radiation. And when transporting radioactive materials, the liquid is transferred to a flask covered with the paper to absorb the moisture and then remove the paper as a radiator.
3- Do not use oral glass pipettes to transport liquid radioactive material, but use a special transparent, scale syringe
4- Radioactive isotopes or solid and liquid radioactive materials are traded from behind a barrier. In the case of liquid radioactive material, should be traded on a smooth table with a semicircular shape with cracks to allow the radioactive material to leak through it without any corners.
5- In the event of a radiological accident, the following measures shall be taken:

- Provide warning signals for light or sound.
- Notify the department's prevention officer
- Identify the pollution area.
- Diluted the radiation material with water
- Pollution is removed using absorbent materials and the prevention expert conducts a radiation survey of the place.

Entry and exit before or after the incident must be calculated according to the following rules:

- Wear special shoes inside the hot lab

- Do not leave the radioactive isotopes room worn in the course of radioactive material circulation
- Measure the radiation dose that the person is subjected to with personal measuring devices
- Put the radiation risk mark in every place where radioactive materials are traded
- Give the liquid radioactive material to the patient in the cups of the cardboard and then the amount of water from the oral and repeated three times to make sure that the whole dose of radiation

Dealing of nursing with the irradiated patient:

When the patient taking the radioactive material becomes radiant and a danger to the surrounding environment. So when vomited or spilling urine or feces on the ground should be taken quick and tight procedures to prevent the leakage of radiation contamination by wiping the patient's special secretion with a piece of cotton cached by long gift , The nurse is required to wear the gloves and lead apron and the cotton is considered as a radioactive waste and then wash the hands with soap and water several times and the official responsible for the prevention of the work of radiation to necessary scanning the area and that is occur when the doses of radiation is small

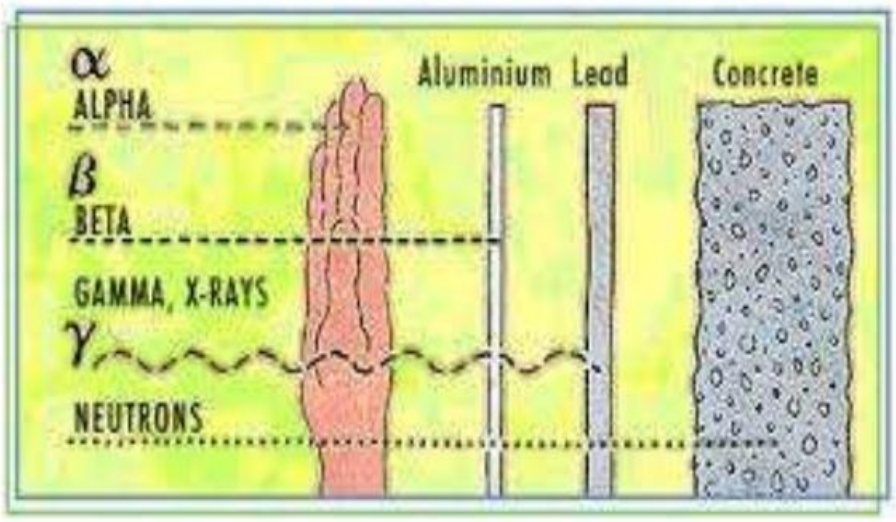
The following should be following in the case of exposure to a radioactive dose more than 35 mm Korean:

- Keep the patient in the hospital and put on the patient's bed a sign of the prohibition of radiation.
- In hot weather the sweat may contain a radioactive substance and the sheets should be disposed of as a radiator.
- A special ampoule should be used for the patient and the waste should be collected in special containers. And the radiation should be measured continuously and then disposed of as a radiator.
- As for the patients nearby, no dangerous in the case of simple doses, but in the case of large doses, it is advisable to put the patient in a private room or in a dormitory with respect to distance.

- **For the service providers to the patient , the following procedures must be follow:**
  - Time - interval separation - Use gloves and lead apron for protection.
  - Avoid the pregnant women and children from visiting and other contact persons must take into account the distance.
  - Radioactive iodine contraindicated with breastfeed because the radioactive material is excreted in the breast milk and reaches the child so we must wean the child before giving the radioactive material.

International organization mean on radiation protection:

1. International Atomic Energy Agency.
2. International Commission on Radiological Protection
3. International Health Organization.
4. International Labor Organization
5. United Nations Food and Agriculture Organization.



Chapter 3

Radiation protection & radiation quality

Objective:

By the end of this chapter, the student will be able to:

- Identify the requirement for diagnostic and therapeutic radiographic devices.
- Identify the different types of prevention barriers.
- Recognize the purpose of radiation quality
- Defined different types of the effect of radiation on the body
- Differentiated the types of radiation dose measurement devices

The requirements for diagnostic and therapeutic radiographic devices: -

Diagnostic radiographic devices:

A - Preventive barriers:

1- Isolation of diagnostic rooms of the surrounding areas to prevent the exposure of workers and public

2- The use of insulating walls of material has the ability to absorb ionizing radiation, such as solid red brick or mutt

3-Take into consideration the installation of the devices directing the radiation to the vacuum

4- Good ventilation in the rooms of radiation.

5- Work ceiling blanket about 2o cm concrete armed.

6-The work of three wings pavilions.

7- Lining rooms radiation by sufficient fire.

Special requirements: -

1-Do not use the X - ray tubes unless the envelope is fully protective

2-Must use a specific radiation where the protective factors are available

3 - Must provide a warning signal on the transmission of radiation

4-Mails and gloves and goggles should be provided in the examination rooms

5 - The theoretical examination should be completed with a rubber band

Therapeutically radiology devices:

Preventive barriers:

- Due to the use of high radiation energy than the diagnostic devices the following should be following:

1 - The use of other insulating materials of reinforced concrete with high intensity

2 - The control units are placed in the isolated room

3 - The work of the doors of an automatic working with the operating device and lined with lead

4 - These units are placed in ground floors.

Special requirements:

1-A statement of the safety guard inside the control room indicates the operation of the device

2- Continuous calibration of the device

3 - The devices must be operated by well trained personnel to be use

4 - The presence of safety keys on the doors of the chamber of radiation

5 - No one exists other than the patient to the treatment rooms

Radiation Quality:

First, the purpose of the Radiation Quality Programs: -

1-Minimize unwanted exposure

2 - Reduce the loss of energy and raw materials.

3- Avoiding the dangers of misuse.

4- Reduction of radiographic re-imaging, which amounted to 25% from the total cases

The importance of the program quality:

1-Conduct physical tests to ensure the good radiation.

2-Early detection of potential disabling devices

3-Avoid re-imaging errors again.

Important tests of radiation quality of devices:

1-Test radiation leakage of the protective envelope of the X-ray:

Steps of the tests: -

- The provisions of the closure of the complex of radiation to be completely closed.

- Operation of the X-ray when suitable operating conditions are available

Measuring the amount of radiation leaking in more than one point after one meter

2 - Test efficiency of the safety circle to warn about the loading of the tube on the radiation.

3 - Make sure the film is affixed to the cassette board.

4-Be sure of the safety of the radiation determinator

5-Test the temporal accuracy of the time in the unit of operation

6 - Test sensitivity of the board of the film cassette

7 - Test the output of radiation

8 - Test kilo volts

Types of radiation effects:

Acute random effects:

Random effects appear in cases of exposure to high ionizing radiation in short or medium duration time in any organ or tissue and the dose may reach to 2 gray and it occur due to a radiation accident or serious human error

Organs that are exposed to these major effects are bone marrow, lung and thyroid.

Exposure to organs or other tissues, such as the digestive system, may be considered less effective than non-fatal, and all this depends on the exposure threshold.

It has been proven from a biological point of view that the dose to cause a certain effect is different when it is fragmented or distributed over time and the degree of effect also depends on the affected tissue:

Example for acute irradiation:

1-The whole body is exposed:

After acute irradiation of the whole body, all the warning projections are directly linked to the dose received by the blood-forming device, ie, the bone marrow, which is the most sensitive body organ. Which is the source of most circulating cells in the human body such as lymphocytes and granules, Platelets and white blood cells.

At 3-5 gray exposures, the number of lymphocytes and the number of other cells decreases within days for exposure and when the whole body exposed to a single dose of 2 gray once at a short period of time The risk of death begins and the clinical symptoms are severe and increase with the increased dose. Symptoms show a severe frequency of blood disorders within a week and the circulatory cells begin to decline

2-Exposed lungs:

Is the most sensitive organs of the chest and despite the large functional reserve, but the chances of renewal again is week. The dose for non-fatal injury is indicated by more than 5gray and the lethal dose of 10 Gray and shows pneumonia caused by radiation after exposure by a month or more and deposition of fibrin on the respiratory alveoli with fibrosis of the lung tissue and damage occurs in the capillaries and small veins and it is estimated that Gray receives to the entire lung of 15 gray has high risk of death as a result of the exposure of the lungs starting.

Delayed randomized effects:

Random effects may appear late and may extend to three years and do not have a specific threshold for exposure that can occur or not occur.

Low doses do not produce effects during short periods but over time it is noted that these effects are related to DNA changes that occur in the formation of cells of the intentions of cells.

DNA: is the expression of amino acids carrying genetic qualities and there is a possibility that a very high or very weak dose can harm the cell and its transformation to a cancer cell.

Examples of inherited effects.

- Early ageing
- Genetic disease
- Transplantation of cancerous cell

Methods of measurement of radiation dose:

First: Means of measuring the radiation dose of people.

Sensitive Film:

This method depends on the passage of ionized radiation during the sensitive imaging films where ionizing emulsion layer of the a silver bromide and sensitive film is a thin slice of transparent plastic covering one side or both sides emulsified material of silver bromide, when

passing ionizing radiation or light on this film lead to ionizing of the emulsion layer of silver bromide and converted into granules of metal silver and is treated with film developer and fixer.

Where the granules of silver metal convert into small granules of metal black silver on the film in places that were exposed to light or radiation and then is measuring the opacity that is formed on the film and the opacity is determined by the amount of radiation and is done by special curves called calibration curves. The user film is a small film Similar to dental film and more commonly used films is Kodak

The sinusoidal measure (dosimeter) .

Is a measure of the personal exposure by rontagn. It is similar to the pen in shape and size. It is a cylindrical tube with a specific volume of gas inside. A metal part is connected to a fine quartz thread and its inner surface is covered with a graphite plate to connect electrical charges and The quartz thread move on the gradient graduated by roentgen. Small telescope is found at the end of the dosimeter to magnify the numbers to be read. The idea of the work of the Dosimeter depends on the ionizing the air inside when charging and unloading when exposed to radiation

Photovoltaic measure:

It is a crystalline element of calcium fluoride or lithium fluoride. It is known as the flasher substances which give a flash when the radiation falls on it and when it is subjected to heat. The energy drops to electron crystals. These electrons move to a higher energy level and when heating the material to a 200 centric degree temperature the electrons return to the original energy level resulting in the emission of energy in the form of visual. Therefore, when measuring the light exit from the heating of the material can determine the dose absorbed of the radiation

Second: Radiation scanning of the region:

The most important radiographic measuring instruments used for the region is the Geiger Muller counter and the Geiger Muller detector consists of: a cylindrical glass tube with a small quantity of argon gas with pressure of 0.25-0.75 cm with a ratio of the alcohol and extends inside the tube on its axis A thin wire of 5-10 diameter represents the positive pole of the detector while its side wall is the negative pole and reaches its source with a 1000 volt of high voltage source

The theory of its work depends on the ionization of the gas inside the tube when the radiation falls, the gas is ionized and the positive ions are directed towards the wall of the pipe and the negative ions to the thin wire, so an electric current pass to the circuit which can be measured and magnified by the external measuring devices

Chapter 4

Effect of radiation

Objective:

By the end of this chapter, the student will be able to:

- Identify the types of radiation effect on the body
- Recognize the effect of radiotherapy on the body
- Identify the effect of diagnostic radiology dose on the different body organs
- Finally identify the unit of measurement of radiation:

Radiation effect on the body:

Radiation damage to living organisms is divided into two categories:

1-somatic effect

2-genatic effect

1-Somatic effect:

Definition:

Somatic damage by radiation is damage to any part of the body except the reproductive organs.

Somatic damage directly affects the individual exposed to the radiation, and does not deal with after-effects in future generations.

Skin that is damaged by excessive radiation exposure may develop cancer later on.

Irradiated bone marrow can cause anaemia (low red blood cell count) and therefore fatigue and muscle weakness.

Poor digestion and absorption of nutrients can stem from an irradiated gastrointestinal tract.

Large doses of radiation cause hair loss and dryness of skin.

Over time, large doses of radiation can cause cancer and the formation of cataracts on the lenses of the eyes.

The risk of developing these types of somatic damage is usually consistent with the level of exposure to radiation beyond a certain threshold amount

2- Genetic Effects

Definition:

Radiation that causes genetic damage directly damages the reproductive organs, and therefore affects any offspring that individual may have after the damage has occurred.

Radiation damage is done to genes and chromosomes, which can be passed on to future generations.

Studies of survivors of the Hiroshima and Nagasaki bombings and of the Chernobyl survivors in Ukraine have shown that there are increased rates of stillbirths, miscarriages, and infant deaths. If the children survive past the first few years of life, they tend to develop leukemia or microcephaly (slower cranial development), have birth defects (limbs missing, large growths), or mental impairments.

If exposure to radiation was not acute, then genetic effects may be minor or may not appear at all. However, Health Canada acknowledges that exposure to even minute doses of radiation from medical procedures such as x-rays or CT scans can have repercussions on the unborn fetus and therefore it is recommended that no procedures involving ionizing radiation be performed during pregnancy

Effect of radiotherapy on the body

The effect of radiation on the skin:

The skin is considered the first tissue and most common for the effect of radiation, where the skin is the direct pathway to the passage of external radiation.

The effect of radiation on the skin varies according to the following factors: -

a) The absorbed dose by the skin depends on the type of external radiation (surface - medium - deep or more than deep)
b) The place of exposure where the degree of skin sensitivity varies from one place to another.
c) Exposure time where exposure time is increased whenever harmful biological effects are present.
d) The age of the exposed person: where we notice the skin exposed to radiation in young people less effective and faster in the healing effects of radiation exposure than older people.
e) The health condition of the skin exposed where the more vital the skin exposed to radiation and the high proportion of blood flowing the less harmful biological effect
f) The size of the exposed part of the radiation: where the larger the exposed area the greater the harmful effect.

The effect of radiation divided to:

Acute effect: -

a) Temporal redness of the skin occurs during the first week and is the result of congestion of the blood vessels and the exit of histamine of the skin.
b) partial hair loss and occur in the range ranging from 10 to14 days since the start of exposure and to scalp hair is more affected by radiation as it falls faster, followed by eyebrows hair followed by axillary hair followed by pubic hair
c) Permanent redness of the skin and be in the end of the second week of exposure where the skin is severe red, hot, swollen and irritated gives a sense of desire to itch.

d) After sever redness occurs the skin become dry and the basal skin cell activated.
e) Dry peeling occurs at the end of the third week of exposure where the surface cells of the skin fall
f) Wet peeling occurs at the end of the fourth week of exposure, where bubbles filled with serous fluid collect under the skin layer together and then explode.
g) Radiation burn is caused by exposure to a high radiation dose where the skin color is dark red and consists of deep bubbles permeate the entire skin layer.

Chronic effect: -

1-A change in the color of the skin where the skin color varies from light brown to dark brown and often is on the form of dark spots surrounded by white patches which is free of melanin.

2-Atrophy of the skin occurs as a result of the exposures that are healed and then the decomposing wet crust and the formation of new cells completely different from the original cells.

3-Increase the thickness of the skin as a result of the formation of tissue tents gives the shape of the scar.

4-chronic ulceration: The atrophied skin may be end by chronic ulceration with a minor wound or itching.

5-vasodilatation of peripheral blood vessels due to the occurrence of narrowing of arteries passing through the skin

6-The cancerous transformation of the skin due to lack or delay in the treatment of ulcers resulting from skin exposure.

7 - The effect of radiation on the sweet glands:

Atrophy and stop working during the first week of exposure and often there is a permanent interruption of the gland function when exposed to 400-500 rad

8- The effect of radiation on the sebaceous glands:

Often occurs as a result of exposure to the dose of 3000 rad and the skin loss its strength due to its impact

9 - The effect of radiation on the nail

Be rough and shiny and have long and superficial cracks , become thinness and lose its vitality.

Radiation treatment system: -

Preventive treatment:

Prevent the person exposed to the changes that may occur as a result of exposure to radiation and its follow-up in terms of:

1- Do not expose the exposed parts of radiation to water and soap.

2- Do not use ointments irritating to the skin.

3 - Avoid contact with sharp objects such as sharp shaving tools or clothing.

4- Do not scratch the area exposed severely.

Curative treatment:

1- Treatment of skin redness dry peeling using the 2% concentration of gentian lotion

2- Treatment of wet peeling ... If the region exposed to radiation is small leaves it where the crust is formed after a period of time. If the area is large we use Vaseline gauze with topical antibiotic.

3-Treatment of radiation burning: It is like wet peeling but for a - longer period.

4- Treatment of radiation ulcers ... If it is small we use Vaseline gauze with antibiotic. And if a large, surgical intervention is done by a grafting of the skin.

Effect of radiation on mucous membranes:

Acute effect: -

1-The effect of radiation on the mouth leads to dry mouth and loss of taste.

2 - The effect of radiation on the pharynx leads to dry throat and difficulty swallowing and loudness in the sound.

3 - The effect of radiation on the stomach and intestines leads to cramps and acute abdominal pain and severe diarrhea.

4 - The effect of radiation on the anus leads to severe pain in the defecation with dysentery.

5 - The effect of radiation on the bladder leads to Difficulty in urination and pain during urination.

Chronic effect: -

1-Fibrosis from chronic ulceration resulting from radiation exposure ends with narrowing of the affected channels.

2 - Occurrence of narrowing and blockage of channels such as blockage of the tear duct.

3. Chronic ulcers may turn into cancerous ulcers

Effect of radiation on the blood & component and tissue produced blood

First, the effect of radiation on the tissues produced blood

Bone marrow:

1- When the whole body exposed to radiation of a dose of 4500 rad (called the lethal dose) the following changes within half an hour of exposure can occur:

- Stop the division of bone marrow cells.
- Increase the number of mature red blood cells and decrease the number of immature cell
- Clear increase in the atrophied red blood cells in the bone marrow

- Mild Decrease in the number of the granular cells
- Mega-karyocyte cells disappear within two days of exposure
- The bone marrow becomes filled with a gelatinous substrate that replace the cells which have been destroyed

Radiation effect on the lymph nodes:

When the whole body exposed to 800 rad which is (a lethal dose) the following occur:

- Damaged lymph nodes within half an hour of exposure time and The highest rate of 8 hour
- Macrophage cells less significantly decrease but turned into active cells phagocytes.
- Megakaryocytic disappear within two days of exposure
- Stop the activity of the lymph nodes and its work gradually when exposure to the dose of 3000 rad but the flow of lymphatic fluid continues.

Radiation effect on the spleen

- When the whole body is exposed to a dose of 800 rad (a lethal dose)the cell division on the spleen stopped within half an hour.
- Effect on lymphocyte cells begins within 3 hours.
- Within 8 hour. The cells of the red pulp of the spleen start to break except for the circulating blood cells in the spleen.
- As the result of the destruction of splenic cells, the spleen begins to shrink significantly.
- The activity of the spleen is affected in the terms of storage of red blood cells, blood flow rate, storage of iron and the production of anti toxic.

The effects of radiation on blood components:

- Factors that help the effect of radiation on blood components:

- The extent of the effect of radiation on the tissues produced blood and the extent of cell sensitivity to radiation.
- The extent of cell division and growth.
- The age of the cells circulating in the blood

The effect of radiation on white blood cells:

There is about 4000 circulating cells in the blood and when exposed to lethal dose the following occur:

- Immediate but temporary reduction of white blood cells.
- There is an increase in the number of white blood cells within hours of exposure.
- During the second day of exposure, it is decrease severely.
- When exposed to doses of radiation is much less than non-lethal doses note the speed of the rise of the number of the white blood cells during 3 days then return to normal count after 10 days to 3 months

The effect of radiation on lymphocytes:

- The decrease occurs immediately after exposure to radiation and then return to its normal rate:
- A sharp drop occurs within 24-48 hours when exposed to non lethal dose of radiation about 500 rad.
- When the whole body is exposed to a dose of 200 -450 Rad the reduction rate decrease and reaches a maximum at 2 or 3 months.
- When the whole body is exposed a dose of 100-200 rad, there is moderate reduction with the probability to rapid return to its normal rate.
- when the whole body is exposed to a dose that is less than 100 rad m the drop of cells is about 25% and then rapidly return to its normal rate

Radiation effect on blood platelets:

- When the body is exposed to a radioactive dose of 150-400 rad, there is increase in the platelate count followed by a significant drop in the count of platelets
- When the whole body exposed once only to high dose more than 400 rad, acute reduction to the circulating platelate occur
- When exposed to dose less than 150 rad, mild reduction of the platelate count which return to normal rat within 20 day.

- When exposed to high dose, death occur to exposed person due to defect in the blood coagulation which is the responsibility of the platelate

Radiation effect on red blood cells:

- When the whole body exposed to radiation dose in the treatment that leads to a slow decline in the number of red blood cells.
- When the body is subjected to high doses of radiation lead to increased permeability to the wall of blood vessels, which allow the passage of the red blood cells lead to its destruction
- when the whole body is exposed to a radiation dose of 400 rad that lead to the reduction of the reticulocytes to zero within 10-15 day

Effect of radiation on the nervous system:

The central nervous system is less affected by radiation and the effect is in the form of:

Acute effect:

Post radiation meningitis after exposure to high dose on short time and the following changes appear:

- Brain edema with increase the intracranial pressure.
- When exposed to high dose of radiation the blood vessels and nervous cells affected.
- Death can occur when exposed to high dose preceded by shivering, loss of appetite loss of light refraction and blindness.

Chronic effect:

When once exposed to radiation dose of 1500- 2000 rad, death not occur but acute changes may be happened:

- Neural tissue necrosis and death is certain.
- Blockage of the blood vessels of the brain as a result of exposure to high doses
- Atherosclerosis of the blood vessels.
- Changes in motor movement and behavior.

- When a large part of the brain is exposed to a high radiation dose, it passes without symptoms, followed by complete nervous relaxation, or cerebral inflammation, and the occurrence of death

The effect of radiation on the peripheral nerves:

The peripheral nerves bear the radiation to a large extent and affect the peripheral nerves as follows:

Fibrosis of the peripheral tissue surrounding the peripheral nerves may occur, leading to the occurrence of terminal symptoms that may result in peripheral nerve paralysis as a result of suffocation.

Radiation effect on the spinal cord:

Two types of injury that affect it, namely:

Temporary myelopathy:

It is an electric shock spread down the back and extends to the extremities and occur within 2-4 months of exposure especially at the cervical region and continuous to several months

Delayed myelopathy:

- It is the appearance of neurological symptoms and signs which does not change over time and is similar to the total or partial tear of the spinal cord presented such as the incidence of paralysis of the lower limbs and lack of control of urination and defecation. These symptoms appear during the 23 months of exposure
- Death may occur as a result of urinary tract infection or pneumonia

Effect of radiation on the lungs

The radioactive effect on the lungs is known as pneumonia, which is divided into:

1. Acute radiation pneumonia.
2. Subcutaneous pneumonia.
3. Chronic radiological pneumonia.

First: acute radiological pneumonia

Its symptoms depend on the size of exposed part of the lung and occurs in duration of 1-3 months after the end of the treatment.

Symptoms :

- In the case of less than half of one lung will appear a slight rise in temperature and light cough
- If a large portion of the lung is exposed to radiation it will show a significant increase in temperature and cough accompanied by breathlessness
- When more than 75% the lung exposed to radiation symptoms are expressed as shortness of breath and cough , It is accompanied by thick sticky sputum and a very high degree of temperature accompanied by secretions of sweat and may lead to an imbalance in the breathing process

Signs :

- Pulmonary fibrosis.
- Inflammation of bronchial tree as a result of serous filtration and swelling of the lining mucosal cells.

Second: Sub-acute radiotherapy pneumonia:

Symptoms

- Blockage in the blood vessels leads to death in the lung tissue.
- The occurrence of lung cavities.
- Shortness of breath and cough accompanied by pus secretions with chest pain

Signs:

- Lung fibrosis with loss of normal breathing sound.
- Collapse of the lung tissue.

Treatment: antibiotic / cortisone / artificial respiration

Third: chronic radiological pneumonia:

Symptoms

- Cough accompanied by mucous secretions stained with blood.
- Difficulty in breathing due to pulmonary embolism and obstruction airway.
- Shortness of breath in the lying situation.
- Right side heart failure with cyanosis of the mucous membrane and splenic enlargement.
- Thick pleura
- Multiple lung and body abscesses and swollen fingers of the hand and foot may end up with death.

Treatment: antibiotic/ artificial respiration/ treatment of anemia if found

Effect of radiation on urinary system

Both kidneys:

Radiation affects the kidneys directly when exposed to radiation or indirectly at the other organs of the body and this leads to:

Congestion - swelling - impairment of the renal functions - atrophy in the renal tubes

They may return to their normal state after radiation therapy has stopped.

Acute effect:

- The acute inflammation occurs during 5 week of exposure to a dose of 2300 rad
- Anemia
- Cardiomegally
- High blood pressure is the biggest indicator of total injury.
- Increase the proportion of proteins in urine
- Renal failure which may lead to death

This situation may end in severe acute inflammation within two months of exposure.

Chronic effect:

Severe acute inflammation of the kidneys causes chronic inflammation within two months of exposure

Which leads to:

- Anemia – albumin in urine - High blood pressure- dysfunction in the kidney.

Chronic inflammation occurs during 3-6 weeks when both kidneys are exposed to dose of 2500: 3250 rad

- **Its Symptoms**:

- High blood pressure - anemia - high blood urea - protein secretion in urine – kidney atrophy and tubular necrosis

Effect of radiation on the urinary bladder:

First acute effect;

Some changes occur in the mucous membrane during 4 weeks of exposed to a dose of 3000 rad, this lead to:

- Serous swelling of the mucosa - paleness of the color of the mucosa - less decrease on the bladder size

When exposed to high dose of more than 3000 rad, marked reduction of the bladder size occur and the mucosa appear reddish and smooth.

When the center of the pelvic exposed to a dose of 6500-7500 rad, the bladder can tolerable this dose and the sign of acute inflammation appear at the end of the treatment course and extend to 3 weeks after stoppage of treatment.

Symptoms of acute inflammation:

Frequent urination - Inflammation of the blood capillaries of the mucus membrane - bleeding under the mucosa – uncontrolled urination.

- **Treatment:** - Antibiotics - complete comfort - disinfectant.

Second: chronic effect:

- Acute inflammation can turn into chronic during the year to four year of exposure.
- Interstitial fibrosis, narrowing of the arteries and widening of the blood capillaries
- When examining the bladder by endoscope, the blood vessels are dilated, tortuous and can bleed leading to hematuria
- Paleness of the lining mucosa.
- Chronic ulceration.
- Bladder fistula. And ulcers of the bladder wall.
- Occurrence of calcified deposits and stones with symptoms of acute pain and difficulty in micturation.
- Inflammation of the ureter and the kidney and may end by renal failure

- **Treatment:** - analgesic __ - antibiotic __ - a diuretic __ total comfort __ renal dialysis __ renal transplantation

Ureter:

Hydronephrosis due to ureteral fibrosis, stricture and bacterial inflammation

Effect of Radiation on the Digestive System

First: Effect of radiation on the mouth and throat:

The mucous membranes of the mouth and throat are covered with basement cells with average sensitivity to the radiation, and when exposed to radiation, a radiological cell inflammation occurs followed

by loss of their vitality and functions which return to normal during 2-3 week after stop of radiation

- Stages of radiation cell inflammation as follows:

- Acute effect:

Swelling of serous membrane - cytotoxic edema __ congested capillary blood - The formation of lymphocytes with multiple nucleoli.

Chronic effect:

The acute effect may turn to chronic and appear as a fibrosis at the site of exposure.

The effects of radiation on the salivary and mucous glands: -

Acute effect:

- Swelling of the glands due to serous inflammation
- Decrease the secretion of saliva which become viscous and thick in texture lead to hardening of swallow.
- Atrophy of the salivary glands with loss of its function which is difficult to return to its normal function.

The effect of radiation on the jaw and teeth.

• First jaw:

• Death occurs in the bone accompanied by destruction of the components of the jaw, including;

- Blood vessels - connective tissue- mucous membrane

Pathological fracture may occur

- **Symptoms:** fallen tooth, bone ache bad mouth odor.

Second teeth:

- When exposed to 1000 Rad m the growth of the tooth bud stop and when exposure to dose more than 1000 rad complete destruction of the bud occur

The effect of radiation on the esophagus:

The esophagus is lined with cells of the basement layer of the average sensitivity to radiation such as the cells in the mouth and throat. These cells with sub mucous cells and muscle cells form longitudinal fold of the esophagus.

- The external muscle layer consists of the striped fibers at the top and smooth at the bottom of the 0.5 - 2.2 mm thickness

Acute effect

When treating lung cancer, the esophagus is exposed to a radioactive dose of 5000- 8000 rad in duration of 6-8 weeks

And the symptoms are:

- Difficulty swallowing and disappearing during 1-2 week of cessation of the exposure
- Sub mucous edema
- The external muscle layer of the esophagus bears the effects of radiation exposure, but when exposed to high doses, the tissue is damaged

Chronic effect

Chronic ulcers m stricture and perforation.

Radiation effect on the stomach:

All parts of the stomach bear radiation except the mucous membrane lining of the stomach is affected by radiation.

- Non autonomic nervous system control the secretions of the stomach

- Radiation affects the stomach, limiting the secretion of the gastric secretions as a result of the effect on the nervous system and the result of the direct destruction of the mucous membrane and the effect of radiation on the blood flow system, which regulates the process of gastric secretions

Acute effect

Began during the first week of exposure on the form of acute inflammation of the mucosa lining the stomach and the effect lasts for one month or more of stopping the exposure.

The stomach appears on endoscopy as follows: -

- Redness of the mucous membrane as a result of increase the blood flow
- Swollen of the inner stomach wall
- Red spots
- Early bleeding and erosion of the mucous membranes.

Chronic effect:

- The gastric secretion affected for a long period of time.
- Anemia may occur
- incomplete healing of mucous membranes and gastric glands may occur

Chronic symptoms:

Anemia - Severe gastric pain - Loss of appetite - Gastric perforation - Burning sensation - and gastric bleeding

The effect of radiation on the intestine

Acute effect:

- Cells lining the wall of the intestine are very sensitive to radiation. When exposed to radioactive dose of 100-500 rad, destruction of the cells with active splitting that covers the hidden folds of the intestine occurs during 24 hours and return to normal during the 96 hours

- cells covering the top of the villi are destroyed during 96 hours and return to normal natural within days

- Serous exudates deposit at sub mucous layer associated with swelling of the intestinal wall , congestion of the blood vessels and hemorrhage of the intestinal wall as well as atrophy of the lymphatic tissue.

- **Symptoms:**

- Loss of appetite - vomiting and diarrhea

Chronic effect:

- Severe fibrosis of the intestinal wall with clear seroma

- Chronic ulcers - narrow bowel - intestinal obstruction

Effects of radiation on the large intestines and the rectum

- When treating the pelvic pronouncement the first members affected by radiation is the large intestines.

Acute effect:

- When the bowel is exposed to radiation, the mucous membranes are triggered with an increase in the bowel movement:
- Vomiting, dysentery and excessive bleeding of the bowel wall
- Inflammation of the mucous lining of the intestinal wall
- Severe inflammation and spread of blood spots.

The treatment is as follows:

- Complete comfort - anti spasmodic - Dry foods - intra venous fluid

Chronic effect

- Uncommon and occurs during two- six months of exposure
- Increase the thickness of the intestinal wall as a result of serous swelling.
- Diarrhea and frequent bleeding.
- Fibrous of the lining tissue of the intestinal wall.
- chronic ulcers and burning of the anus
- perforation of the anus wall
- Intestinal obstruction which may need surgical intervention.

The effect of radiation on the eye:

The effect of radiation on the eyelashes.

- Eyelashes are terminal members serving the touch system by means of non autonomic nervous reflux

When the eyelashes are exposed to the radiation dose of 2300-2800 rad in the eyelashes fall. The eyelashes may grow again after stopping the radiation exposure and being scattered on the eyelid and it is short and growth inward leading to friction with the cornea of the eye.

The effect of radiation on the eyelid of the eye.

Eyelid is thin skin membrane lined by mucous membrane, this structure allows for rapid movement of the eyelid

Acute effect:

When the eyelid is subjected to radiation doses redness of the lining mucous membrane followed by the formation of a layer of plaster and its causes of rapid or uneven healing of the membrane without the occurrence of obvious changes

Chronic changes

Eyelid fibrosis ends with a shrinkage of the eyelid and changes in its strength leading to an effects on the cornea with serious ulcers

The effect of radiation on the lacrimal glands

The lacrimal gland is responsible for the secretion of the tear, which acts as a moisturizer and protector of the conjunctiva and cornea.

When the eye is exposed to a high dose of radiation, there is a deterioration or interruption of the gland function and stope discharge of the lacrimal fluid, leading to serious complications in the eye, including poor vision and the occurrence of acute pain in the eye.

The effect of radiation on the nasopharyngeal canal and lacrimal sac

Act as a conduit for the lacrimal fluid where they are lined by cells of the epithelial layer and cells when exposed to radiation, these cells fall and inflammation and obstruction occurs

Effects of radiation on the cornea

From the anatomical point of view we find that the blood vessels extend to the eye cavity does not extend to the inside of the cornea

Also that all the layers of the cornea, including the outer cover of the cells of the basement and its thick connective tissue does not reach the blood vessels so the effect of radiation on the cornea not depend on the blood vessels but depends on the effect on the activity of cell division and connective tissue layers

- Inflammation of the vasculature of the cavity of the eye

1 - Serous swollen with corneal ulceration

2 - Inflammation of the cornea

3 - The effect of squamous cell membranes covering the frontal part of the cornea occur within 3-5 weeks of exposure to 3000-5000 rad on the form of inflammatory spots

Symptoms:

The desire to rub the cornea

Excessive lacrimation

Treatment

Use of eye drops against allergy, antibiotic , permanent eye wash and antibiotic ointment.

The effect of radiation on the lens of the eye

Eye lens is a transparent body, the blood vessels does not reach to it.

Effects of the radiation on the lens of the eye as follows

A malfunction in the cells near the line of the lens and this imbalance is difficult to repair where turn these cells to fiber.

When the lens is exposed to a dose of 1000 rad, it become opacified after a period of time

When the lens exposed to a larger dose, this lead to a defect in the process of building cells and special fiber of the lens end by cataract

The effect of radiation on the retina

Within one week of exposure of the retina to 1000-3000 rad, the following occur:

- Narrow vascular blood feeder network.
- A defect in the substance of chromatin specific for nerve cells

Effect of Radiation on the Bone System

First: the effect of radiation during bone transformation

- Bone growth stops or delays in terms of thickness and diameter
- Decreases the ability to calcify
- Delayed growth in jaw bones
- Automatic bone fracture occurs followed by atrophy of muscles
- Crooked bones result in exposure of children to radiation

Second: The Effect of Radiation on Whole Bone Growth

The bone growth is completely affected due to affection of its components (cells and blood vessels) by radiation

- When the bone exposure to radiation detachment of the periosteal layer occur leading to bone death
- Affection of bone forming cells.
- The occurrence of bone cancer

Effect of diagnostic radiology dose on the body

1-Hair

The losing of hair quickly and in clumps occurs with radiation exposure at 200 rems or higher

2-Brain

Since brain cells do not reproduce, they won't be damaged directly unless the exposure is 5,000 rems or greater. Like the heart, radiation kills nerve cells and small blood vessels, and can cause seizures and immediate death

3-Thyroid

The certain body parts are more specifically affected by exposure to different types of radiation sources. The thyroid gland is susceptible to radioactive iodine. In sufficient amounts, radioactive iodine can destroy all or part of the thyroid. By taking potassium iodide, one can reduce the effects of exposure

4-Blood System

When a person is exposed to around 100 rems, the blood's lymphocyte cell count will be reduced, leaving the victim more susceptible to infection. This is often referred to as mild radiation sickness. Early symptoms of radiation sickness mimic those of flu and may go unnoticed unless a blood count is done. According to data from Hiroshima and Nagasaki, show that symptoms may persist for up to 10 years and may also have an increased long-term risk for leukemia and lymphoma

5-Heart

Intense exposure to radioactive material at 1,000 to 5,000 rems would do immediate damage to small blood vessels and probably cause heart failure and death directly

6-Gastrointestinal Tract

Radiation damage to the intestinal tract lining will cause nausea, bloody vomiting and diarrhea. This is occurs when the victim's exposure is 200 rems or more. The radiation will begin to destroy the cells in the body that divide rapidly. These including blood, GI

tract, reproductive and hair cells, and harms their DNA and RNA of surviving cells

7-Reproductive Tract

Because reproductive tract cells divide rapidly, these areas of the body can be damaged at rem levels as low as 200. Long-term, some radiation sickness victims will become sterile

8- **Pregnancy**

Fetal sensitivity to radiation-induced health effects is highly dependent on fetal dose, and the mother's abdomen provides some protection from external sources of ionizing radiation. In addition, noncancerous health effects depend on gestational age. This document should provide helpful information about the complex issue of prenatal radiation exposure to physicians counseling expectant mothers who may have been exposed to ionizing radiation

Acute Radiation Dose* to the	**Blastogenesis Up to 2 weeks**	**Organogenesis (2-7 wks)**	**(8–15 wks)**	**(16 –25 wks)**	**26-38 wks**
< (5 rads) 5-50 rads	No effect Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	No effect •Incidence of major malformations may increase slightly •Growth retardation possible	No effect •Growth retardation possible •Reduction in IQ possible (up to 15 points, depending on dose(•Incidence of severe mental retardation up to 20%, depending on dose	No effect Noncancer health effects unlikely	**No effect** **Noncancer health effects unlikely**

(50 reds The expectant mother may be experiencing acute radiation syndrome in this range, depending on her whole-body dose	Incidence of failure to implant will likely be large,‡ depending on dose, but surviving embryos will probably have no significant (noncancer) health effects	Incidence of miscarriage may increase, depending on dose • Substantial risk of major malformations such as neurological and motor deficiencies • Growth retardation likely	• Incidence of miscarriage probably will increase, depending on dose • Growth retardation likely • Reduction in IQ possible (> 15 points, depending on dose) • Incidence of severe mental retardation > 20%, depending on dose • Incidence of major malformations will probably increase	Incidence of miscarriage may increase, depending on dose Growth • retardation possible, depending on dose Reduction in • IQ possible, depending on dose Severe • mental retardation possible, depending on dose Incidence of • major malformations may increase	**Incidence of miscarriage and neonatal death will probably increase depending §on dose**

Gestational age and radiation dose are important determinants of potential noncancerous health effects. The following points are of particular note

Before about 2 weeks gestation (i.e., the time after conception), the health effect of concern from an exposure of > 0.1 gray (Gy) or 10 rads1 is the death of the embryo. If the embryo survives, however, radiation-induced noncancerous health effects are unlikely, no matter what the radiation dose. Because the embryo is made up of only a few cells, damage to one cell, the progenitor of many other cells, can cause the death of the embryo, and the blastocyst will fail to implant in the uterus. Embryos that survive, however, will .exhibit few congenital abnormalities

In all stages of gestation, radiation-induced noncancerous health effects are not detectable for fetal doses below about 0.05 Gy (5 rads). Most researchers agree that a dose of < 0.05 Gy (5 rads)

represents no measurable noncancerous risk to the embryo or fetus at any stage of gestation. Research on rodents suggests a small risk may exist for malformations, as well as effects on the central nervous system in the 0.05–0.10 Gy (5–10 rads) range for some stages of gestation. However, a practical threshold for congenital effects in the human embryo or fetus is most likely .(between 0.10–0.20 Gy (10–20 rads

From about 16 weeks' gestation to birth, radiation-induced noncancerous health effects are unlikely below about 0.50 Gy (50 rads). Although some researchers suggest that a small possibility exists for impaired brain function above 0.10 Gy (10 rads) in the 16- to 25-week stage of gestation, most researchers agree that after about 16 weeks' gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50–0.70 Gy (50–70 rads).

Measurement Units

A Historical Approach

Because ionizing radiation can cause biological damage to both the person exposed to it and to the offspring of that individual, scientists have devised ways to quantify radiation.

There are three main measurement methods used: exposure, absorbed dose, and biologically equivalent dose.

Exposure:

Measures the amount of ions produced by x-rays or gamma rays in air. It was the first radiation method to be defined, with the unit of measurement named after one of the scientists studying radiation effects.

Though the roentgen (R) is still used today

The System International (SI) unit of measurement for exposure is defined as coulombs per kilogram (C/kg). This unit stems from the

method of measurement, whereby a beam of x-rays or gamma rays is sent through a given mass (kg) of dry air at standard temperature and pressure.

This beam produces positive ions with a total measurable charge (C).

To convert from roentgens to coulombs per kilogram: Exposure (in roentgens) = 2. 58x10-4m In other words, 1 R = 2.58x10-4 C/kg the units of measurement for exposure do not connect radiation effects to living tissue, however. For living tissue,

Absorbed dose:

Is the energy absorbed from radiation per unit of mass of absorbing material (or living tissue)

The SI unit for absorbed dose is the gray (Gy), which is equivalent to joules per kilogram (J/kg). Another unit, not part of the System International, is the rad (rd). The word "rad" stands for radiation absorbed dose. To convert from rads to grays, 1 rad = 0.01 gray

The absorbed dose unit was an improvement on the exposure units developed earlier, however researchers soon realized that the amount of damage to living tissue by ionizing radiation varied with differing forms of radiation.

The absorbed dose units gave no indication of those differences. To compare damage caused by different types of radiation, the relative biological effectiveness (RBE) or quality factor (QF) is used

The dose of 200 keV x-rays that produces a certain biological effect

Relative biological effectiveness (RBE)

The RBE depends on the type of ionizing radiation and its energy, as well as the type of tissue being irradiated. The RBE for gamma rays and negative beta particles (electrons) is 1, whereas the RBE for protons is 10. The larger RBE value for protons indicates that more tissue damage is done than by gamma rays or beta particles. Alpha particles, protons, and neutrons all have larger RBE values than gamma rays and beta particles. Sometimes, the RBE and the

absorbed dose in reds are combined to form what is called the biologically equivalent dose

The unit of measurement for the biologically equivalent dose is the ram, “short for roentgen equivalent, man”.

Occupational radiation exposure is measured in Rems.

Typically, there are no observable biological effects if an individual is exposed to up to 25 Rems of radiation.

(Note that there are government-imposed limits on the amount of radiation workers are exposed to in the workplace – no more than 5 Ram is allowable.)

- **Book Coordinator ; Mostafa Fathallah**

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