



Radiology Team

Lecture 2

Contrast Media and Safety in Radiology

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Safety in Radiology

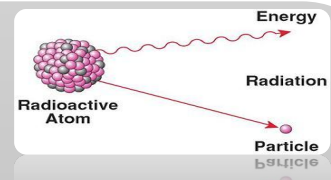
Major Sources of Risk in Radiology:

- Radiation hazard. As In x-ray
- Radioactive materials hazard.
- Magnetic field hazard.
- Contrast agents hazard.

Radiology is a diagnostic tool people start to use in wrong way they didn't think it could harm to them until they found some people they develop tumors, burns,..etc..

What is Radiation?

Radiation is energy emitted from a substance:



- **Non-ionizing:** Microwave oven, Television, Radiowaves.
- **Ionizing:** means alpha particles (α), beta (β), gamma (γ) and X-rays (among others) that are capable of producing ions.

Radiation comes when you hit any excited atoms e.g.: in x-ray tube they produce different voltage that will excite atoms which will produce x-rays

Early Pioneers in Radioactivity

- Rutherford: Discoverer Alpha and Beta rays 1897
- Roentgen: Discoverer of X-rays 1895
- Becquerel: Discoverer of Radioactivity 1896
- The Curies: Discoverers of Radium and Polonium 1900-1908



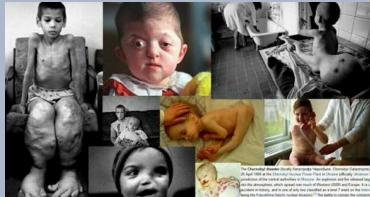
What is an X-ray?

- X-rays are very short wavelength electromagnetic radiation.
- **The shorter the wavelength, the greater the energy and the greater the ability to penetrate matter.**
- Ionizing radiation such x-ray can be carcinogenic and, to the fetus, mutagenic or even lethal.

X-rays short wavelength means higher frequency, so it can go through the tissues and saw in detector or films

Goals of Radiation Safety:

- Eliminate **deterministic** (acute) effects.
- Reduce incidence of **stochastic** (Chronic) effects.

	Deterministic (acute) Effects	Stochastic (chronic) Effects
Definition	<p>Acute radiation symptoms are caused by high levels of radiation usually over a short period of time.</p> 	<ul style="list-style-type: none"> • Also referred to as(Probabilistic), probability of occurrence depends on absorbed dose. • Chronic radiation symptoms are caused by low-level radiation over a long period of time
Characteristics	<ul style="list-style-type: none"> • They cannot be predicted with certainty • severity of damage increases with increasing dose above that threshold. • All machines are made so that the radiation does not exceed the threshold, but repeated exposure to radiation can lead to deterministic effects. 	<ul style="list-style-type: none"> • The effect may (potentially) occur following any amount of exposure, there is no threshold. • Even the smallest quantity of ionizing Radiation exposure can be said to have a finite probability of causing an effect. • Severity of the effect is not dose related.
Examples	<ol style="list-style-type: none"> 1. Cataract 2. Skin reddening (erythema). 3. lowering of the white blood cell count 4. hair loss 5. Bone marrow failure. 6. Lung Fibrosis. 7. Infertility. 	<ol style="list-style-type: none"> 1. Carcinogenic effect. 2. Genetic effect. 

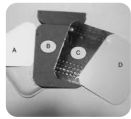
- **Gray is unit of exposure of radiation.**
- One chest x-ray 0.15 mGray. If patient did 100 x-rays he is in the safe said because they use very low amount but it doesn't mean we just expose patient to x-rays :)
- To reach the hazardous level of 2 Gray you need 10000 chest x ray or 100 CT abdomen or 30 mins to 1 hr fluoroscopy exposure. 1CT= 1000 x-rays
- **fluoroscopy has the highest and X-ray has the lowest**

Major organs annual dose limits for preventing deterministic effects are as follows:

Threshold for deterministic effects (Gy)			
	Effects	One single absorption (Gy)	Prolong absorption (Gy-year)
testis	permanent infertility	3.5 - 6.0	2
ovary	permanent infertility	2.5 - 6.0	> 0.2
Lens of eyes	milky of lens	0.5 - 2.0	> 0.1
	cataract	5.0	> 0.15
Bone marrow	Blood forming deficiency	0.5	> 0.4

- The numbers in the table represent the threshold that we should not exceed, to avoid deterministic effects. (the doctor said don't memorize the numbers)

Typical Radiation Detectors:



Film packet



Thermoluminescent Dosimeter (TLD)



Ionization chamber in the machine to check if there is any leakage of radiation in the room which shielded with lead



Geiger-Müller (GM) Detector portable detector for any radiation leakage.



Scintillation Detector as same as Geiger-Müller

Radiation Exposure Levels:	Effects:
0.62 rem/y	average annual radiation exposure.
2 rem/y	international radiation exposure limit.
25 rem	measurable blood changes.
100 rem	onset of radiation sickness.
200 rem	radiation sickness with worse symptoms in less time.
400 rem	approximately the lethal dose for 50% of the population in 30 days .
1,000 rem	death probable within about 2weeks, effects on the gastrointestinal tract.
5,000 rem	death probable within 1-2 days, effects on the central nervous system.

LIMITING YOUR EXPOSURE:

❖ General Methods of Protection:

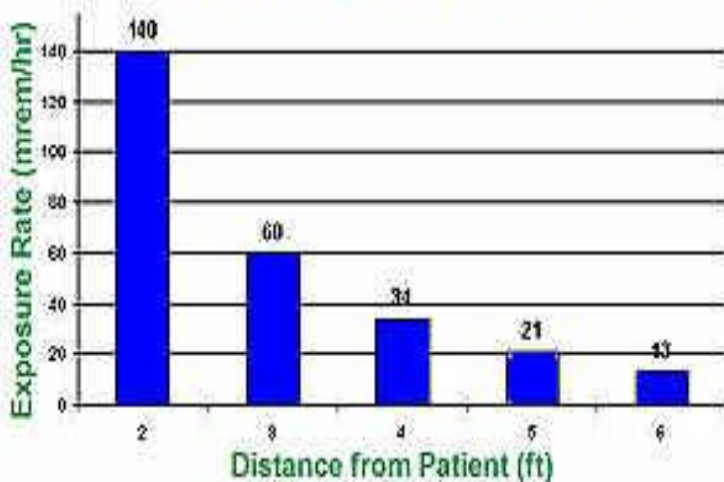
- ❖ Three basic methods for reducing exposure of workers to X-rays:
 - ❖ Minimize exposure time.
 - ❖ Maximize distance from the X-ray source.
 - ❖ Use shielding.

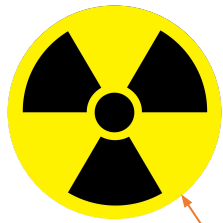
❖ Exposure varies inversely with the square of the distance from the X-ray tube:

❖ Shielding:

- ❖ Operators view the target through a **lead glass screen**.
- ❖ Wear **lead aprons**. Almost any material can act as a shield from gamma or x-rays if used in sufficient amounts.
- ❖ Standard 0.5mm lead apron Protect you from **95%** from radiation exposure.

Increasing Distance Benefits





Radiation Hazard symbol displayed at places where radioactive materials are used and stored.

Use alternative (US or MRI).

ALARA Rule:
Stands for
(As low as reasonably achievable)

Reduce number of exams.

Reduce time of exams.

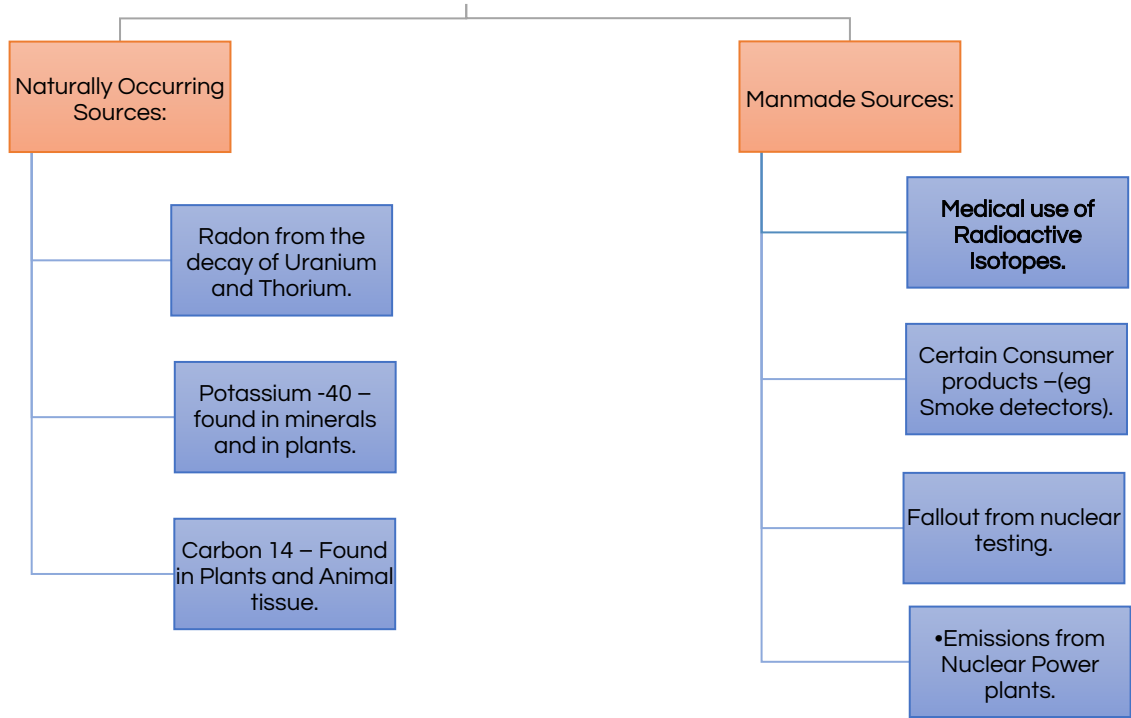
(Usually, there's a 48--hour interval between 2 procedures, unless the case is an emergency)

Radioactive Material Hazards:

What do we mean by Radioactivity?

- Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting radiation in the form of particles or electromagnetic waves.
- An unstable nucleus releases energy to become more stable.

Where are the Sources of Radioactivity?

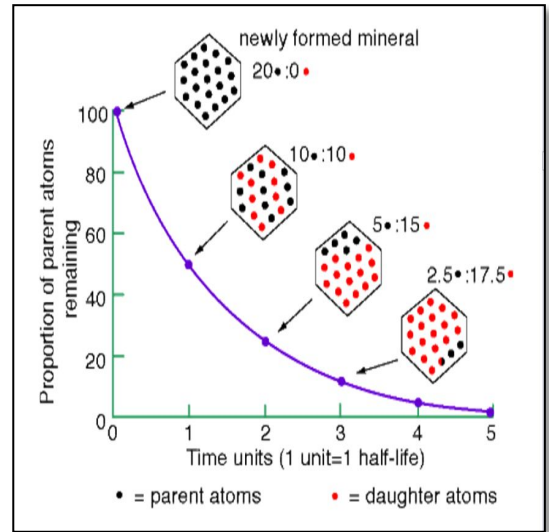


Radioisotopes:

- Isotopes of an atom that are radioactive are called **radioisotopes**.
- These atoms are radioactive because they have too much energy to be stable; they will release energy until they become stable this is called **radioactive decay**.

Radioactive Decay:

- In the process of radioactive decay, an atom actually changes from one element to another by changing its number of protons.
- The **half-life** of a radioactive substance is the amount of time required for it to lose *one* half of its radioactivity and transform into another element.



Medical use of Radioactive Isotopes:

Radioactive isotopes introduced into the body are distinguishable by their radiation from the atoms already present.

This permits the relatively simple acquisition of information about the dynamics of processes of uptake, incorporation, exchange, secretion, etc.

Radiopharmaceuticals:

- The most widely used radioisotope is **Technetium (Tc)**, with a half-life of six hours.
- activity in the organ can then be studied either as a two dimensional (2D) picture or, with a special technique called tomography, as a three dimensional (3D) picture (SPECT, PET).

The radiotracer, injected into a vein, emits gamma radiation as it decays. A gamma camera scans the radiation and create an image.



Handling Radiopharmaceuticals:



No radioactive substance should be handled with bare hands. Alpha and beta emitters can be handled using thick gloves.

Radioactive materials must be stored in thick lead containers.

The workers must be checked regularly with dosimeters, and appropriate measures should be taken in cases of overdose.

Radioactive waste must be sealed and buried deep in the ground



Reactor and laboratories dealing with radioactive materials must be surrounded with thick concrete lined with lead.

People working with radioactive isotopes must wear protective clothing which is left in the laboratory.



Spill Response:

- **On Skin** → flush completely
- **On Clothing** → remove
- **If Injury** → administer first aid
- **Radioactive Gas Release** → vacate* area, shut off fans, post warning
- Monitor all persons and define the area of contamination.

Magnetic field hazards:

- MRI is one of the imaging modality that is widely used in radiology.
- There is no dangerous radiation in MRI instead it uses very high magnetic field up to 3Tesla (1 Tesla = 20000 times earth gravity).

This strong magnetic field produces powerful attractive force and torque which the magnet exerts on ferromagnetic objects, this is called missile effect

The **missile effect** can pose a significant risk to anyone in the path of the projectile, and cause significant damage to the scanner.

The effect is clearly greater for high field systems .

Continue Magnetic Resonance Hazard ...

To guard against accidents from metallic projectiles, the "5 gauss line" should be clearly demarcated and the area with that line kept free of ferromagnetic objects.

It is essential that patient with ferromagnetic surgical clips, implants containing ferromagnetic components, and persons who have suffered shrapnel or steel fragment injuries, especially to the eyes, be excluded from the imager.

A number of general precautions must be taken to ensure the safety of patients and personal working in the imaging suite

Some implants are paramagnetic, or even ferromagnetic. These implants tend to move and align with the main magnetic field

Credit cards and watches with mechanical parts should be left outside the imaging area to prevent magnetic tape erasure and watch malfunction

Access to the imaging area should be limited, and signs should be displayed to warn persons with cardiac pacemaker or neuro-stimulators not to enter the area

This results in a force and torque on the implant and the implant may become dislodged, resulting in severe injury to the patient.

Aneurysm clips are examples of implants that can result in death if displaced.

Pacemaker and implanted cardiac defibrillator are typical examples of such devices.

Contrast medium Hazard:

Contrast Agents:

- Compounds used to improve the visibility of internal bodily structures in an image.
- Since their introduction in the 1950s, organic radiographic iodinated contrast media (ICM) have been among the most commonly prescribed drugs in the history of modern medicine.
- These contrast agents attenuate x-rays more than body soft tissues due to their high atomic weight.
- Millions of intravascular contrast media examinations are performed each year.
- Iodinated contrast media generally have a good safety record.
- Adverse effects from the intravascular administration of ICM are generally mild and self-limited; reactions that occur from the extravascular use of ICM are rare.
- Nonetheless, severe or life-threatening reactions can occur with either route of administration.

Types of Contrast Agents

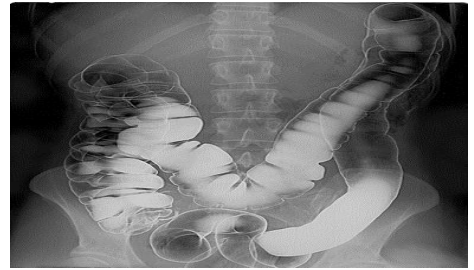
Negative contrast

- ❖ Organs become more radiolucent.
- ❖ X-rays penetrate more easily.
- ❖ Low atomic # material
- ❖ Black on film
- ❖ **Example: air, CO₂.**



Positive contrast

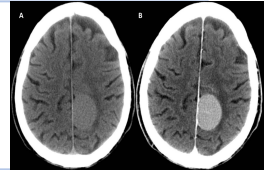
- ❖ **More common**
- ❖ Substance absorbs x rays, organ become radiopaque.
- ❖ High atomic # material
- ❖ White on film
- ❖ **Most common media:**
 - ✓ **Iodinated contrast agent.**
 - ✓ **Barium sulfate.**



Iodinated Contrast Agents:

WHY IODINE?

- IODINE (atomic wt 127) provides excellent radio-opacity.
- Higher atomic number maximizing the photo-electric effect.



Principal classes of iodinated radiological contrast medium:

1- Conventional High osmolar CM

- Ionic monomer (single benzene ring)

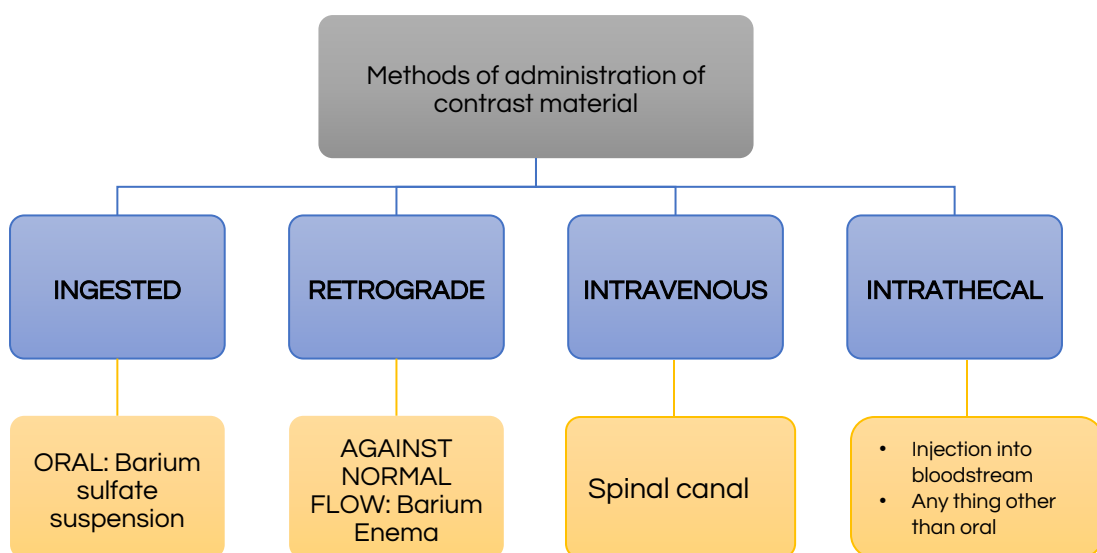
2- Low osmolar CM (most common)

- Ionic dimer (molecule with two benzene rings)
- Non ionic monomer
- Non ionic dimer

- The toxicity of contrast agents decreases as osmolality approaches that of serum.
- This has been accomplished by developing nonionizing compounds and then combining two monomers to form a dimer.
- Currently used iodinated agents are cleared almost completely by glomerular filtration.
- Circulatory half life is 1–2 hours, assuming normal renal function.

Effect of ionic Vs. Nonionic Contrast Media:

Ionic	Nonionic
Dissociate into separate ions when injected	Does not dissociate
Create hypertonic condition	Remains near isotonic
Increase in blood osmolality	No significant increase in osmolality
Less money	More money
More reactions	Less reactions



Reaction Classification:

Immediate reactions: were defined as those occurring within the department (within one hour).

Delayed: as those occurring between the time the patients left the department and up to seven days later.

Delayed contrast reactions can occur anywhere from 3 hours to 7 days following the administration of contrast.

It is important for anyone administering intravenous contrast media to be aware of delayed reactions.

The more common reactions include a cutaneous exanthema, pruritus without urticaria, nausea, vomiting, diarrhea, drowsiness, dizziness, fever and headache.

Flu like symptoms, delayed arm pain, salivary gland swelling and Steven Johnson Syndrome

Infants and patients older than 60 years are at increased risk of developing a side effect.



•The American College of Radiology has divided adverse reactions severity to contrast agents into the following categories:

1- Mild Reaction	2- Moderate Reaction	3- Severe Reaction
<p>Signs and symptoms appear self-limited without evidence of progression, 5%. Nausea, vomiting, warmth, headache, dizziness, shaking, altered taste, itching, flushing, chills, sweats, rash, nasal stuffiness, swelling: eyes, face and anxiety.</p>	<p>Reactions which require treatment but are not immediately life-threatening, 1%. Tachycardia/ bradycardia, hypertension, pronounced cutaneous reaction, hypotension, dyspnea, pulmonary edema, bronchospasm, wheezing and laryngeal edema.</p>	<p>•Life-threatening with more severe signs or symptoms including, 0.05%. •Laryngeal edema (severe), profound hypotension, convulsion, unresponsiveness and cardiopulmonary arrest.</p>
<p>Treatment: Observation and reassurance. Usually no intervention or medication is required; however, these reactions may progress into a more severe category.</p>	<p>Treatment: Prompt treatment with close observation.</p>	<p>Treatment: Immediate treatment, antiemetic drugs. Usually requires hospitalization</p>

- ❖ **EXTRAVASATION:**
- ❖ Contrast material has seeped outside of vessel.
- ❖ Apply WARM Compress 1st 24 hours.
- ❖ Cool compress for swelling.

Extravasation of Contrast into soft tissue of arm



Contraindications for Contrast:

- **Renal Failure**(Check BUN & Creatinine): Elevated levels could cause renal shutdown (If needed we must do hemodialysis immediately after exposure)
- **Anuria** (no urine production)
- **Asthma** (possible allergies)
- **Hx of Contrast Allergy / Reactions**
- **Diabetes** - get a hx of medications taken: **glucophage must be stopped 48 hrs before contrast injection**
- **Multiple Myeloma**
- **Pregnancy** (risk of fetal Thyroid toxicity).
- **Allergic Reaction, Pre – medication is available.**

MRI Contrast :

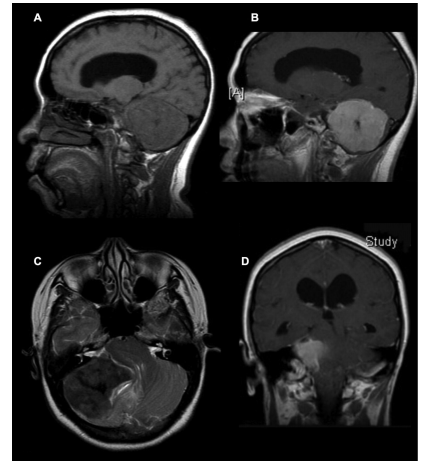
➤ The Contrast used in MRI is based on paramagnetic ions **eg. Gadolinium.**

➤ In MRI we excite the proton and then we measure the relaxability

➤ Gadolinium it has the ability to relax after the excitation and its relaxation is very fast, so when we inject the patient with gadolinium it will appear bright

➤ Gadolinium by themselves these ions are highly toxic so bound up in large molecules **eg. DTPA.**

➤ Provides a greater contrast between normal and abnormal tissues.



Gadolinium Side Effects:

➤ With impaired kidney function, gadolinium could lead to a serious and potentially fatal disorder called **Nephrogenic Systemic Fibrosis. (NSF)**

● Some Reaction Medications:

- Aggressive fluids.
- Lasix
- Dopamine
- Mannitol



Don't Forget !

- ★ The shorter the wavelength, the greater the energy and the greater the ability to penetrate matter.
- ★ Goals of Radiation Safety are Eliminate deterministic (acute) effects and Reduce incidence of stochastic (Chronic) effects.
- ★ General Methods of Protection are minimize exposure time, maximize the distance from x-ray source and use shielding
- ★ **ALARA Rule:**
 - Reduce number of exams.
 - Reduce time of exams.
 - Radiation Hazard symbol displayed at places where radioactive materials are used and stored.
 - Use alternative (US or MRI).
- ★ The most widely used radioisotope is **Technetium (Tc)**, with a half-life of six hours.
- ★ The toxicity of contrast agents decreases as osmolality approaches that of serum.
- ★ **Immediate reactions:** were defined as those occurring within the department (within one hour).
- ★ **Delayed:** as those occurring between the time the patients left the department and up to seven days later.
- ★ The Contrast used in MRI is based on paramagnetic ions **eg. Gadolinium.**
- ★ Gadolinium by themselves these ions are highly toxic so bound up in large molecules **eg. DTPA.**
- ★ With impaired kidney function, gadolinium could lead to a serious and potentially fatal disorder called **Nephrogenic Systemic Fibrosis. (NSF)**
- ★ **Take precaution before giving contrast agent to a patient with sickle cell anemia, multiple myeloma, or a pregnant.**

MCOs

- **1- Which of the following is a type of ionizing radiation:**

- A. Microwave oven
- B. Television
- C. X-ray
- D. Ultrasound

- **2- Which of the following is a characteristic of X-ray :**

- A. Shorter wavelength and high frequency
- B. High wavelength and Shorter frequency
- C. Shorter wavelength and shorter frequency
- D. High wavelength and high frequency

- **3- Deterministic effects appears when:**

- A. Low radiation over long period of time
- B. Low radiation over short period of time
- C. high radiation over short period of time

- **4- The most commonly used medical Radioisotope is :**

- A. Tritium (^3H)
- B. Potassium-40
- C. Technetium-99m
- D. Xenon-135

MCOs

- **5- Which of the following is an example of Negative contrast agent:**

- A. CO₂
- B. Iodinated contrast agents
- C. Barium sulfate

- **6- Which of the following is an example of positive contrast agent:**

- A. CO₂
- B. Air
- C. Barium sulfate

- **7- circulatory half life of iodinated contrast agent is :**

- A. 1-2 hours
- B. 3-4 hours
- C. 5-6 hours
- D. 7-8 hours