



Color Index:

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[Editing File](#)

Contrast Media and Safety in Radiology

objectives:

- Recognize and evaluate essential information on the biologic effects of ionizing radiation and radiation safety to ensure the safe use of X-Rays in diagnostic imaging.
- Know radiation quantities and units, regulatory and advisory limit for human exposure to radiation.
- Know equipment for radiation protection and measurement.
- Understand the fundamental principles of MRI safety.
- Know the contrast agents reactions and safety.
- Understand how to prepare patients for radiology studies.

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Introduction

Major Sources of Risk in Radiology:

1. Radiation hazard.
2. Radioactive materials hazard.
3. Magnetic field hazard.
4. Contrast agents hazard

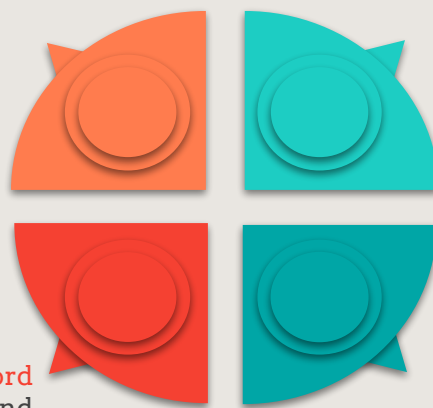
Research Pioneers in Radioactivity:

Roentgen
Discovered X-Rays in 1895

Becquerel
Discovered Radioactivity in 1896

Rutherford
Discovered Alpha and Beta Rays in 1897

The Curies
Discovered of radium and polonium 1900-1908

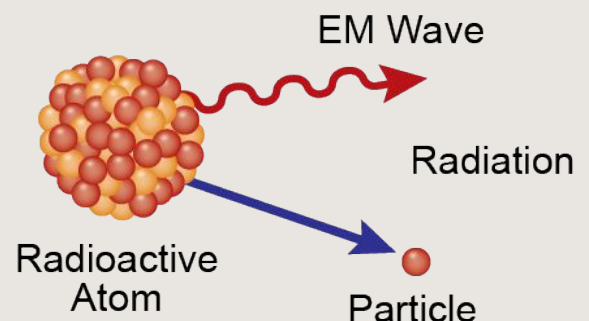


What is Radiation?

Radiation is an energy emitted from a substance, subdivided into:

1. **Non-ionizing** (non hazard): Microwave oven, Television, Radio Waves, Ultrasound and MRI. We use them in daily life and they are safe and there is no biological effect of using it.
2. **Ionizing** : alpha particles (α), beta (β), gamma (γ) and X-rays (among others) that are capable of producing ions.
Ionizing radiation can be carcinogenic and, to the fetus, mutagenic or even lethal.

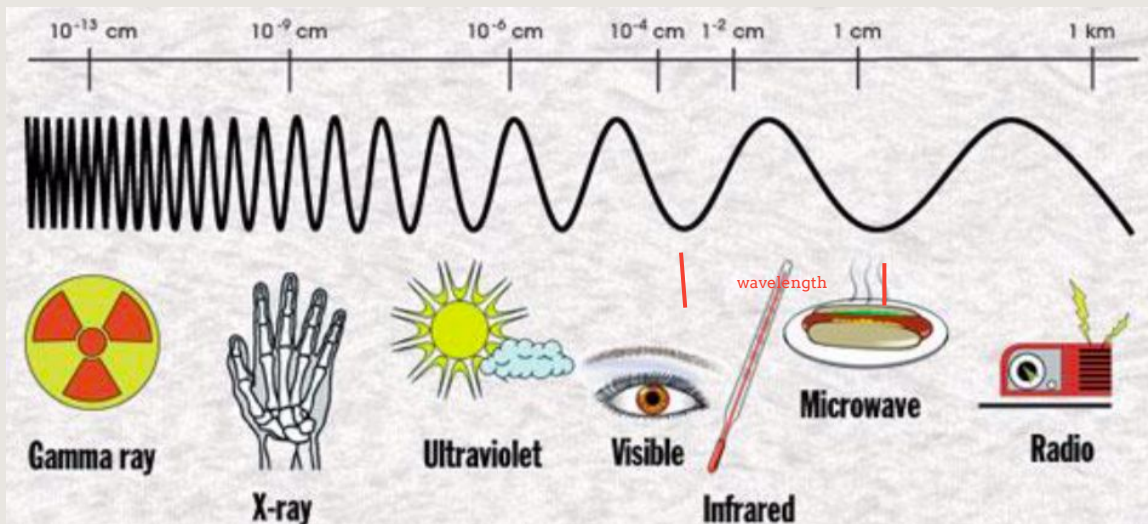
Explanation:
a radioactive atom has an unstable nucleus; it tends to lose energy to reach a more stable state, causing radiation.
Radiation will ionize atoms in living cells, damaging them.



Introduction

What is X-Rays?

- X-rays are very short wavelength electromagnetic radiation.
- The shorter the wavelength and the higher the frequency, the greater the energy and the greater the ability to penetrate matter.
- Ionizing radiation such as X-Ray can be carcinogenic and to the fetus mutagenic or even lethal, causes DNA damage.



The higher the the frequency, the higher Energy released.

Radiation Units:

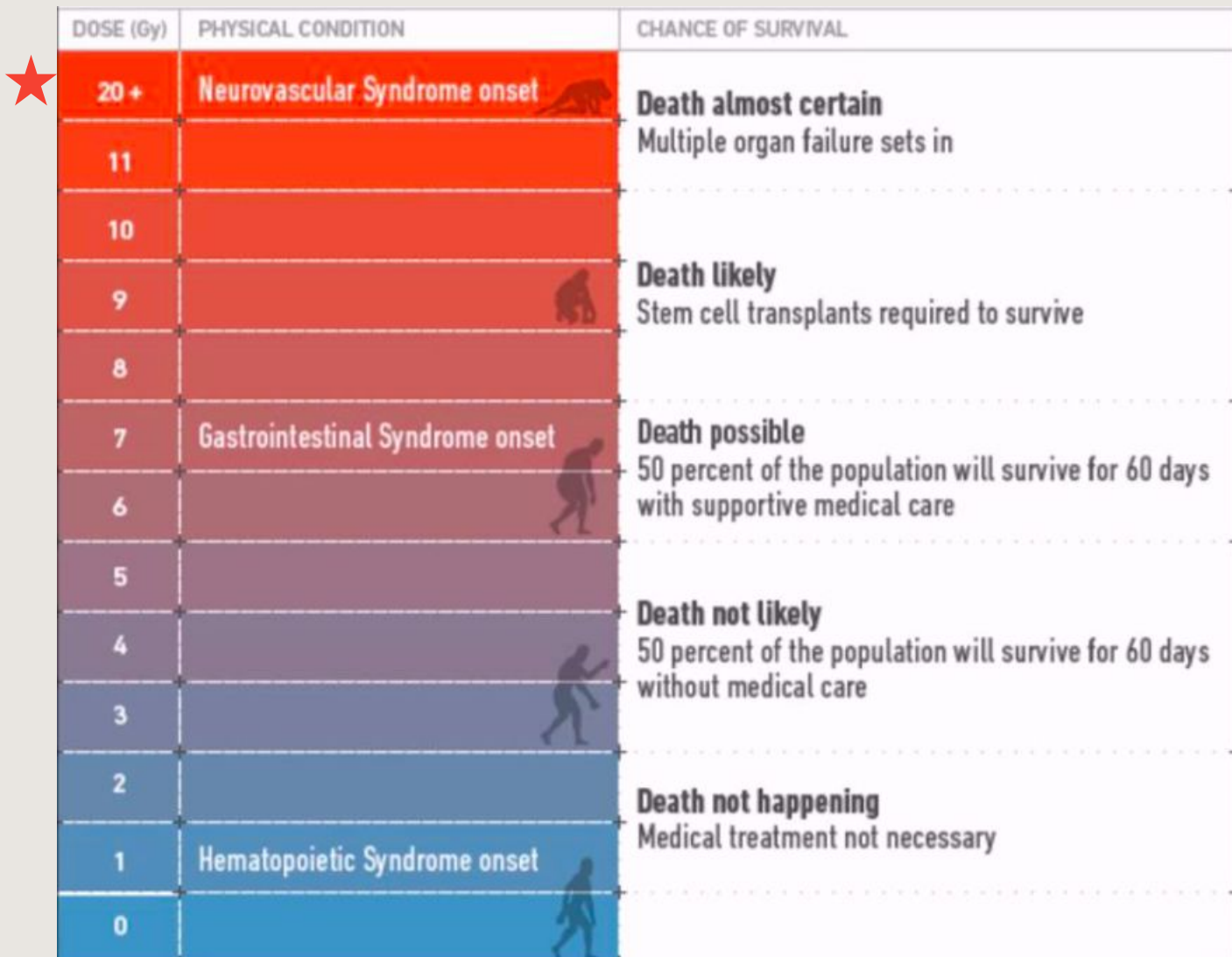
1. **RAD (Radiation Absorbed Dose):**
Original measuring unit for expressing the absorption of all types of ionizing radiation (alpha, beta, gamma, neutrons, etc) into any medium.
2. **REM (Roentgen Equivalent Man):**
is a measurement that correlates the dose of any radiation to the biological effect of that radiation. Since not all radiation has the same biological effect, the dosage is multiplied by a "quality factor" (Q). For example, a person receiving a dosage of gamma radiation will suffer much less damage than a person receiving the same dosage from alpha particles, by a factor of three.

RAD :e.g.: patient exposed to 2 RAD radiation, it means the amount of radiation.
However, to quantify the risk we use REM. which= $RAD \times Q$.
Q is the danger of that factor, depend on type of ionizing radiation

Quantity	Unit	SI unite	Relation between units
Absorbed Dose	Rad	Gray (Gy). <i>More common</i>	1Gy= 100 rad 100 mGy = 10 rad 10 mGy = 1 rad 1 mGy = 100 mrad
Equivalent Dose	Rem	Sievert (sv)	1Sv = 100 rem 100 mSv = 10 rem 10 mSv = 1 rem 1 mSv =100 mrem

- Gray, Rem, Rad, Curie, Becquerel and Sievert are units of radiation.
- **One chest X-ray= 0.15 mGy.**
- **To reach the hazardous level of 2 Gray you need 10000 chest x ray, 100 abdominal CT or 30 mins to 1 hr fluoroscopy exposure.**
- 1CT = 100 X-rays.
- Fluoroscopy has the highest and X-ray has the lowest.

The Effects of Nuclear Exposure



Radiation Hazard

Goals of Radiation Safety:

To eliminate **deterministic** (**acute**) effects.

To reduce incidence of **stochastic** (**Chronic**) effects.

Deterministic and Stochastic Effects: **IMPORTANT**

	Acute/deterministic effects	Chronic/Stochastic effects. (Random events)
Definition	Acute radiation symptoms are caused by <u>high levels</u> of radiation usually over a <u>short period of time</u> .	<ul style="list-style-type: none">- Also referred to as (Probabilistic), probability of occurrence depends on absorbed dose.- Chronic radiation symptoms are caused by <u>low-level</u> radiation over a <u>long period of time</u>.
Characteristics	<ul style="list-style-type: none">- They cannot be predicted with certainty.- Severity of damage increases with increasing <u>dose</u> above that threshold.	<ul style="list-style-type: none">- The effect may (potentially) occur following any amount of exposure, there is no threshold. (By accumulation)- 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 formation2. Bone marrow failure3. Lung Fibrosis4. Infertility5. hair loss6. lowering the WBC count7. Skin reddening (erythema).	<ol style="list-style-type: none">1. Carcinogenic effect2. Genetic effect

Radiation Hazard

Acute Deterministic Effects



Chronic Stochastic Effects



Radiation Hazard

Threshold for Deterministic Effects:

doctor said numbers aren't important just know the effects and compare between them

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

Organ	Effects	One single absorption (Gy)	Prolong absorption (Gy-year)
Testes	permanent infertility	3.5-6	2 This is the hazardous level
Ovaries	Permanent infertility	2.5-6	>0.2
Eye lens	Milky of lens cataract	0.5-2 5	>0.1 >0.15
Bone marrow	Blood forming deficiency	0.5	>0.4

Organs Sensitivity to Radiation:

1. High Sensitivity:

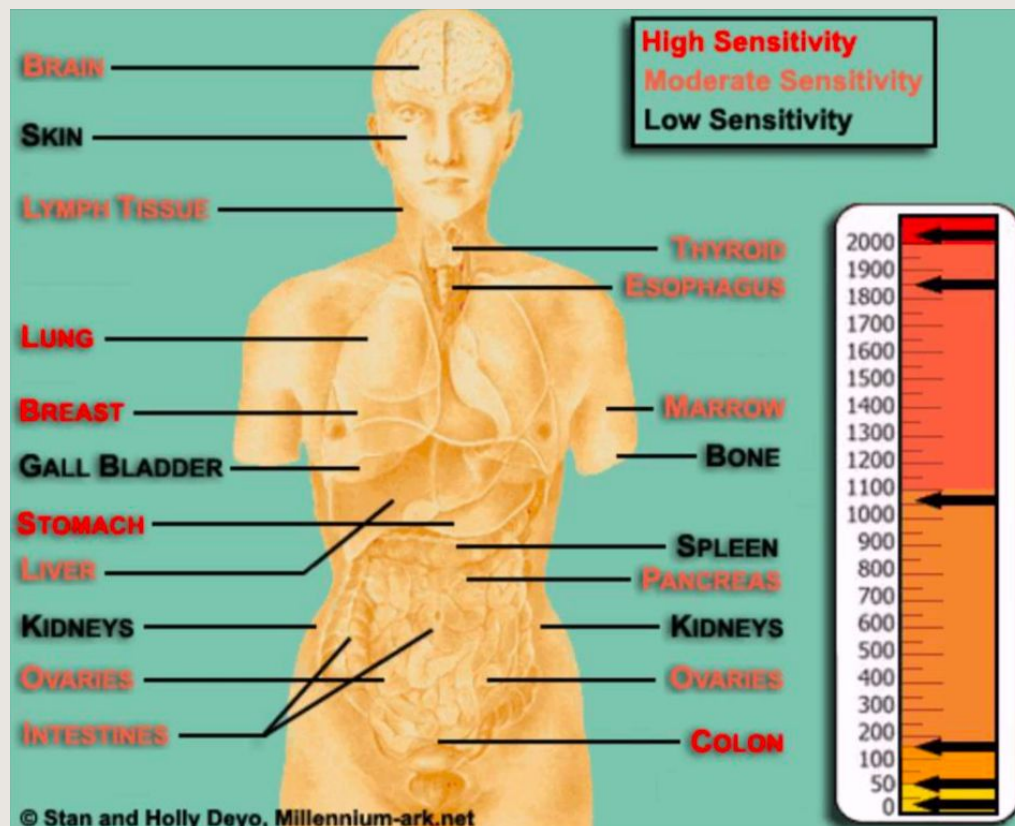
- Lungs
- Breasts
- Stomach
- Colon

2. Moderate Sensitivity:

- Brain
- Lymph tissue
- Thyroid
- Esophagus
- Marrow
- Liver
- Páncreas
- Ovaries
- Intestines

3. Low Sensitivity:

- Skin
- Bone
- Gall bladder
- spleen
- kidneys



Radiation Hazard



Radiation Exposure Levels and Effects:

0.62 REM/year

average annual radiation exposure.

2 REM/year

international radiation exposure limit.

25 REM/year

measureable 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 2 weeks, effects on the GI tract.

5,000 REM

death probable within 1-2 days, effects on the central nervous system like exposing to a nuclear bomb

Typical Radiation Detectors

1. Film packet
2. Thermoluminescent Dosimeter (TLD)
Radiology staff carry it to measure radiation exposure.
3. Ionization chamber Detect radiation leakage
4. Geiger-Müller (GM) detector
5. Scintillation Detector

Radiation Hazard

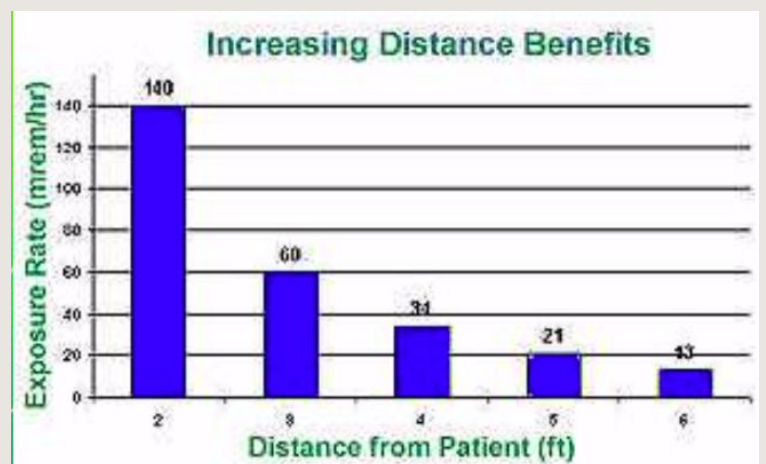
General Methods of Protection:

What are **Three basic methods** for reducing exposure of workers to X-rays?

1. **Minimize exposure time.**
2. **Maximize distance from X-Ray source.**
3. **Use shielding (stand behind lead protection).**

2. Maximize Distance:

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



3. Use 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 protects you from 95% from radiation exposure.



ALARA Rule: **VERY IMPORTANT**

As Low As Reasonably Achievable:

- Reduce number of exams.
- Reduce time of exams.
- Radiation Hazard symbol displayed at places where radioactive materials are used and stored.
- Use alternative (**Ultrasounds or MRI**).



Radioactive Materials Hazard

What Does Radioactivity Means?

These are other hazard found in the department in the department other than x-ray radiation

- 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.

Sources of Radioactivity:

- **Naturally Occuring Sources:**
 1. Radon from the decay of uranium and thorium.
 2. Potassium -40, found in minerals and in plants.
 3. Carbon 14, found in plants and animal tissue. *it's used to know the age of fossils.*
- **Manmade Sources:**
 1. Medical use of Radioactive Isotopes.
 2. Certain consumer products e.g. Smoke detectors.
 3. Fallout from nuclear testing.
 4. Emissions from nuclear power plants.

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.

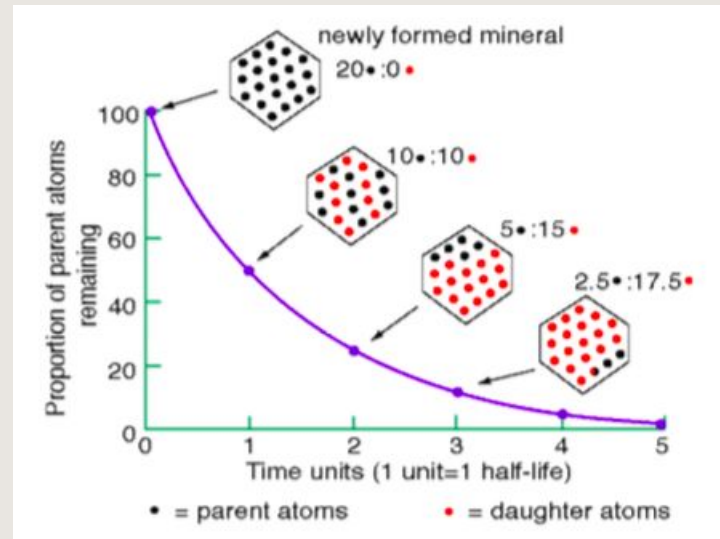
This is called radioactive decay.

- **Medical Uses of Radioactive Isotopes: Important**
 1. Radioactive isotopes are introduced into the body and can be distinguishable by their radiation from the atoms already present.
 2. This permits the relatively simple acquisition of information about the dynamics of processes of uptake, incorporation, exchange, secretion, etc. *e.g in the thyroid scan we know that iodine accumulated in thyroid so we inject the patient with ionized iodine which will accumulate there to and then scan the patient to see how much accumulated.*

Radioactive Materials Hazard

Radioactive Decay

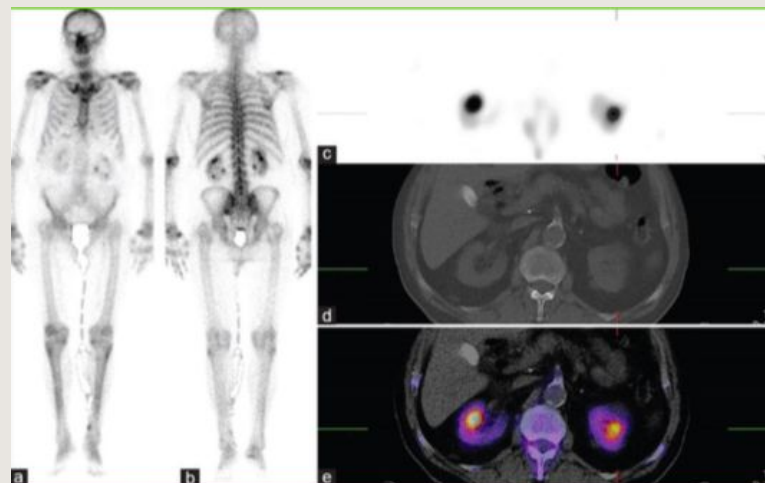
- In the process of radioactive decay. An atom actually changes from one element to another by changing its number of protons.
- The **half-life** of radioactive substances is the amount of time they require to lose one half of their radioactivity and transform into another element.



Radio-Pharmaceuticals

- The most widely used radioisotope is **Technetium** (Tc), with a half-life of **six hours**. (Important to tell us when to scan)
- The activity in the organ can then be studied either as a two dimensional picture or, with a special technique called tomography, as a three dimensional picture (SPECT, PET). so the patient will be first injected with Tc then after 6 h he will come to be scanned and we will be able to trace Tc

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



Radioactive Materials Hazard

Handling of Radiopharmaceuticals

- ✓ No radioactive substances 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.
- ✓ 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.
- ✓ 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.



Spill Response: **IMPORTANT**

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

Magnetic Field Hazard

-Equipment made specific for MRI room are made of diamagnetic material (such as wood and stainless steel). Interesting video (How dangerous are magnetic items near an MRI magnet?) [Click here.](#)

MRI Hazard:

- 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 **3 Tesla (1 Tesla = 20000 times earth gravity)**.
- This strong magnetic field produces a 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.

there are two units for measuring a magnetic field: Tesla and Gauss, where 1 tesla = 10,000 gauss

Precautions:

- 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.
- The 5, 10 and 200 Gauss lines are marked on the floor of each magnet room. These Gauss lines serve as a reminder that you are inside a magnetic field which increases sharply as you move closer to the magnet. The 5 Gauss line (the outermost line) defines the limit beyond which ferromagnetic objects are strictly prohibited.
- Some body implants are paramagnetic, or even ferromagnetic. These implants tend to move and align with the main magnetic field.
- This results in a force and torque on the implant and the implant may become dislodged, resulting in severe injury to the patient or death if displaced such as **Aneurysm clips, Pacemaker and implanted cardiac defibrillator**.
- it's essential that patient with ferromagnetic surgical clips, implants containing ferromagnetic components and who have suffered shrapnel or steel fragments injuries (such as those who work in mines), especially to the eyes, to 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:
 1. 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.
 2. Credit cards and watches with mechanical parts should be left outside the imaging area to prevent magnetic tape erasure and watch malfunction.

Contrast Medium Hazard

Contrast Agents

- Compounds used to improve the visibility of internal bodily structures in an image.
- Since their introduction, 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 (ICM)

- 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.
- Nevertheless, severe or life-threatening reactions can occur with either route of administration.

Types of Contrast Agents

Negative Contrast

- ✓ Organs become more radiolucent (more DARK).
- ✓ X-Rays penetrate more easily.
- ✓ Low atomic weight.
- ✓ Appears black on film.
- ✓ Examples of negative contrast:
 1. Air
 2. CO₂.
- ✓ Commonly used to inflate a structure; distinguish colon from other structures.



Positive Contrast

- ✓ Organ become radioopaque (LIGHT).
- ✓ Substance absorbs X-Rays hence why it becomes more light.
- ✓ High atomic weight.
- ✓ Appears white on film
- ✓ Examples of Positive contrast:
 1. Iodinated contrast agent.
 2. Barium sulfate

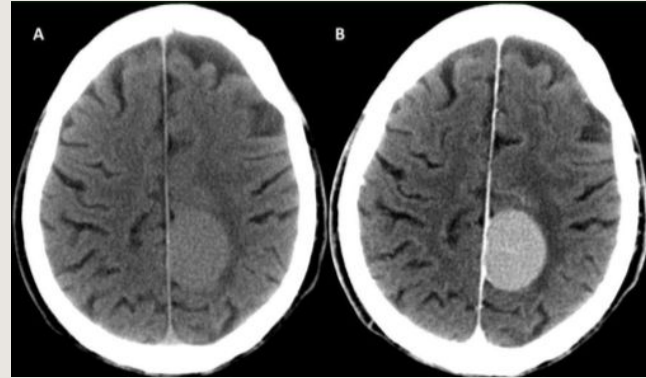
Urogenital Studies
Vascular Studies



Contrast Medium Hazard

Why Iodine?

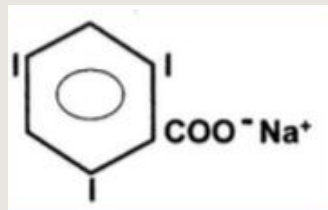
- IODINE (atomic wt 127) provides excellent radio-opacity.
- Higher atomic number maximizing the photoelectric effect.



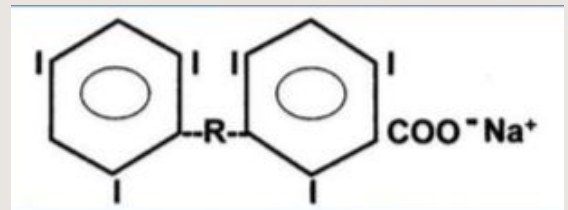
Classification of Agents:

Contrast agents are classified based on three properties:

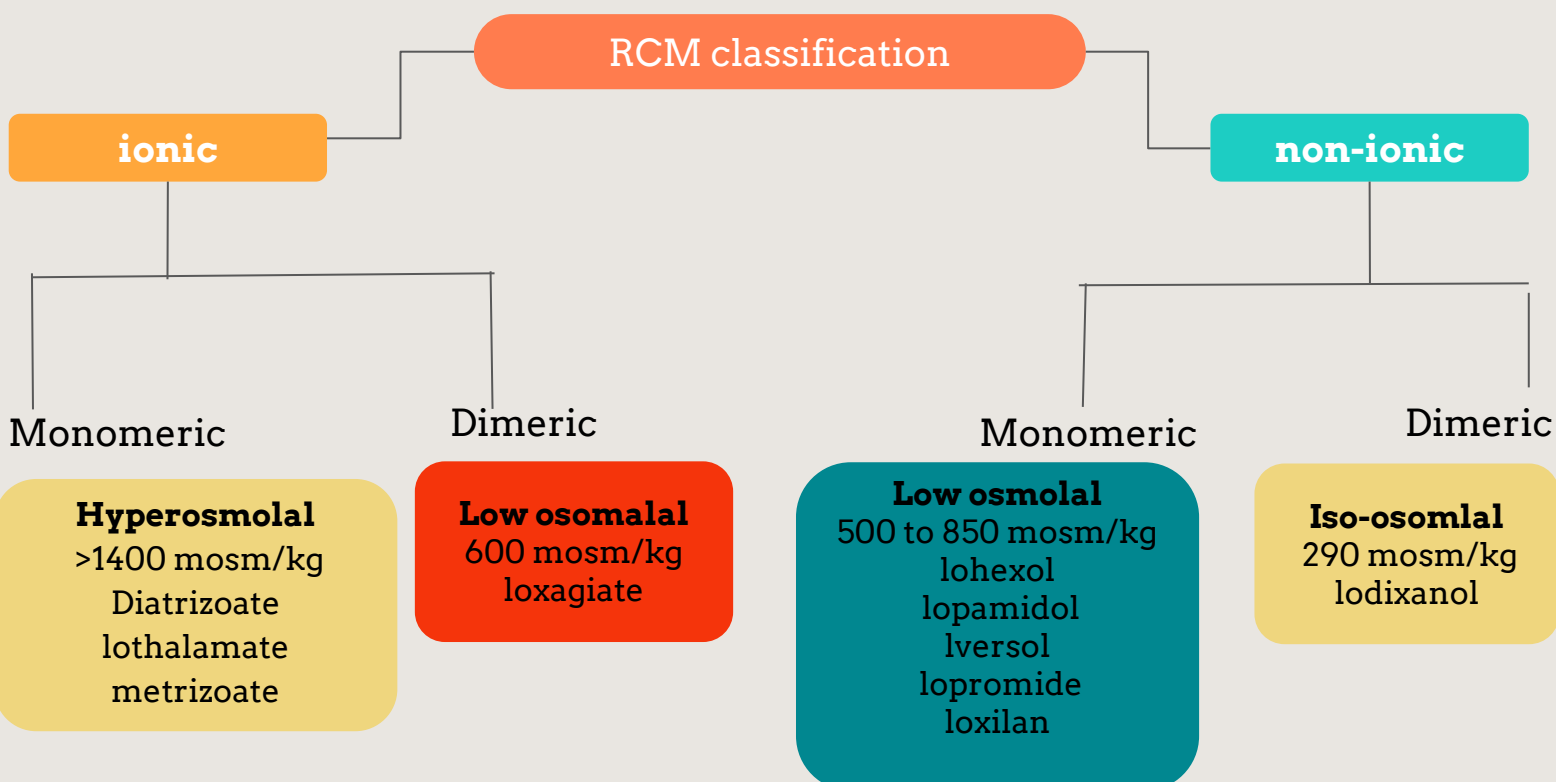
1. The charge of the iodinated molecule (ionic or nonionic).
2. The molecular structure (monomeric or dimeric).
3. The osmolality of the injected preparation (hyperosmolal, low osmolal, or iso-osmolal relative to normal serum osmolality [275 to 290 mosm/kg])



monomeric



dimeric



Contrast Medium Hazard

Iodinated Contrast Agents

- The toxicity of contrast agents decreases as osmolality approaches that of serum.
- This has been accomplished by developing non-ionizing 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. Non-ionic Contrast Agents:

Ionic	Non ionic
Dissociate into separate ion when injected	does not dissociate
creates hypertonic condition	remains near isotonic
increase in blood osmolality	no significant increase
less money	more money
more reaction	less reaction

Methods of Administration of Contrast Material

- 1. INGESTED**
 - Oral: Barium sulfate suspension.
- 2. RETROGRADE**
 - Against normal flow: Barium enema.
- 3. INTRATHECAL**
 - Spinal canal CSF.
- 4. INTRAVENOUS Most Common Method!**
 - injecting into bloodstream.
 - anything other than oral.

Contrast Medium Hazard

Reaction Classification

1. Immediate reactions:

- were defined as those occurring within the department (within one hour).

2. Delayed reactions:

- as those occurring between the time the patient left the department and up to seven days later.

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

- Mild
- Moderate
- Severe

Mild Reaction (5%)

- Signs and symptoms appear self-limited without evidence of progression
- Nausea, vomiting, warmth, headache, dizziness, shaking, altered taste, itching, flushing, chills, sweats, rash, nasal stuffiness, swelling: eyes, face and anxiety.
- Treatment: Observation and reassurance. Usually no intervention or medication is required; however, these reactions may progress into a more severe category.

Moderate Reaction (1%)

- Reactions which require treatment but are not immediately life-threatening
- Tachycardia/ bradycardia, hypertension, pronounced cutaneous reaction, hypotension, dyspnea, pulmonary edema, bronchospasm, wheezing and laryngeal edema.
- Treatment: Prompt treatment with close observation.

Severe Reaction (0.05%)

- Life-threatening with more severe signs or symptoms including: Laryngeal edema (severe), profound hypotension, convulsion, unresponsiveness and cardiopulmonary arrest.
- Treatment: Immediate treatment, antiemetic drugs. Usually requires hospitalization.

Contrast Medium Hazard

Some Reaction Medications:

1. Aggressive fluids
2. Lasix
3. Dopamine
4. Mannitol

Delayed Contrast Reactions

- 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, drowsiness, and headache.**
- **Other symptoms: Flu like symptoms, delayed arm pain, rash/pruritus, Salivary gland swelling, Steven Johnson syndrome.**
- Skin effects included itching, rash, and hives.
- Nausea, vomiting, and diarrhea were the GI side effects.
- General side effects included headache, dizziness, and fever.
- Infants and patients older than 60 years old are at increased risk of developing a side effect

Contraindications For Contrast

1. Renal failure
 - **check BUN and Creatinine**, elevated levels could cause renal shutdown
2. Anuria (**no urine production**)
3. Asthma
 - **possible allergies**
4. History of contrast allergy/ reactions
5. Diabetes
 - get a history of medications taken
 - **Glucophage must be stopped 48 hrs before contrast injection.**
6. Multiple Myeloma
7. Pregnancy
 - **Risk of fetal thyroid toxicity**
8. Allergic reaction, pre-medication is available

Stop metformin 48 H prior to contrast, if creatinine is high.

Contrast Medium Hazard

Extravasation

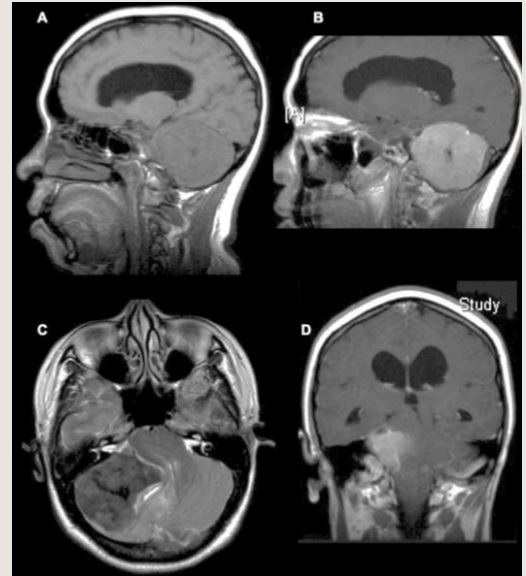
- Contrast material has seeped outside of vessel.
- Apply **warm** compress 1st 24 hours.
- Cool compress for swelling

Extravasation of Contrast into soft tissue of arm



MRI Contrast Agents

- The Contrast used in MRI is based on paramagnetic ions e.g. 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)**

-NSF: Nephrogenic systemic fibrosis (NSF), also known as nephrogenic fibrosing dermopathy (NFD), is a disease of fibrosis of the skin and internal organs reminiscent but distinct from scleroderma or scleromyxedema. **It is caused by gadolinium exposure** used in imaging in patients who have renal insufficiency. It could even lead to death.<-google

-Check if the patient has renal failure, decreased GFR, decreased creatinine before giving Gadolinium.



SUMMARY

Radiation hazard

hazardous ionizing radiation comprise (α , β , γ) particles, and X-rays.

Acute/deterministic effects	Chronic/Stochastic effects
caused by high levels of radiation usually over a short period of time.	caused by low-level radiation over a long period of time .
Severity of damage increases with increasing dose above that threshold.	Severity of the effect is not dose related.
Cataract formation, Bone marrow failure, Lung Fibrosis, Infertility, hair loss, lowering the WBC count, Skin reddening (erythema).	1. Carcinogenic effect 2. Genetic effect

Threshold for deterministic effect:

- One chest X-ray= 0.15 mGy.
- hazardous level = 2 Gray =10000 chest x ray=100 abdominal CT = 30 mins to 1 hr fluoroscopy exposure.

General Methods of Protection:

1-Three basic methods for reducing exposure of workers to X-rays:

- Minimize exposure time.
- Maximize distance
- Use shielding:

2- ALARA Rule: As low as reasonably achievable:

- Reduce number of exams.
- Reduce time of exams.
- Radiation Hazard symbol displayed at places where
- radioactive material are used and stored.
- Use alternative (US or MRI).

Radioactive materials hazard.

Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting radiation in the form of particles or electromagnetic waves.

examples:

- Radioisotopes
- Radiopharmaceuticals

Spill response:

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

Magnetic field hazard.

MRI safety:

- the “5 gauss line” should be clearly demarcated and the area free of ferromagnetic objects
- 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.

MRI contraindications:

Patients with ferromagnetic surgical clips
Pacemaker, shrapnel or steel fragment injuries...

MRI Contrast Agents:

- The Contrast used in MRI is based on paramagnetic ions e.g. **Gadolinium**.
- With impaired kidney function - , gadolinium could lead Nephrogenic Systemic Fibrosis. (NSF)

SUMMARY



Contrast Agents

adverse effects :

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**

Classification of contrast agents:

The toxicity of contrast agents decreases as **osmolality approaches that of serum**.
(non-ionizing ,dimeric compounds)

Ionic	Non ionic
creates hypertonic condition	remains near isotonic
increase in blood osmolality	no significant increase
less money	more money
more reaction	less reaction

reaction classifications:

The most common reactions include:

a cutaneous exanthema, pruritus without urticaria, nausea, vomiting, drowsiness, headache ,flu like symptoms delayed arm pain , salivary gland swelling, and Steven Johnson syndrome

duration:

- 1-immediate reaction
- 2- delayed reaction

severity:

- 1-Mild Reaction (5%)
- 2- Moderate Reaction (1%)
- 3- Severe Reaction (0.05%)

Reaction medications

- Aggressive fluids
- Lasix
- Dopamine
- Mannitol

Extravasation

Apply a WARM Compress 1st 24 hours and cool compress for swelling.

Contraindication for contrast:

- Diabetes
- Multiple Myeloma.
- Renal Failure
- Anuria
- Asthma
- Hx of Contrast Allergy / Reactions
- Pregnancy
- Allergic Reaction.
- get a hx of medications taken

QUESTIONS

1. Which of the following qualifies as stochastic effect?

- a) Cataract
- b) Bone marrow failure
- c) erythema
- d) Carcinogenic effect

2. which modality can reach the hazaras level of radiation faster than the others?

- a) fluoroscopy
- b) CTscan
- c) 1000 x-rays
- d) MRI

3. the radiation exposure level at wich 50% of the population will die within 30 days?

- a) 2 rem/y
- b) 100 rem
- c) 400 rem
- d) 1,000 rem

4. a Standard 0.5mm lead apron will protect against of radiation exposure

- a) 55%
- b) 95%
- c) 85%
- d) 67%

5. the least toxic class of contrast agents:

- a) non ionic, dimer
- b) non ionic, monomer
- c) ionizing, dimers
- d) ionizing, monomers

6. sever reaction to contrast agents appear in...of the population.

- a) 5%
- b) 0.05%
- c) 1%
- d) 2%

7. delayed contrast reaction occurs within?

- a) 3-7 days
- b) 3-7 hours
- c) 48 hours
- d) 1-2 weeks

8. a single chest x-ray equals?

- a) 0.15 gy
- b) 0.15 mgy
- c) 0.3 gy
- d) 0.3mgy

9. the area around the MRI should be clear of any ferromagnetic objects due to?

- a) missile effect
- b) patient falls
- c) radiation
- d) distorted results

- a (6)
- q (8)
- a (7)
- p (9)
- a (5)
- b (4)
- c (3)
- a (2)
- d (1)

ANSWERS

help us improve with your feedback:



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please fill this very very quick form



References

- ✓ Slides
- ✓ 436 Teamwork



THANK YOU FOR CHECKING OUR WORK

