Contrast Media & 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 about contrast agents reactions and safety.
- Understand how to prepare patients for radiological studies.

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Color Coding

Important | Notes | Extra

Editing File

Major Sources of Risk in Radiology:

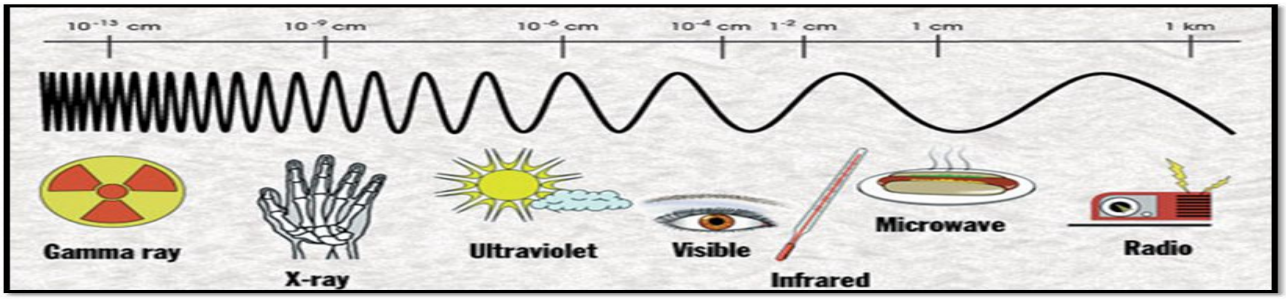
1. Radiation hazard.
2. Radioactive materials hazard.
3. Magnetic field hazard.
4. Contrast agents hazard.

What is Radiation?

radiation is an energy emitted from a substance, subdivided into:
- **Non-ionizing** (non hazard): Microwave oven, Television, Radiowaves, MRI , Ultrasound. We use them in daily life and they are safe and there is no biological effect of using it.
- **Ionizing** (hazard) : alpha particles (α)(harmless), beta (β), gamma (γ) to scan the bone and X-rays.

*Ionizing radiation can be carcinogenic and, to the fetus, mutagenic or even lethal.

Radiation Spectrum: the higher the frequency the more the risk



Research pioneers:

Roentgen: Discoverer of X-rays 1895.

Becquerel: Discoverer of Radioactivity 1896.

Rutherford: Discoverer Alpha and Beta rays 1897.

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 and higher the frequency, the greater the energy and the greater the ability to penetrate matter.

تخيلوها زي المطرقة إللي راسها نحيف (طول موجي صغير) وتدق بالجدار بسرعة (تردد عالي) تخترقه بصورة أقوى من المطرقة إللي راسها كبير وتدق بشويش

Goals of radiation safety:

- To eliminate deterministic (acute) effects.
- To reduce incidence of stochastic (Chronic) effects.

Deterministic and Stochastic Effects

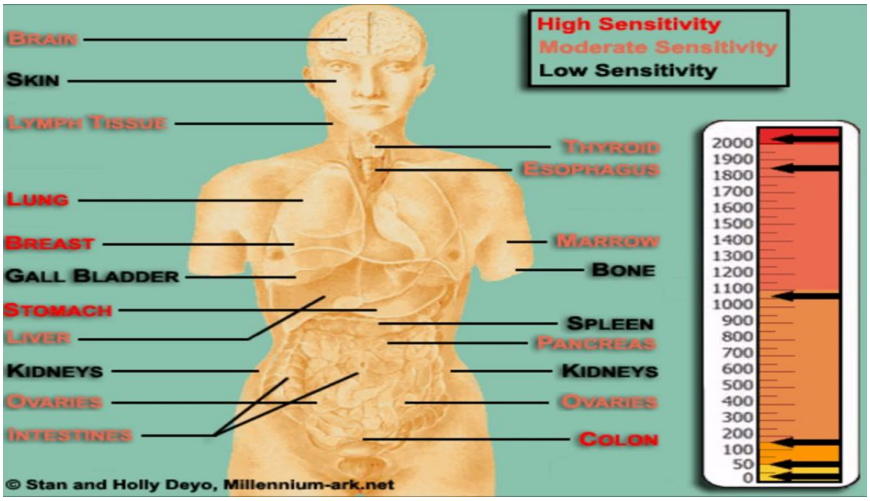
	Acute/deterministic effects	Chronic/Stochastic effects
Definition	Acute radiation symptoms are caused by high levels of radiation usually over a short period of time. Example: explosion of a nuclear reactor	Also referred to as (Probabilistic), probability of occurrence depends on absorbed dose. • Chronic radiation symptoms are caused by low-level radiation over a long period of time. Example: living near a nuclear reactor
Characteristics	• They cannot be predicted with certainty. we can't tell if someone going to develop these effects for sure. • 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.	• 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.
Exampl	Cataract formation, Bone marrow failure, Lung Fibrosis, Infertility, hair loss, Cataract formation, lowering the WBC count, Skin reddening (erythema).	1. Carcinogenic effect 2. Genetic effect for example people who was in hiroshima their generations going to have genetic effect of that exposure.

Threshold for deterministic effects:

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:



- 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. The risk is accumulative the whole life. that's why the risk in children is higher because they have more chances of exposure to radiation later in their lives.
- **1CT =** 1000 X-rays.
- Fluoroscopy has the highest and X-ray has the lowest.

Radiation Units

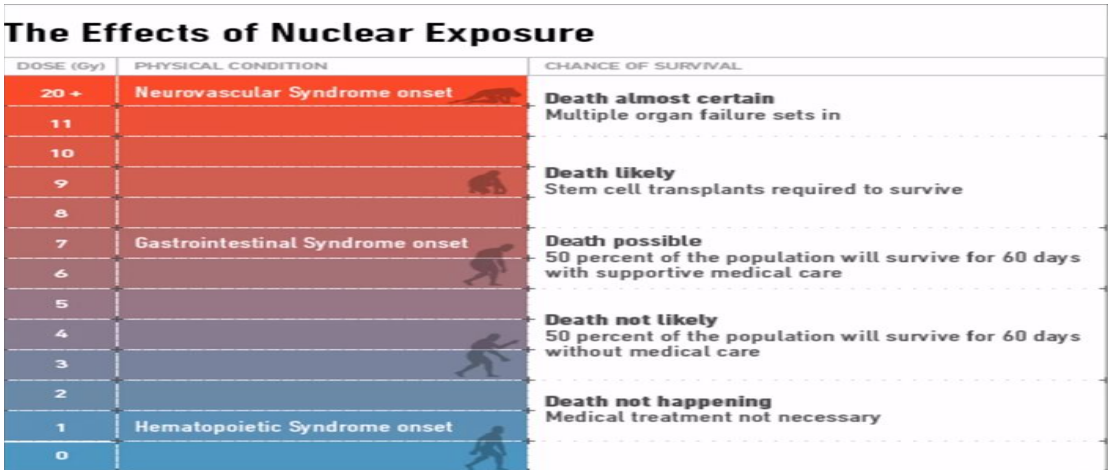
•**RAD**: Radiation Absorbed Dose. Original measuring unit for expressing the absorption of all types of ionizing radiation (alpha, beta, gamma, neutrons, etc) into any medium.

•**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.

Quantity	Unit	SI unit	Relation between unit
Absorbed dose	Rad	Gray (Gy)	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

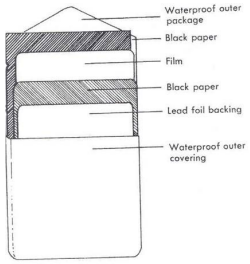
Radiation Exposure Levels & Effects

0.62 rem/y	average annual radiation exposure.
2 rem/y	international radiation exposure limit. Shouldn't exceed
25 rem/y	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 2weeks, effects on the GIT tract.
5,000 rem	death probable within 1-2 days, effects on the central nervous system. like exposing to a neaulear pump.

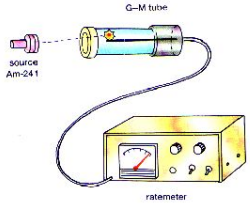


Typical radiation detectors

- Film packet. Made of plastic or paper

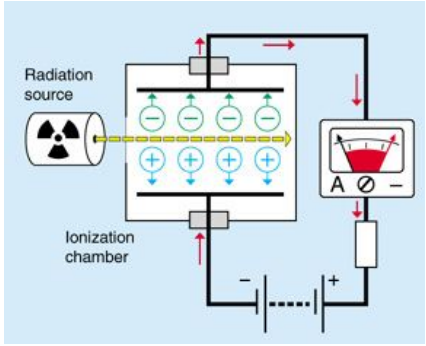


- Geiger-Müller (GM) Detector

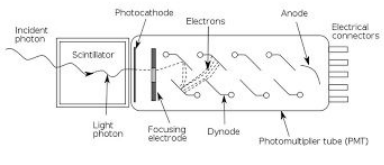


- Thermoluminescent Dosimeter (TLD) people who works in radiology carry it to measure the radiation.

- Ionization chamber



- Scintillation Detector



General Methods of Protection

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

1. **Minimize exposure time**. especially in procedures with high radiation like angiography
2. **Maximize distance** from the X-ray source (Exposure varies inversely with the square of the distance from the X-ray tube) 2 meters you will be exposed to 100% , 9 feet 60%.
3. **Use shielding:**
   - Operators view the target through a leaded glass screen.
   - Wear lead aprons (in the picture below). 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.

- **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).

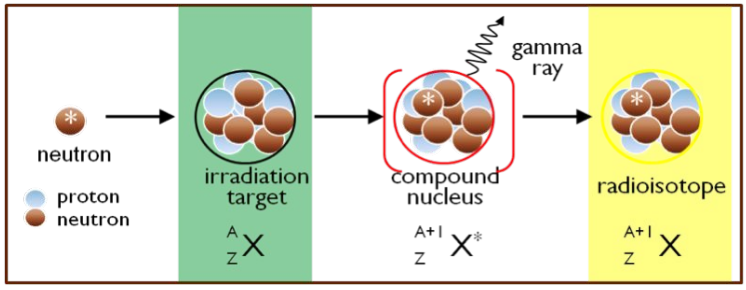
Radioactive Material Hazards These are other hazard found in the department in the department other than x-ray radiation

- **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.

Radioactivity Sources	
Naturally Occurring Sources. Usually are within the accepted limits	- Radon from the decay of Uranium and Thorium. - Potassium -40: found in minerals and in plants. - Carbon 14: Found in Plants and Animal tissue This one is used to know the age of fossils.
Manmade Sources:	- Medical use of Radioactive Isotopes (more explanation in the next slide) . - Certain Consumer products: (eg Smoke detectors). - Fallout from nuclear testing. - 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.



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Medical uses: Important

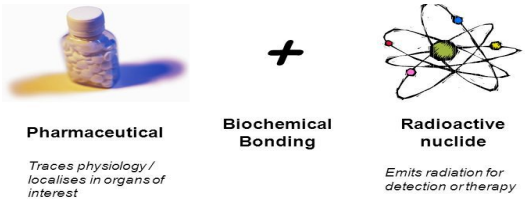
Radioactive isotopes are introduced into the body and can be distinguishable by their radiation from the atoms already present.

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

e.g in the thyroid scan we know that iodin 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.

- **Radiopharmaceuticals:**

The most widely used radioisotope is Technetium (Tc), with a half-life of six hours very important because it will 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



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Handling 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.

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. this is the time when they will be divided and the radiation will be emmeted so we can capture it.

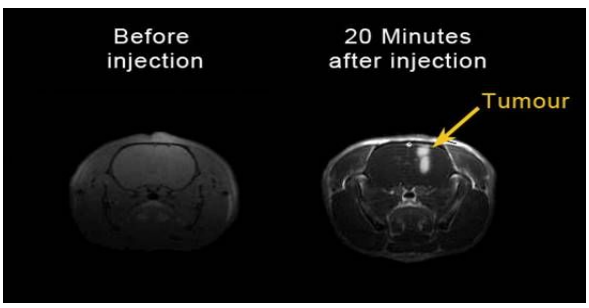
Magnetic field Hazard:

- 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 3Tesla (Tesla is a unit used to measure the magnetic field just like RAD REM) (1 Tesla = 20000 times earth gravity) There is a smaller unit than tesla known as gauss and it's used to measure 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 We call it like this because it happens within fractions of seconds. 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.
- 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 (materials that can be magnetized by an external magnetic field and remain magnetized after the external field is removed).
- 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.
- **MRI contraindications:** Patients with ferromagnetic surgical clips (Aneurysm clips), Pacemaker (now there is compatible pacemakers but they have to be reprogrammed before and after MRI), implanted cardiac defibrillator, implants containing ferromagnetic(attract to magnets) or paramagnetic (weekly attracted to magnets)components. And people who have suffered from shrapnel or steel fragment injuries, especially to the eyes.
- 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.
- Credit cards and watches with mechanical parts should be left outside the imaging area to prevent magnetic tape erasure and watch malfunction.
- Some 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.
- Aneurysm clips are examples of implants that can result in death if displaced.

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 (The idea is that these are thick monitors & the x-ray can penetrate them) 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. Nevertheless, severe or life-threatening reactions can occur with either route of administration.



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Contrast type	Negative	Positive
Organs become	Radiolucent 	Radiopaque 
Atomic weight	Low atomic	High atomic
Color on film	Black	White
Examples	air CO2	Iodinated contrast agent. Barium sulfate
Uses	inflate a structure: distinguish colon from other structures	Urogenital Studies Vascular Studies

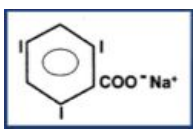
Why Iodine?

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

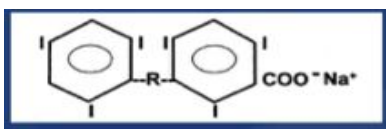
Classification of agents

Contrast agents are classified based on 3 properties:

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



Monomeric



Dimeric

RCM classification

Ionic

- Monomeric
  - Hyperosmolal >1400 mosm/kg Diatrizoate Iothalamate metrizoate
- Dimeric
  - Low osomalal 600mosm/kg Ioxagiate

Non-ionic

- Monomeric
  - Low osmolal 500 to 850 mosm/kg Iohexol Iopamidol Iversol Iopromide Ioxilan
- Dimeric
  - Iso-osomlal 290 mosm/kg Iodixanol

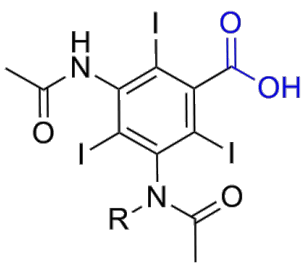
- The toxicity of contrast agents decreases as osmolality approaches that of serum. This has been accomplished by developing non-ionizing compounds and then combining two monomers to form a dimer.
- Currently used iodinated agents are cleared almost completely by glomerular filtration.
- Circulatory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

Effect of ionic VS non-ionic contrast agents

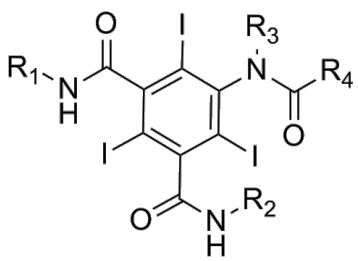
normal serum osmolality [275 to 290 mosm/kg]

Ionic	Non ionic
dissociate into separate ions 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

ionic contrast media



non-ionic contrast media



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Reaction Classification:

Immediate reactions: occur within the department (within one hour).(While the patient still on the table)

Delayed 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 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

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

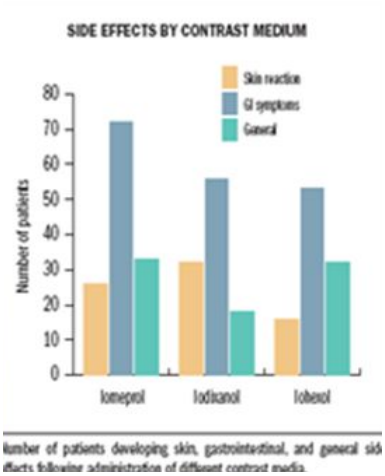
Mild Reaction (5%)	Signs and symptoms appear self-limited without evidence of progression, • **Nausea, vomiting, warmth, headache, dizziness,** shaking, altered taste, itching, flushing, chills, sweats, rash, nasal stuffiness, swelling: eyes, face and anxiety. **Treatment:** Observation and reassurance. 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**.

Reaction medications

- Aggressive fluids
- Lasix
- Dopamine
- 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



Number of patients developing skin, gastrointestinal, and general side effects following administration of different contrast media.

- Skin effects included itching, rash, and hives.
- Nausea, vomiting, and diarrhea were the GI side effects.
- General side effects included headache, dizzines, and fever.
- Infants and patients older than 60 years old are at increased risk of developing a side effect.

Contraindication for contrast:

- Diabetes (get a hx of medications taken, glucophage must be stopped 48 hrs before contrast injection).
- Multiple Myeloma.
- Renal Failure (Check BUN & Creatinine)
- Anuria (no urine production)
- Asthma (possible allergies)
- Hx of Contrast Allergy / Reactions
- Pregnancy (risk of fetal Thyroid toxicity).
- Allergic Reaction, Pre – medication is available.
- get a hx of medications taken glucophage must be stopped 48 hrs before contrast injection

Extravasation

Contrast material has seeped **outside of vessel**. To treat Apply a **WARM** Compress 1st 24 hours and 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 they bind up in large molecules eg. DTPA.
- Provides a greater contrast between normal and abnormal tissues.
- With **impaired kidney function** - renal patients -, gadolinium could lead to a serious and potentially fatal disorder called **Nephrogenic Systemic Fibrosis**. (NSF)

Methods of administration of contrast materials

INGESTED	ORAL: Barium sulfate suspension
RETROGRADE	AGAINST NORMAL FLOW: Barium Enema
INTRATHECAL	Spinal canal
INTRAVENOUS	Injecting into bloodstream (anything other than oral)

Summary

Types of radiation effects:	
1.Deterministic (Acute)effects	**2.Stochastic (chronic) effect**
•High radiation over Short time	•Low radiation over long time
•Hair loss •Erythema •cataract	•Carcinogenic effect •Genetic effect
Protection methods:	
•Minimize time & distance •Use shielding	
MRI contraindication :	
•Surgical clips •Pacemakers •shrapnel or steel fragment injuries	
Ionic & non-ionic contrast agents :	
Ionic	**Non ionic**
•Increase in blood osmolality. •Less money. •More reaction.	•No change in blood osmolality. •More money. •Less reaction.
Reactions to contrast :	

Mild 5%	Moderate 1%	Sever 0.05%

Questions

Q1-Which of the following is an example of stochastic effects?
a-Cataracts
b-Infertility
c-Genetic abnormalities
d-Lung fibrosis

Q2-Which following has the highest radiation exposure?
a-Fluoroscopy
b-X-ray
c-CT
d-MRI

Q3-At which level of radiation exposure we can detect measurable blood changes?
a- 2 rem/y
b- 25 rem/y
c- 100 rem/y
d- 200 rem/y

SAQ: Mention the three basic methods of protection against radiation exposure.

1- Minimise exposure time.
2- Maximise the distance from source.
3- Use shielding.

Answers :
1-c
2-a
3-b