

Radiation Hazards & Protection in Diagnostic Radiology

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Definitions : -

1. X-RAYS : X-Rays are produced by energy conversion when a fast stream of electrons is suddenly struck on the anode of an X-ray tube.
2. Radiation Dose : Generalized term for radiation exposure.
3. Absorbed Radiation Dose : Radiation exposed to a specific body tissues or specific reference point in or on the body.

4. Gray (Gy) : The unit of absorbed dose in the international system of units is called the Gray (Gy).

$$1 \text{ Gy} = 100 \text{ rads} = 1 \text{ joules / Kg.}$$

5. In diagnostic radiology,
1Roentgen = 1 rad = 1 rem

6. Exposure : The beam of X-rays causes ionization of the air which it passes. This is called exposure.

Health Effects of Ionizing Radiation:-

When X-radiation interacts with the matter, energy is absorbed mainly by the process of ionization. The mean energy imparted by ionizing radiation per unit mass at a point in the human body is known as the absorbed dose in tissues. The unit of absorbed dose in the international system of units is the Gray (Gy).

Radiation energy absorbed in living tissues initiate physical & chemical reactions, resulting in biological changes. Improperly used radiological X-ray equipments is capable of causing acute tissues damages.

However, in properly conducted diagnostic X-rays examinations, these acute radiation effect donot occur because doses are well below the threshold for such effect.

Absorbed dose in body tissues

The absorbed doses in tissues for a given examination are highly dependent on:

1. Technical factors.
2. Characteristics of the X-ray equipments.
3. Characteristics of the X-ray beam.
4. Number of radiographs made.
5. Irradiation time on fluoroscopy.

World Health Organization (WHO):

Radiology is overused all over the world. According to a WHO document : Any attempt to limit diagnostic radiology is a complex process. Over the years radiology has become a universal diagnostic tool. Patients expect a perfect result; their physicians are usually aware of the possibility of error or of incomplete information but may not realize the extent. Patients have come to believe that no examination by their doctor is complete unless they have been X-rayed.

The actual procedure is satisfying because it is usually dramatic yet causes little discomfort or inconvenience. For the physician, requesting an X-rays has become a comforting rituals.

This WHO document : (A Rational Approach to Radioagnostic Investigations 1983) recommends that medical practitioners should have more frequent recourse to radiological consultation in order to make the best use of radiological examinations. They should know how necessary it is on occasion not to request an examination.

The tissue reaction to X-rays in order of decreasing radiosensitivity can be given as follows: -

- i. **Lymph tissue**, especially lymphocytes
- ii. White blood cells and immature red cells of bone marrow.
- iii. Cells lining the gastrointestinal tract.
- iv. Gonadic cell.
- v. Skin specially the proliferating cell.
- vi. Blood vessels and body cavity lining.
- vii. Tissues of glands and liver.
- viii. Muscles
- ix. **Nerves.**

Harmful effects of radiation

They are classified into two categories:

1. Somatic effect : This arises from damages to somatic cell & effect on the exposed individual.
2. Hereditary / Genetic effect: This results due to damages to the reproductive cells and manifest in the progeny of exposed person.

Radiation effects on human body can also be classified as:-

- Stochastic effect : Any dose, however small, is effective for a certain level of risk for induction of stochastic effects. The risk increases as the dose increases. Hence, there is no threshold level / dose. It cannot be completely avoided but can be minimized to an acceptable level.

Examples :-

1. Hereditary effect.
2. Induction of cancer.

Non-Stochastic effect (Deterministic effect)

Somatic effects of radiation : -

- a. Early somatic effects
(whole body irradiation)

Dose range

Effect

➤ Less than 0.1 Gy

No detectable damage

➤ Above 0.1 Gy

**Chromosome
aberrations detectable**
(1-2acentrics in 500
cells)

➤ Above 0.5 Gy

Above effect + transient
reduction in WBC count
Temporary sterility in
males.

➤ Above 1.0 Gy

Above + radiation sickness like loss of appetite, nausea, vomiting, diarrhea (NVD): complete recovery possible at low doses.

➤ Above 3.0 Gy

Severity of above effects increases + damage to blood forming organs (bone marrow, spleen, lymph node) : death in 4 – 8 weeks possible (>10%)

➤ 3.0 to 5.0 Gy

All the above with increased severity + Anemia, infection, high fever (bone marrow syndrome), about 50 % of the exposed persons may die within 60 days (LD_{50/60})

➤ 8.0 to 15.0 GY

Severity of above effects increases + cells in the gastrointestinal system get severely damaged leading to gastrointestinal syndrome (GIS) like diarrhea, weight loss and fever., Death may occur in 1-2 weeks (100%)

➤ Above 20 .0 Gy

All the above +
manifestation of skin
damage.

➤ > 25 Gy

All the above + severe
depression, fatigue,
delirium, coma etc. {
Central nervous
system syndrome
(CNS)}. Death occurs
in a few hours to
days.

b. Early somatic effects
(Partial body irradiation)

<u>Dose</u>	<u>Region</u>	<u>Effect</u>
0.15 Gy	Testes	Temporary sterility
<u>3.5 – 6.0 Gy</u>	Testes	Permanent sterility
1.5 – 2.0 Gy	Ovaries	Temporary sterility
<u>2.5 – 6.0 Gy</u>	Ovaries	Permanent sterility

3 Gy	Hair follicles	Epilation (Fall of hair)
<u>5 Gy</u>	Eyes	Cataract (after 2-3 yrs)
6 Gy	Skin	Reddening of skin (erythema) Permanent epilation
10 -20 Gy	Skin	Burns, blisters, wounds, death of tissues.

➤ Late Somatic Effects :-

Exposure to low levels of radiation over a prolonged period, which normally not produce any early effects, may lead to late effects. Late effects are characterized by latent period, which can be as long as 30 years. The important late effects are Cataract and Cancer.

Radiation induced acute effects of skin.

Dose Qty	Lesion	Time of appearance	Signs and Symptoms
5	Initial erythema	1 – 3 days	Reddening
	Dry desquamation	2 – 3 weeks	Scaling, pigmentation
	Erythema proper	3 – 4 weeks	Itching, Depilation, Redding

Dose Qty	Lesion	Time of appearance	Signs and Symptoms
20	Moist desquamation	4 – 3 weeks	Blister oozing
50	Cell death	2 – 3 weeks	Necrosis

Bone marrow doses during different examinations

<u>X-ray examinations</u>	<u>Mean marrow doses (mrad)</u>
❖ Skull	50
❖ Cervical spine	20
❖ Full mouth dental	25
❖ Chest	10
❖ <u>Stomach /Upper GI</u>	400

❖ Gallbladder	300
❖ <u>Lumbar spine</u>	400
❖ <u>IVP</u>	400
❖ Abdomen	80
❖ Pelvis	100
❖ Extremity	10

Skin exposure (mrads) per projection.

<u>X-ray examinations</u>	<u>Skin exposure(mrads)</u>
➤ Chest (PA)	10 - 20
➤ Skull (Lat)	100 – 200
➤ Abdomen (AP)	250 – 500
➤ Cervical spine (AP)	5 - 150

➤ <u>Thoracic spine</u>	300 – 600
➤ <u>IVP</u>	300 – 600
➤ Extremity	50 - 200
➤ Dental	200 – 500

Dose from fluoroscopic procedures

Exams	Skin exposure R/min	Mean active marrow dose per exams	Gonadal dose / exam mrad	
			Male	Female
Barium enema	4.0	875	175	903
Upper GI	4.2	835	1	171
Gall bladder	3.0		0.5	78

Approximate fetal dose (mrads)

<u>Examination</u>	<u>Fetal dose (mrads)</u>
<input type="checkbox"/> Skull	0.01
<input type="checkbox"/> Full mouth dental	0.01
<input type="checkbox"/> <u>Chest</u>	0.01
<input type="checkbox"/> Stomach	25

<input type="checkbox"/> Gallbladder	3
<input type="checkbox"/> Lumbar spine	250
<input type="checkbox"/> IVP	265
<input type="checkbox"/> Abdomen	265
<input type="checkbox"/> <u>Pelvis</u>	295
<input type="checkbox"/> Extremity	0.01

Irradiation in utero

(Nominal risks for irradiation in utero for absorbed doses in the embryo or foetus)

<u>Time after conception</u>	<u>Nominal risk per milligray</u>
• <u>First two weeks</u>	Minimal
• 3 rd through 8 th weeks	potential for malformation of organs

• 8th through 15th weeks

severe mental
retardation 1 in 2,500

• 16th through 25th
weeks

severe mental
retardation 1 in 10,000

• Throughout
pregnancy

Childhood cancer 1 in
50,000

Typical absorbed doses in selected tissues from a few common diagnostic X-ray exams

X-rays exams	Active bone marrow	Absorbed dose (mGy)		
		Breast	Uterus (embryo / foetus)	Thyroid
Chest	0.04	0.1	*	0.07
Skull	0.3	*	*	2
Cervical spine	0.1	*	*	4
Thoracic	0.4	3	*	0.8

Lumbosacra l spine	2	*	6	*
Intravenous pyelogram	1	*	8	*
Barium enema (including fluoroscopy)	10	*	35	*
Mammo graphy (film screen)	*	2	*	*

* less than 0.01 mGY.

Permissible doses :

The maximum permissible doses can be calculated by the formula – $5 (N - 18)$

N is the age of person concerned in years.

Dose limits Recommended by ICRP(ICRP 60 – 1990) is given below in table form ;

Application	Dose Limit	
	Occupational	Public
<u>Whole body;</u> effective dose	<u>20 mSv per</u> <u>year</u> averaged over defined period of 5 yrs with no more than 50 mSv in a single year.	<u>1 mSv in a</u> <u>year</u> , averaged over 5 years

Parts of the body:

(equivalent dose) Lens of the eye

skin *

Hands and feet**

150 mSv per year

500 mSv* per year

500 mSv** per year

15 mSv in a year

50 mSv in a year

Equivalent dose to the surface of the abdomen of pregnant women

2 mSv after declaration of pregnancy up to the term

Protection from Radiation Hazards

The International Commission on Radiological protection (ICRP) set up guidelines on the safety standards in the use of radiation.

1. Prevent detrimental deterministic effects.
2. Limit the probability of stochastic effects to level deemed acceptable.
3. Ensure that practices involving radiation exposure are justified.

Consequently the commission has recommended a system of radiological protection based on the following principles.

- No practice shall be adopted unless its introduction produces a positive net benefit (**Justification of practice**)
- All exposure shall be kept as low as reasonably achievable (**ALARA**), economic and social factors being taken into account (**Optimization of protection**) and
- The combined effect of all relevant practices on any individual should be subject to dose limits.

Basic Principles of Radiation Protection

As recommended by ICRP the principle of ALARA should be strictly followed. The three most important factors which influence the radiation exposure and radiation dose are :

- a. Time: Lower the time of exposure ; lower the dose to patient and radiation workers.
- b. Distance: More the distance from the source lesser the radiation dose.
- c. Shielding : Larger the shielding thickness, lower the exposure rate.

Protection for the Radiologist and the Radiographer.

All diagnostic departments should conform with laid down requirements of radiation protection to walls, floor, ceiling and doors to shield persons in adjacent rooms, the use of modern equipment with adequate protection around the X-ray tube apart from the main beam and protection for the radiologist during fluoroscopy. Protective body aprons and gloves should be available.

In addition to above, there are number of ways in which radiographer can actively help to keep radiation to a minimum for them and to other fellows.

1. To keep away as far as possible from all sources of radiation, whether primary or scattered and never stay in primary beam .
2. If child or unsteady patient needs support, it should be done by accompanying parent or person not concerned with X-ray deptt. He or she should be provided protective clothing.
3. Always use smallest possible X-ray beam which minimizes radiation to the radiographer.
4. Not to remain in X-ray room unnecessarily during exposure.

5. In a small room it is essential to provide with protective clothing / screen with windows (lead glass) to reduce the scatter to the radiographer.

6. During fluoroscopy, stand whenever possible behind the well-protected radiologist only. During horizontal screening, radiographer must always wear a lead apron to protect the body.

7. Use film badge monitoring. A continuous personal record can be kept of every worker's exposed dose.

Protection of the Patient

The use of up-to-date equipments and accessories helps to reduce radiation to the patient. A permanent total filter of 2mm should be fitted to all equipments. It will absorb soft rays thus reducing skin dose.

1. No patient should be irradiated unnecessarily if relevant information can be gathered by previous X-ray taken at some another hospital.

2. Fluoroscopy should not be used if same information can be gathered by X-ray.
3. To minimize radiation to the fetus, the pelvis should not be radiographed during pregnancy.
4. Any woman of child bearing age can be in the early stage of pregnancy, hence, X-ray should be undertaken during the first 10 days of the menstrual cycle only.
5. The fastest possible film screen combination should be used.

6. Practice a good radiographic technique to produce good quality X-ray to avoid “repeat X-ray” and curtail further exposure.
7. Always use the smallest possible field size. Use of circular cone to cover a rectangular film exposes more to the patient.
8. Whenever possible direct the beam away from gonads.
9. The kilovoltage used should be neither too low nor too high.

References:

1. Protection of the patient in diagnostic radiology: *Summary of the current ICRP principles (AERB), Bombay.*
2. Workshop on establishment of directorate of Radiation safety organized by Radiological Safety Division, Atomic Energy Regulatory Board (AERB) Mumbai, January 2, 2009
3. Radiophysics and Darkroom Procedures *by LC Gupta and Abitabh Gupta (Third Edition).*

Thank YOU