Radiation Safety Training Module: Diagnostic Radiology
Radiation Safety for X-ray Technologist in Diagnostic Radiology

Radiological Safety Division
Atomic Energy Regulatory Board
Content

- Introduction
- Mission of AERB
- Biological Effects of Radiations
- Types of Radiation Generating Equipment: (RGE)
- Typical patient dose
- Radiation Safety Aspects
- Principle for Radiological protection(Practice)
- Basic Factors for Radiation Protection
- Radiation safety methodology
Radiation: energy in motion

- **Non-Ionizing Radiation**: Radiation that does not have sufficient energy to eject orbital electrons. e.g.: microwaves, ultraviolet light, lasers, radio waves, infrared light, and radar.

- **Ionizing Radiation**: Radiation that has sufficient energy to eject orbital electrons. e.g.: alpha particles, beta particles, neutrons, gamma rays, and x-rays.
Amongst man made radiation sources, Medical diagnostic x-ray examinations contribute the largest dose to population.
WHY TO ADDRESS RADIATION SAFETY IN USE OF X-RAYS

❖ **ANNUAL GLOBAL X-RAY EXPOSURES**

- Diagnostic X-ray Examinations: 3.1 billion
- Dental X-ray Examinations: 0.5 billion
- Collective effective dose: $4 \times 10^6$ man-Sv
- Effective dose per person: 0.62 mSv
- Contribution due to CT scans: 43% of collective dose
- Contribution due to IR procedures: 8% (during last 10 years)

*Diagnostic X-ray examinations in 1996: 2.4 billion*

Data Source: UNSCEAR Report 2008
Mission of the AERB

The Mission of the AERB is to ensure the use of ionising radiation and nuclear energy in India does not cause undue risk to the health of people and the environment.

The constitution of AERB together with the Atomic Energy (Radiation Protection) Rules, 2004, has mandated AERB to develop and issue safety codes and standards and to develop safety policies in radiation and industrial safety areas.
Biological Effects of Radiations

*Deterministic effects:*
There is a threshold dose below which no effect is observed. Above this threshold, the severity of the effect increases with dose.

- **Temporary Sterility**
- **Epilation**
- **Nausea, Vomiting and Diarrohea (NVD syndrome)**
- **Erythema**
- **Cataract**
- **Skin burn**

Whether working in an X-ray facility can cause any of these effects: **NO**
Whether working in an IR facility can cause any of these effects: **NO** (with proper use of safety accessories)
**Stochastic / Probabilistic effects**
- There is no established threshold dose.
- The probability of the effect increases with dose.
  - Cancer
  - Leukaemia
  - Hereditary effect

*No threshold dose is defined!!*

<table>
<thead>
<tr>
<th>Stochastic Effects</th>
<th>Deterministic Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Due to cell changes (DNA) and proliferation towards a malignant disease</td>
<td>Due to cell killing</td>
</tr>
<tr>
<td>No dose threshold- applicable also to very small doses</td>
<td>Involve a large number of cells</td>
</tr>
<tr>
<td>Probability of effect increases with dose</td>
<td>Have a dose threshold -typically several Gy</td>
</tr>
<tr>
<td>Severity (example cancer) independent of the dose</td>
<td>Specific to particular tissues</td>
</tr>
<tr>
<td></td>
<td>Severity increases with dose eg. Skin injuries</td>
</tr>
</tbody>
</table>
RADIATION SAFETY PROGRAMME SHOULD BE DESIGNED TO

1. PREVENT DETRIMENTAL DETERMINISTIC EFFECTS

II. LIMIT or MINIMIZE THE PROBABILISTIC EFFECTS TO LEVELS OF ACCEPTABLE
Types of Different Modalities Diagnostic Radiology Equipment

- Computed Tomography
- Interventional Radiology
- Radiography (Fixed/Mobile)
- C-Arm/ O-Arm
- Mammography
- BMD
- Dental (Intraoral/OPG/CBCT)

Note: MRI and Sonography (Ultrasound) or non-ionising RGE do not come under purview of AERB regulations
Equipment's used in Diagnostic Radiology Facilities

- Radiography (fixed)
- Interventional Radiology
- Computed tomography
- Dental (intra-oral)
- Mammography
- Dental (OPG)
- BMD
# Typical Patient Doses in X-ray Procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective Dose mSv</th>
<th>Increased Risk of Cancer</th>
<th>Equivalent Period of Natural Background</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Dose</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Chest X ray</td>
<td>&lt;0.1</td>
<td>One in a million</td>
<td>Few days</td>
</tr>
<tr>
<td>• Extremities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intermediate Dose</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• IVP</td>
<td>1 - 5</td>
<td>1 in 10,000</td>
<td>Few months to a few years</td>
</tr>
<tr>
<td>• Lumbar spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Abdomen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• CT head and neck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Higher doses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Chest or abdomen CT</td>
<td>5 - 20</td>
<td>1 in 2,000</td>
<td>Few years to several years</td>
</tr>
<tr>
<td>• Nuclear cardiogram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cardiac angiogram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Barium enema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Natural background</strong></td>
<td>2.4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Ref: IAEA: Radiation Protection of Patients (RPOP)
Safety of Equipment (Type Approval by AERB)

Adequately shielded Room Layout

Safety of Equipment (Type Approval by AERB)

Radiation safety Training, QA, qualified staff

Safe work practice and dose optimization

Built in (Design) Safety

Operational Safety

Radiation Safety
Operational Safety

Components of operational safety

- Handling of equipment by Qualified persons
- Usage of Personnel monitoring (TLD)
- Preventive maintenance (QA) of equipment
- Interaction with regulatory body
- Use of safety accessories -
  - Mobile Protective Barrier, Lead Apron, Organ shield etc.
Built-in Radiation Safety

Design Safety of the Equipment:

Install only those equipment that are Type Approved by AERB
Take requisite AERB permissions prior to installation
Ensure the performance evaluation of the equipment is acceptable after installation
Use the equipment after obtaining license for operation

Design Safety of Installation:

Install the equipment in an adequately shielded room
Ensure all the equipment specific safety (such as ceiling suspended lead glass, couch hanging lead rubber flaps etc) accessories are provided
Refer Model Layout of X-ray installations provided on AERB web site
Basic Principles of Radiation Protection

1) JUSTIFICATION: No practice shall be adopted unless its introduction produced a net positive benefit

2) OPTIMIZATION OF EXPOSURES: All exposures shall be kept As Low As Reasonably Achievable (ALARA), economic & social factors being taken into account

3) DOSE LIMITS: Dose to individuals shall not exceed recommended limits (Applicable to occupationally exposed personnel)

Exposure due to natural background radiation & medical exposure excluded in arriving at the dose limits.
## Dose Limits prescribed by the Competent Authority in India

<table>
<thead>
<tr>
<th>Part of the body</th>
<th>Occupational Worker</th>
<th>Member of Public</th>
<th>Trainee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body (Effective dose)</td>
<td>20 mSv/year averaged over 5 consecutive years; 30 mSv in any single year</td>
<td>1 mSv/year</td>
<td>6 mSv in a year</td>
</tr>
<tr>
<td>Lens of eyes (Equivalent dose)*</td>
<td>150 mSv in a year</td>
<td>15 mSv/year</td>
<td>50 mSv in a year</td>
</tr>
<tr>
<td>Skin (Equivalent dose)</td>
<td>500 mSv in a year</td>
<td>50 mSv/year</td>
<td>150 mSv in a year</td>
</tr>
<tr>
<td>Extremities (Hands and Feet) Equivalent dose</td>
<td>500 mSv in a year</td>
<td>----- -----</td>
<td>150 mSv in a year</td>
</tr>
</tbody>
</table>

For female workers, once pregnancy is declared the equivalent dose limit to embryo / fetus shall be 1 mSv for the remainder of the pregnancy.

ICRP has recently revised the dose limit for lens of eyes as 20 mSv in a year for occupational workers.
Basic Three Factors for Radiation Protection
(Working Personnel & Public)

• Time
• Distance
• Shielding
TIME

- Exposure from X-ray unit is directly proportional to time

- Reduce period of exposure to radiation to reduce the dose received from source.
DISTANCE

- Increase distance from source to decrease exposure rate.

- $I_1 d_1^2 = I_2 d_2^2$ (INVERSE SQUARE LAW)

- Double the distance from the source; dose-rate falls to $\frac{1}{4}$ the original value.

- Halve the distance from the X ray source; dose-rate increase to 4 times the original value.

More the distance from source (X-rays) - Lesser the radiation
Effect of Distance on Dose Rate-Inverse Square Law:
Increase Distance

X-Rays

25 mR/hr @ 100cm  100 mR/hr @ 50cm
SHIELDING

Use an appropriate shielding material or protection devices

\[ I = I_0 e^{-\mu t} \]

\( \mu \) - linear attenuation coefficient

**USE LARGE SHIELDING THICKNESS (High Z materials eg Lead, Steel etc)) - REDUCE THE EXPOSURE RATE**
To reduce the Radiation dose to the individual-

• Reduce the time of exposure

• Increase the distance from the X-ray source

• Interpose a shielding material between source and working person-- *(Use of radiation protection accessories)*
Radiation Protection Accessories of Operator/Staff

- Use protective devices

- use of lead apron (0.25 mm lead equivalent)

0.25 mm Lead Eqv. glass eyewear with side protection

Use TLD with the cassette.
Wear TLD below apron, at the Chest Level

Radiation dose would be reduced by more than 90 % by using lead apron
Use ceiling suspended screens, lateral shields and table curtain in fluoroscopy procedure.

90% protection from scattered radiation

Should not be removed
Proper storage of radiation protection devices - Lead apron

Proper storage maintains good quality of the lead apron. Shielding adequacy of the lead apron should be checked at least once in two years.
Use of TLD Badge

What is TLD Badge

TLD Badge is a radiation dose measuring device. This provides us to know if we are working within the safe limits (TLD does not protect us from radiation).

What is Your TLD Badge Number

000297C0198/
000297W0198
The Cassette has three windows with different filters for estimation of radiation doses from different types of radiation. Wearing a BARE TLD card will give a very WRONG estimation of the dose.
Wear TLDs below Lead Apron

TLD below apron

TLD above apron

The lead apron provides protection from radiation. Wearing a TLD below lead apron estimates the actual received dose by radiation worker. Above lead apron will give a very WRONG estimation of the dose.
Where to Store TLD badge

Never store/leave TLD badges (control/personnel) in X-ray Room/Radiation Area.

Store control TLD badge in radiation free area all the time. Store personnel TLD badge in radiation free area when not in use. (e.g., office room)

Storing of TLD badge in radiation area after work, provides unnecessary exposure i.e. non-genuine dose to TLD badge
Radiation Protection Accessories

- Mobile Protective Barrier (MPB)- 1.5 mm Lead Eqv
- Lead Aprons - 0.25 mm Lead Eqv
- Thyroid Shield -0.25 mm Lead Eqv
- Gonads Shield- 0.25 mm Lead Eqv
- Eye Wear (Shield)- 0.25 mm Lead Eqv
- Rubber hanging Flaps (In IR)-0.5 mm Lead Eqv
- Hand Gloves -0.25 mm Lead Eqv
- Lead Glass window- 1.5 mm Lead Eqv
- Door (Lead Lined)-1.7 mm Lead Eqv

Accessories provide the shielding which will drastically reduce the radiation dose to operator. Never forget to use them.
Radiation Safety in Radiography

Always work behind a protective barrier (min. 1.5 mm lead)

Use of Mobile Protective Barrier (MPB)

By proper use of MPB, during radiographic procedures technician/operator is protected from scatter and leakage radiation.

Wear TLD badge at the chest level
use collimator (diaphragm) to limit the field size to the area of interest

Cont’d

Collimation

Collimate tightly to the area of interest.

- Reduces the patient’s total entrance skin exposure.
- Improves image contrast.
- Scatter radiation to the operator will also decrease.
Use of Antiscatter Grids

• Antiscatter grids

Antiscatter grids reduce scattered radiation reaching the film thus improving the quality of the resulting radiograph and reducing chances of repeat exposures. Antiscatter grids increase the radiation dose to patient and hence where required use the grids. For pediatric patient do not use grids.
Always use TLD at the chest level, inside lead apron

Operate the mobile X-ray machine from a distance using control cable of 2 m length, Use Lead Apron

By using 2m cable, distance increases and radiation exposure reduces

Extendable Control Cable
Radiation Safety in Computed Tomography

Mandatory requirement of separate control room

Operate the CT equipment from the control room

2 mm lead equivalence viewing window

Always use TLD at the chest level, operating the equipment

Never leave TLD badge at control room after work
Use Ceiling Suspended screen, couch hanging flaps and Lead Apron, Lead glasses, Thyroid shield.

90% protection from scattered radiation

Always use TLD at the chest level, inside lead apron

Never leave TLD badge near the X-ray equipment

Radiation Safety in Interventional Radiology

Screen

Flaps

Keep X ray tube under the patient table and not over it
Operate the mammography machine behind mobile barrier

Mobile barrier of min.1.5 mm lead equivalence

Use of Mobile Protective Barrier (MPB)
Ensure availability of Lead lined cone for the dental-IOPA X-ray unit.

Proper shielding of dental cone

Plastic Cone should not be used.

Ensure that the Cone is lead lined. Plastic Cone increases the radiation dose to patient and worker and should not be used.
Use of Mobile Protective Barrier (MPB) to operate dental OPG/CBCT if separate control not available

- stand behind the protective barrier during operation
- keep the TLD badge away from radiation area when not in use
- TLD badge below the lead apron
Radiation safety of patient is ensured by

- Limiting the total “beam-on” time in flouroscopic procedures
- Avoiding oblique lateral projections (especially in flouroscopy and IR)
- Collimation to limited field size – Area of Interest
- Selecting low dose protocol whenever feasible (High kV and Low mAs)
- Use of Exposure protocols for patient examinations including paediatric protocols
- Monitor the DLP in CT and DAP values for IR procedures
- Maintain the Record of of patient’s doses for CT and IR procedures.
More points to Remember

• Carry out QA testing of each & every X-ray equipment once in TWO YEARS to maintain the quality of equipment and imaging standard.

• Use equipment “Type Approved” by AERB. Type Approved Comply with design safety requirements

• Operate X-ray equipment which is licensed by AERB

• If new X-ray equipment is being purchased, do it only after taking “Procurement Permission” from AERB

• Do a Radiation Protection Survey report (RPS) of X-ray facility to ensure radiological safety of the installation
1. What are the basic factors for radiation protection in Diagnostic radiology?
Ans: Time, Distance & shielding

2. What is the relation between distance & X-rays exposure?
Ans: X-ray exposure follows inverse square law with distance
\[ I_1 \ d_1^2 = I_2 \ d_2^2 \]

3. What are the different types of radiation protection accessories to be used during the diagnosis of patients?
Ans: Lead apron, protection barrier, lead eye glass, gonad shield, hand gloves, thyroid shield etc.

4. Where to store the TLD badge after the routine work.
Ans: In radiation free area (Outside the X-ray installation room)

5. What is the mission of AERB?
Ans: The Mission of the AERB is to ensure the use of ionising radiation and nuclear energy in India does not cause undue risk to the health of people and the environment

6. What are the common shielding materials used for protection in Diagnostic Radiology?
Ans: Lead, Steel and brick, concrete etc
<table>
<thead>
<tr>
<th>List of presentations in the training Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basics of Diagnostic X-ray Equipment</td>
</tr>
<tr>
<td>Biological effects of Radiations</td>
</tr>
<tr>
<td>Medical X-ray imaging techniques</td>
</tr>
<tr>
<td>Planning of Diagnostic X-ray facilities</td>
</tr>
<tr>
<td>Quality Assurance of X-ray equipment</td>
</tr>
<tr>
<td>Quality Assurance of Computed Tomography equipment</td>
</tr>
<tr>
<td>Radiation Protection in Diagnostic Radiology Practice</td>
</tr>
<tr>
<td>Causes, prevention and investigation of excessive exposures in diagnostic radiology</td>
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<td>Regulatory Requirements for Diagnostic Radiology Practice</td>
</tr>
</tbody>
</table>
THANK YOU