

***Booklet on Radiation Safety in Diagnostic Radiology-
Information for X-ray Technologist***



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Preface

Since the discovery of X-rays in 1895, X-ray examinations have become an integral part of medical diagnostic radiology practice. Society is deriving immense benefits from the use of X-rays, by detection of a variety of diseases, bone fractures and deformations. Though the use of X-rays has given tremendous benefits to the society, excess radiation dose of X-rays is harmful to human beings. With increase in the medical applications of X-rays, concern over radiation safety has also grown.

The aim of this booklet is to provide basic information as a quick reference for X-ray Technologist(s) pertaining to usage of diagnostic X-rays and radiation safety in various modalities of X-ray imaging.

This booklet gives a brief overview of radiation, types of radiation, sources of ionisation radiation, diagnostic X-ray equipment, various modalities of X-ray imaging and the precautions that need to be taken by X-ray Technologist(s) during operation of these modalities of X-ray equipment.

We hope that this booklet will help in achieving radiation safety in diagnostic X-ray imaging.

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14. Questions and Answers



Important: Do not forget to read the answers of frequently asked questions by X-ray Technologist(s)

To have a quick understanding on radiation safety aspects, read



Text written in such boxes are very important from radiation safety view point

1. Radiation

- Radiation is the energy that travels in the form of waves or particles.
- Radiation includes electromagnetic radiation, such as radio waves, microwaves, visible light, X-rays and gamma rays (γ).
- Radiation is present everywhere in the universe.

2. Types of Radiation

There are two types of radiation:

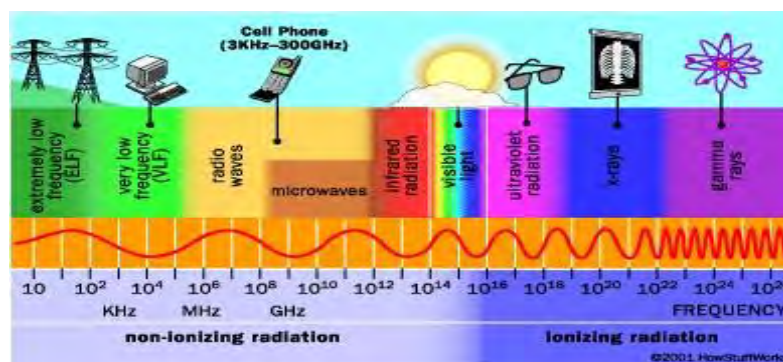
- Ionising Radiation
- Non-Ionising Radiation

Ionising Radiation

- Radiation that has sufficient energy to eject electrons from atoms of matter or body tissues through which it traverses is called ionising radiation.
Examples: Medical and dental radiography, computed tomography (CT), nuclear medicine and fluoroscopy procedures are examples of diagnostic examinations that use ionising radiation.

Non-Ionising Radiation

- Non-ionising radiation is the radiation that has enough energy to vibrate atoms but does not have enough energy to remove electrons from atoms of matter or body tissues.
Examples: Radio waves and microwaves.
Ultrasound and magnetic resonance imaging (MRI) are examples of diagnostic examinations that use non-ionising radiation.



1. Electromagnetic Spectrum

X-ray units are regulated by AERB while Ultrasound and MRI units are not regulated by AERB.

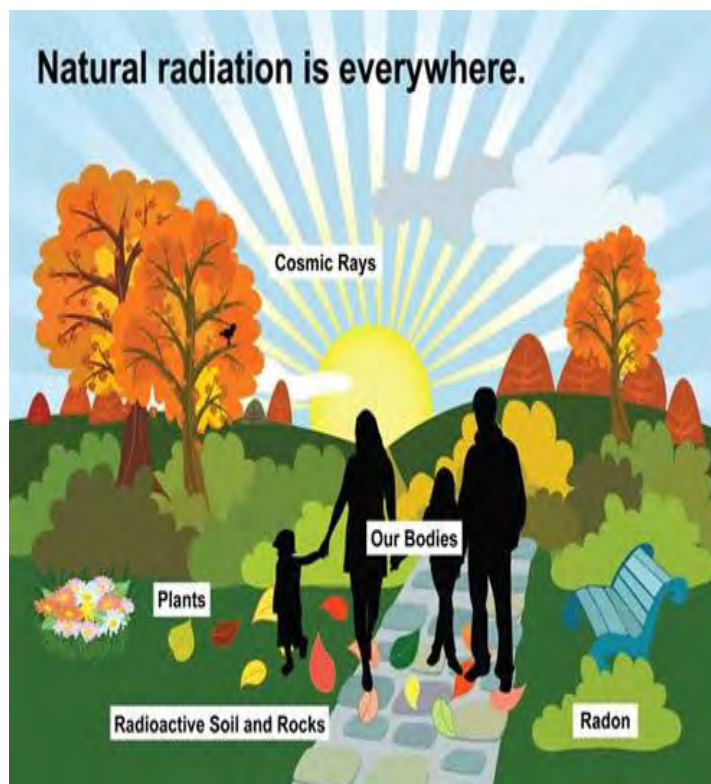
3. Sources of Ionising Radiation:

Sources of ionising radiation are of two types:

- Natural sources of ionising radiation
- Manmade sources of ionising radiation

Natural sources of ionising radiation

- Ionising radiation is present everywhere in nature in varying amounts at different locations and it is a part of our daily life.
- We all are exposed to natural background radiation every day in our lives. This comes from the ground and building materials around us, the air we breathe, the food we eat and even from outer space (cosmic rays).
- Depending upon the location where one individual lives, each individual is exposed to 1 to 3 mSv every year, with global average of **2.4 mSv from the natural sources of ionising radiation.**



2. Natural Sources of Radiation

Natural radiation sources of ionisation radiation are not amenable to control and therefore excluded from regulatory control.

Manmade sources of ionising radiation

- The use of ionising radiation in medicine is the largest source of manmade radiation today.
- The most well-known application is diagnostic X-ray equipment, which uses X-rays for examining chest, teeth, broken bones etc.



3. Medical Application of Radiation (Diagnostic X-rays)

- Another application of manmade source of ionising radiation is nuclear medicine, in which small amount of radioactive material (isotope) is injected into the veins of a patient, which concentrates in a particular organ of interest, for example in the skeleton for a bone scan. The radioactive material emits gamma rays, which are a type of radiation that behave like X-rays. A special camera detects the gamma rays coming out from the body of the patient and builds up an image of what is happening inside the body of the patient.
- Other manmade source of ionising radiation includes industrial radiography and nucleonic gauging applications which are used in various industries such as construction, civil engineering and oil well-logging applications.

4. Basic Principle of Radiation Protection:

Justification

- It should be ensured that a diagnostic X-ray examination on a patient will do more good than harm.
- Medical practitioner and radiology department should ensure that when radiation (X-rays) is used, the benefits from making the right diagnosis and consequently giving the right treatment to the patient, is always greater than any small risk involved.

Justification of application of X-rays in medical diagnosis by clinician.

Optimization

- It is important to deliver the smallest amount of radiation (X-rays) needed to obtain images for desired purposes. In other words, application of X-rays during diagnostic examinations are so optimized by proper selection of operating parameters (kV, mA, X-ray ON time and field size) that it provides acceptable image quality with minimum patient dose.
- It should also be ensured that during diagnostic X-ray examinations, radiation dose to the operator(s) are kept as low as reasonably achievable (ALARA).

Optimization of medical exposure by operator– minimum dose for desired Image.

Dose Limits

- Radiation dose to any individual (radiation worker(s) or member of public) from radiation source (X-ray equipment) should not exceed the prescribed Dose Limits.
- *Dose Limits are not applied to patients undergoing X-ray examinations as they are benefitted with right diagnosis.*

AERB has prescribed dose limit for occupational workers such as X-ray Technologists and medical practitioner(s) as 20 mSv in a year averaged over five consecutive years and dose limit for members of public as 1 mSv in a year.

5. Health Effects of Ionising Radiation

- Every individual receives average 2 mSv radiation from natural sources of ionising radiation whereas radiation received by a patient in diagnostic X-ray examinations varies typically from 0.2 to 1.8 mSv. In such low radiation levels, no health effects are detected. As per dose records of radiation workers of diagnostic radiology practice in India, majority of persons working with X-ray equipment receive radiation doses less than 1mSv in a year.
- It may be noted that radiation effects can be seen in human being at cellular level only when the whole body radiation received by an individual exceeds 100 mSv. The other noticeable health effects can be seen above a dose of 1000 mSv.
- However, the radiation protection community assumes that any amount of radiation may induce some effects which are not detectable at low level of radiation. Therefore, it is appropriate to follow safety precautions to minimize the effects of radiation on human health as much as possible.

X-ray equipment installed in a room with proper shielding and use of protection devices (protective barrier or lead apron) by X-ray Technologist(s) during operation of X-ray equipment ensure that radiation dose received by X-ray Technologist(s) is as low as reasonable achievable (ALARA).

6. Atomic Energy Regulatory Board (AERB)

- AERB regulates all facilities using radiation sources including medical diagnostic X-ray equipment (e.g. CT scans, General X-rays, Dental X-rays etc.) used in hospitals/clinics in the country.
- AERB regulates radiation facilities such as X-ray facilities by issuing licence for operation of their X-ray equipment and approving design of diagnostic X-ray equipment.

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

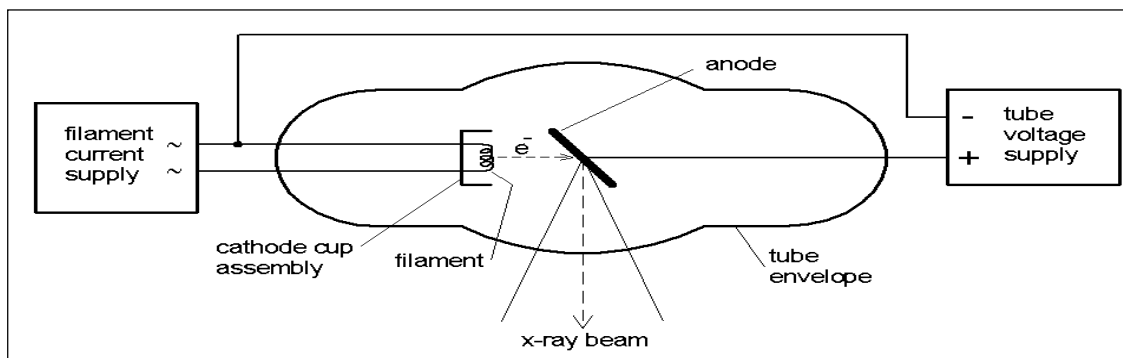
7. Responsibility of Licensee

Although radiation dose received by X-ray Technologist(s) and medical practitioner(s) in diagnostic radiology practice is very low, however, it is the responsibility of the owner (employer) of the facility for providing personnel monitoring devices (TLD badges) to radiation workers such as X-ray Technologists and medical practitioner(s) and to ensure that dose received by radiation worker(s) are as low as reasonable achievable (ALARA).

It is the prime responsibility of the owner (employer) of radiation facility such as X-ray facility to ensure radiation safety of radiation workers and members of public on account of operation of his X-ray equipment.

8. Diagnostic X-ray Equipment

- Diagnostic X-ray equipment is an equipment in which X-rays are produced when accelerated electrons hit the target material (generally made up of tungsten) and convert their kinetic energies into X-rays.
- Typical diagnostic X-ray equipment includes a generator (tube voltage supply), X-ray tube, patient positioning table and screen-film system.



4. Schematic Diagram of X-ray Equipment

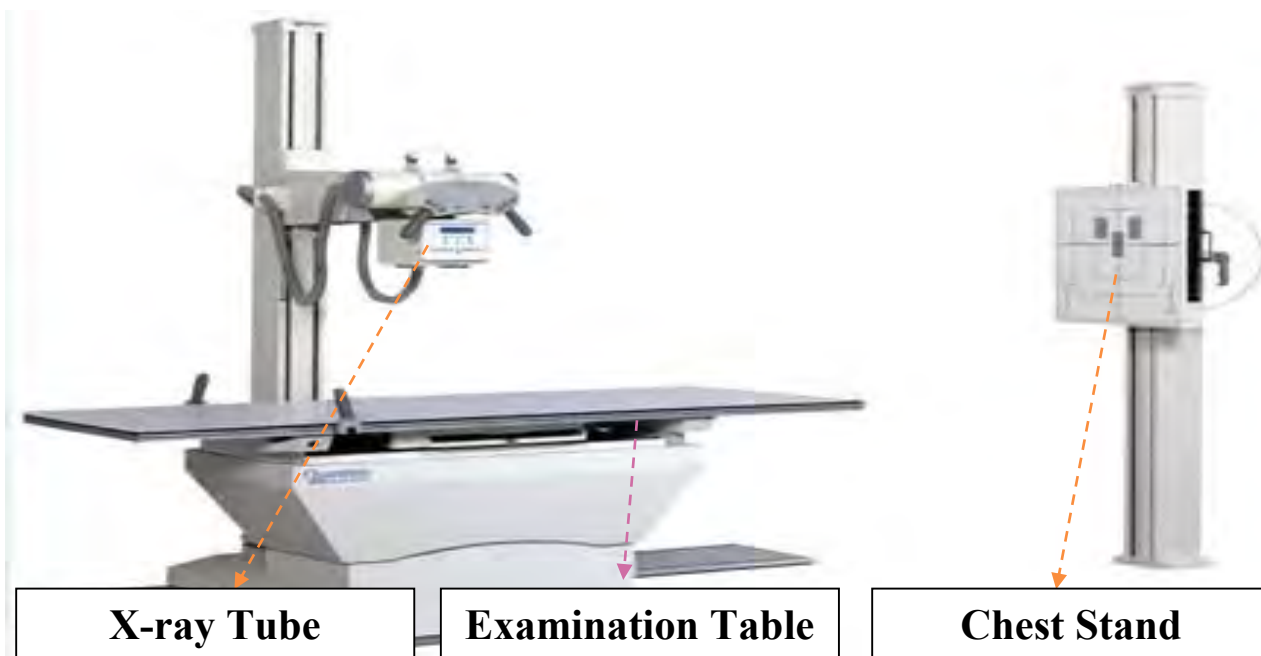
9. Different Modalities of X-ray Imaging

A Radiography

In radiography, a short duration pulse of X-rays is emitted by the X-ray tube, a large fraction of X-rays interacts in the patient body and some of the X-rays pass through the patient body (transmitted X-rays) and reach the detector.

These transmitted X-rays form the radiographic image of a patient on the film/detector.

Generally Radiography equipment is used for chest, abdomen and extremities (hands & feet) examinations.



5. Radiography (fixed) X-ray Equipment

B. Fluoroscopy:

Fluoroscopy is an imaging modality that uses X-rays to obtain real-time moving images of the internal organs of a patient.

Fluoroscopy is performed by two types of equipment:

(i) C-Arm Equipment

It is a C-shape equipment in which X-ray tube is at one end and an image intensifier/ digital detector at other end of equipment.

It shows continuous images of a body part on the TV monitor, much like an X-ray movie.

Generally, C-arm is used in orthopedic and urology department.



6. C-Arm X-ray Equipment

(ii) Interventional Radiology Equipment

Interventional radiology (IR) equipment uses high capacity C-arm equipment for fluoroscopically guided interventional procedures.

Generally, IR equipment is used in cardiac studies.



7. Interventional Radiology X-ray Equipment

C. Mammography

It is especially designed X-ray equipment used for obtaining radiographic images of breast.

It is employed both for screening as well as diagnosis of breast ailments.



8. Mammography X-ray Equipment

D. Bone Mineral Densitometer (BMD):

It is also called dual-energy X-ray absorptiometry (DEXA) system and uses X-rays to measure the strength of bones.



9. Bone Mineral Densitometer X-ray Equipment

E. Computed Tomography (CT):

Computed tomography (CT) scanner is a particular type of X-ray equipment in which X-ray tube produces a beam in the shape of a fan and moves around the patient in a circle.

The X-rays are detected electronically and a computer uses the information to reconstruct an image of the region of the body exposed.



10. Computed Tomography X-ray Equipment

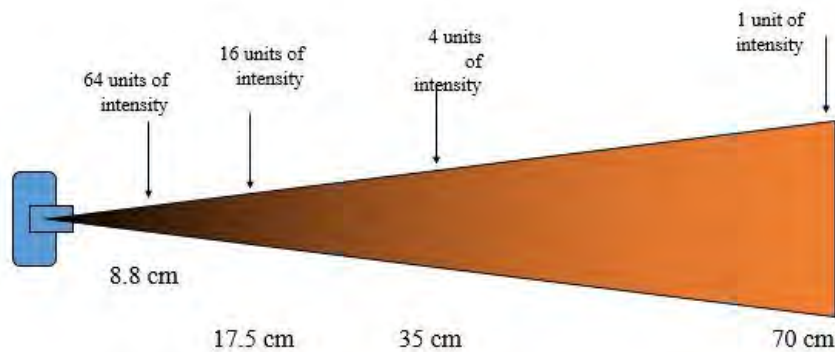
10. Basic Factors of Radiation Hazard Control

Time, Distance and Shielding are basic factors for controlling radiation hazard from diagnostic X-ray equipment.

Time: The amount of radiation dose an individual receives, will depend on how long the individual stays in the radiation (X-ray) field. Radiation dose from X-ray equipment is directly proportional to time.

**Safe, when X-rays are OFF.
Lesser the time of X-rays ON, lesser will be the radiation received by an individual.**

Distance: The exposure rate at any point from an X-ray equipment at a specified distance varies inversely as the square of the distance.

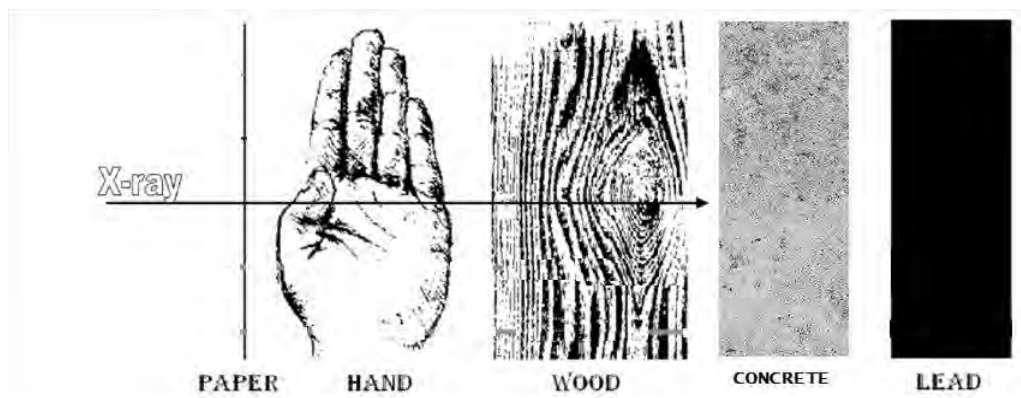


11. Inverse Square Law

X-ray intensity decreases sharply as a person moves farther away from the X-ray unit.

Shielding: The exposure rate decreases exponentially with the increasing thickness of shielding material placed between the X-ray beam and the point of interest (e.g. location of X-ray Technologist).

Generally lead and brick are used as shielding material in X-ray facilities.



12. Penetration of X-rays

The thicker the shielding material placed between the person and X-ray Unit, the lesser the radiation to which a person will be exposed.

11. Radiation Monitoring

- TLD badge is a radiation dose measuring device.
- TLD badge enables us to know whether we are working within the safe dose limit prescribed by AERB.
- TLD badges should always be used with cassettes as bare TLD card provides wrong information of individual's dose.
- TLD badges should always be stored in radiation free area (outside the X-ray installation room).
- TLD cards should be changed in every monitoring period (e.g. quarterly monitoring period) and used TLD cards should be returned back to accredited laboratory for dose assessment.



13. TLD badges loaded in cassettes



TLD with
cassette



TLD without
cassette

14 Use TLD Badge with Cassette

TLD badges should be used by radiation workers such as X-ray Technologists and medical practitioner(s) during operation of X-ray equipment or working in the proximity of diagnostic X-ray equipment.

12. Radiation Safety during operation of X-ray equipment:

A. Radiography (Fixed) Installation:

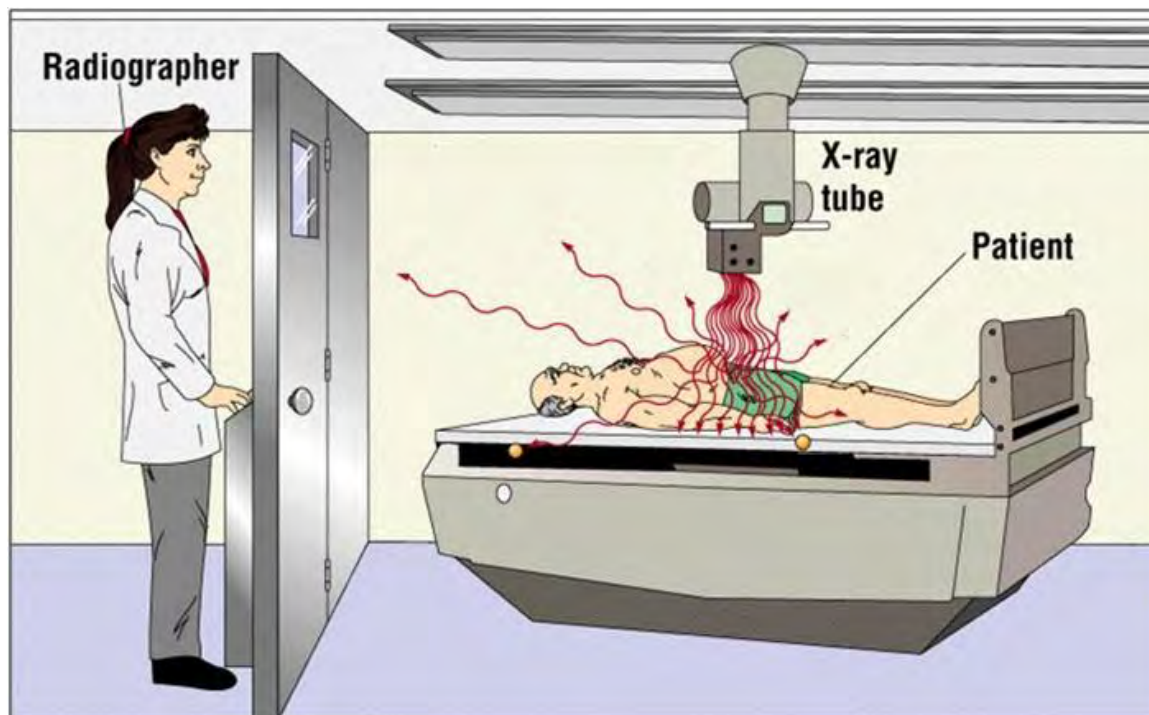
Always wear TLD badge at chest level.

Always stand behind the protective barrier while operating X-ray equipment. It protects X-ray Technologist(s) from scattered radiation emitted from patient during X-ray imaging.

Avoid self-holding of the patient for X-ray imaging. If needed, ask the patient's relative to assist the patient by providing him a lead apron.

Use collimator (diaphragm) to limit the X-ray field size to the area of interest.

Ensure X-ray room door(s) is closed during X-ray imaging.



15. Safe Operation in Fixed X-ray Installation

B. Radiography (Mobile):

Always wear TLD badge at chest level below lead apron.

Operate the mobile X-ray equipment by extending the control cable.

Use lead apron during X-ray imaging.



16 Safe Operation of Radiography (Mobile) X-ray Equipment

C. Computed Tomography (CT) Installation:

Always work from the control room.

Always wear TLD badge at chest level.

Avoid self-holding of the patient during CT scan. If needed, ask the patient's relative to assist the patient by providing him a lead apron.

Ensure CT room door(s) is closed during CT imaging.



17. Correct way of wearing TLD Badge



18. Operation of CT equipment from Control Console

D. Interventional Radiology Installation:

Always wear TLD badge at chest level below lead apron.

Use lead apron during X-ray based interventional radiological procedures.

Use ceiling suspended screens and couch hanging lead rubbers flaps attached with IR equipment during IR procedures.

Position the X-ray tube under couch and Image Intensifier/detector over couch during IR procedures.



19. Wear TLD badge below lead apron



20. Safe operation and use of protective devices in Interventional Radiology Installation

E. Mammography Installation:

Always wear TLD badge at chest level.

Always stand behind the protective barrier while operation.

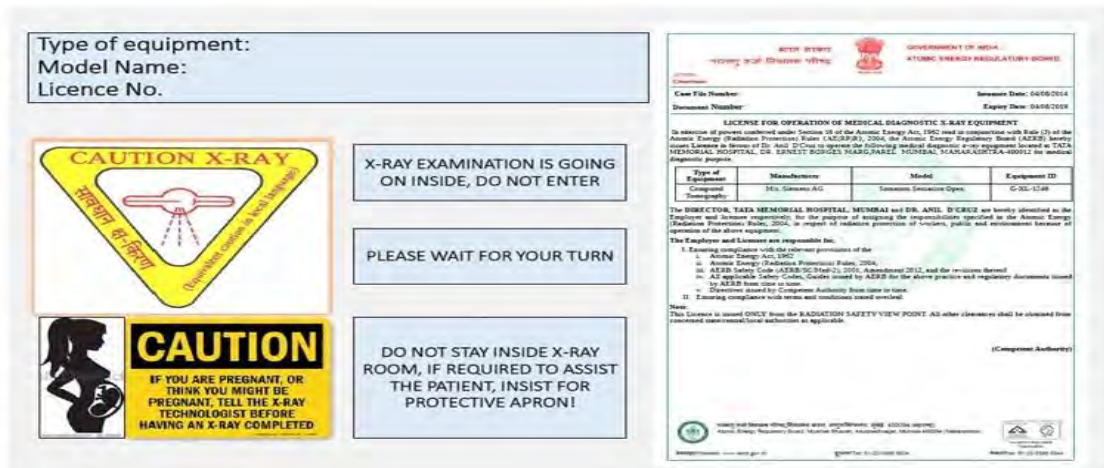


21. Operate Mammography X-ray Equipment behind the protective barrier

13. Regulatory Requirements for Diagnostic X-ray Facilities:

- It is mandatory for all users/owners of diagnostic X-ray facilities to obtain Licence for operation of their diagnostic X-ray equipment from AERB under the provision of Atomic Energy (Radiation Protection) Rules 2004.
- Licence for operation of diagnostic X-ray equipment can be obtained through e-licensing of radiation applications (e-LORA) system available at AERB website (www.aerb.gov.in) by following ways:
 - a. Institute Registration to get user ID and password for submission of applications in e-LORA system.
 - b. Apply for Procurement Permission for purchase or import of X-ray equipment.
 - c. Submission of details of X-ray Technologist(s), medical practitioner(s) and protective devices.
 - d. Apply for licence for operation.

More information for obtaining Licence for operation of diagnostic X-ray equipment can be downloaded from AERB’s website through the following link: <https://aerb.gov.in/index.php/english/regulatory-facilities/radiation-facilities/application-in-medicine/diagnostic-radiology>



22. Warning Placard for display outside the X-ray Installation.

Display copy of AERB Licence along with warning placard outside X-ray Installation.

14. Questions and Answers:

Q.1 Who has the prime responsibility for ensuring radiation safety in X-ray facility?

Ans. Employer of the institution has the prime responsibility for ensuring radiation safety in X-ray facility.

Q.2 How long X-ray exists after the exposure is over?

Ans. When the exposure is over, the X-ray unit does not emit X-ray radiation. It means that when X-ray is OFF, there is no radiation safety concern. It is similar to switching-off an electric bulb where no light exists after it is switched-off.

Q.3 List basic factors for radiation hazard control from an X-ray equipment?

Ans. It should be noted that when X-rays are ON, there is radiation safety concern. Therefore, during X-ray ON condition, spend less 'Time' in X-ray room, keep away from X-ray equipment (maintaining Distance) and stand behind the protective barrier while working in X-ray room (Shielding-use of protection device).

Q.4 List safety procedures to be followed by an X-ray Technologist while operating fixed radiography X-ray facility?

Ans. X-ray Technologist should follow the following procedures:

- a) Always stand behind the protective barrier while operating X-ray equipment;
- b) Always wear TLD badge at chest level;
- c) Ensure X-ray room door(s) is closed during X-ray imaging;
- d) Use collimator (diaphragm) to limit the X-ray field size to the area of interest and
- e) Avoid self-holding of the patient during X-ray imaging. If needed, ask the patient's relative to assist the patient by providing him a lead apron.

Q.5 Where to store TLD badges after the routine work?

Ans. In radiation free area (outside the X-ray room). TLD badges should not be stored in the control panel/control console room of X-ray equipment.

Q.6 Whether TLD badge provide radiation safety to X-ray Technologist?

Ans. NO, TLD badge only measures the radiation dose received by an X-ray Technologist.

Q.7 What are the annual radiation dose limit for an X-ray Technologist and members of public?

Ans. Annual dose limit for radiation worker such as X-ray Technologist is 20 mSv in a year averaged over five consecutive years and annual dose limit for members of public is 1 mSv in a year.

Q.8 How many X-ray exposures are permitted to be performed in a day as well as in a month by an X-ray Technologist?

Ans. AERB has NOT prescribed the maximum / mandatory working hours in a day / week / month and / or maximum no. of exposures permitted to be performed by a radiation worker such as X-ray Technologist in a day / week / month in a radiation facility (X-ray facility). However, the employer and X-ray Technologist(s) should ensure that the radiation dose received due to working with X-ray equipment shall not exceed the occupational dose limits specified by AERB. Radiation worker (X-ray Technologist) can find his radiation dose from TLD Dose reports.

Q.9 Is there any 'risk leave' for X-ray Technologist(s) in the hospital prescribed by AERB? Whether radiation 'risk allowances' should be given to X-ray Technologist(s)?

Ans. There is NO risk leave and/or risk allowance prescribed by AERB for radiation workers (X-ray Technologists).

Q.10 How safe the radiation worker(s) are in diagnostic radiology practice in India?

Ans. As per dose records of radiation workers of diagnostic radiology practice in India, annual average dose to a radiation worker(s) of diagnostic radiology practice in India is about 0.64 mSv which is below the dose limit of members of public. This low radiation dose to radiation worker(s) in diagnostic radiology practice can be attributed to the following factors: (1) improved engineering safety in the X-ray equipment which is ensured by AERB through issuance of type approval of every new model of X-ray equipment (2) use of protection devices by operators viz. protective barrier or protective lead apron during X-ray imaging and (3) improved awareness on radiation safety.

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