

Radiation Safety Training Module: Diagnostic Radiology

Radiation Protection in Diagnostic Radiology



**Radiological Safety Division
Atomic Energy Regulatory Board**

Content

- Mission of AERB
- ICRP-Principle for Radiological protection(Practice)
- Types of Radiation Generating Equipment: (RGE)
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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.

To protect people (workers, public and patients) from harmful effects of ionising radiation without unduly limiting the use of techniques that may cause radiation exposure

**INTERNATIONAL COMMISSION ON RADIOLOGICAL
PROTECTION(ICRP) RADIATION SAFETY PROGRAMME SHOULD
BE DESIGNED TO :**

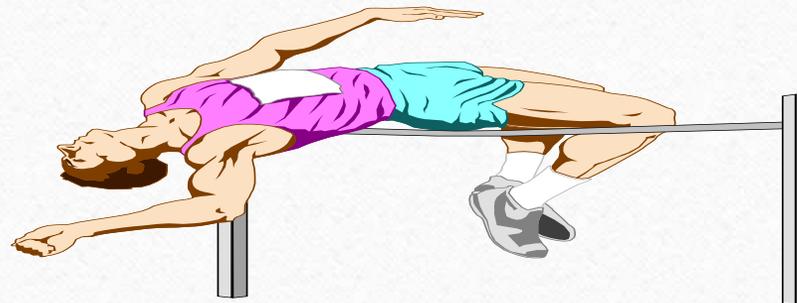
PREVENT DETRIMENTAL TISSUE REACTIONS (DETERMINISTIC EFFECTS)

LIMIT or MINIMIZE THE PROBABILISTIC EFFECTS TO ACCEPTABLE LEVELS

ICRP-Principle for RADIOLOGICAL PROTECTION



- **JUSTIFICATION**
- **OPTIMISATION (ALARA)**
- **DOSE LIMITATIONS**
Never exceed Dose Limits



JUSTIFICATION

- The most common type of ionizing radiation used in medicine all over the world are X-rays since its discovery.
- There are obvious benefits from medical uses of X-rays , however there are well established health risks from radiation if improperly applied. Hence every medical procedure involving radiation needs to be justified.
- It is fact that diagnostic x-ray examinations contribute the largest fraction to population dose from man made radiation sources.

OPTIMIZATION

- All living things are exposed to ionising radiation from the natural (called background radiation) and man made radiation sources
- Ionising radiation may cause biological changes in the exposed person hence the doses to the occupational workers shall be kept as low as reasonably achievable and doses to patients shall be optimized.
- Suitable control measures shall be employed to minimise radiation exposure so that maximum benefits are derived with minimum radiological risk.

DOSE LIMITS

Part of the body	Occupational Exposure	Public Exposure
Whole body (Effective dose)	20 mSv/year averaged over 5 consecutive years; 30 mSv in any single year	1 mSv/y
Lens of eyes (Equivalent dose)	150 mSv in a year	15 mSv/y
Skin (Equivalent dose)	500 mSv in a year	50 mSv/y
Extremities (Hands and Feet) Equivalent dose	500 mSv in a year	-

For pregnant radiation workers, after declaration of pregnancy 1 mSv on the embryo/fetus should not exceed

Types of Radiation Generating Equipment: (RGE)

- 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

Computed Tomography



Interventional Radiology



Radiography /Fluoroscopy



C-Arm



Mammography



BMD



Dental OPG/CBCT

Dental-IOPA



Average Effective Dose (mSv) for diagnostic radiology procedures



Exam	Dose (mSv)
Dental x-rays	0.01
Mammogram	0.04
Chest x-ray	0.10
Abdomen x-ray	0.7
Lumbar spine	1.5
Chest CT	7.0
Abdominal CT	8.0

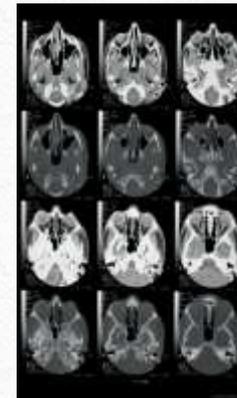


Natural Background 3.1 mSv/ year

Computed Tomography Equipment



Patient Effective Dose: 2-20 mSv



Interventional Radiology (Angiography & Angioplasty procedures)



**Patient Effective Dose
: 1 to 100 mSv**



General Radiography



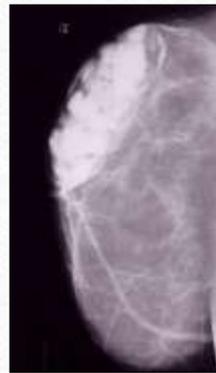
Patient Effective Dose :
0.1 – 1 mSv



Mammography Unit



Patient Effective Dose : ~ 0.4 mSv



Dental Radiography (IOPA)

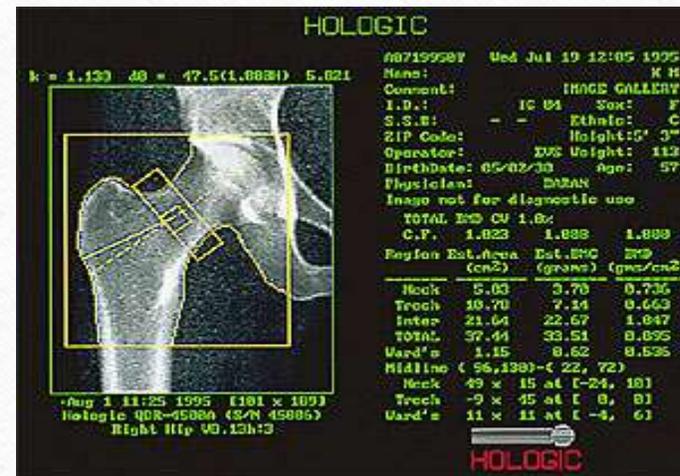


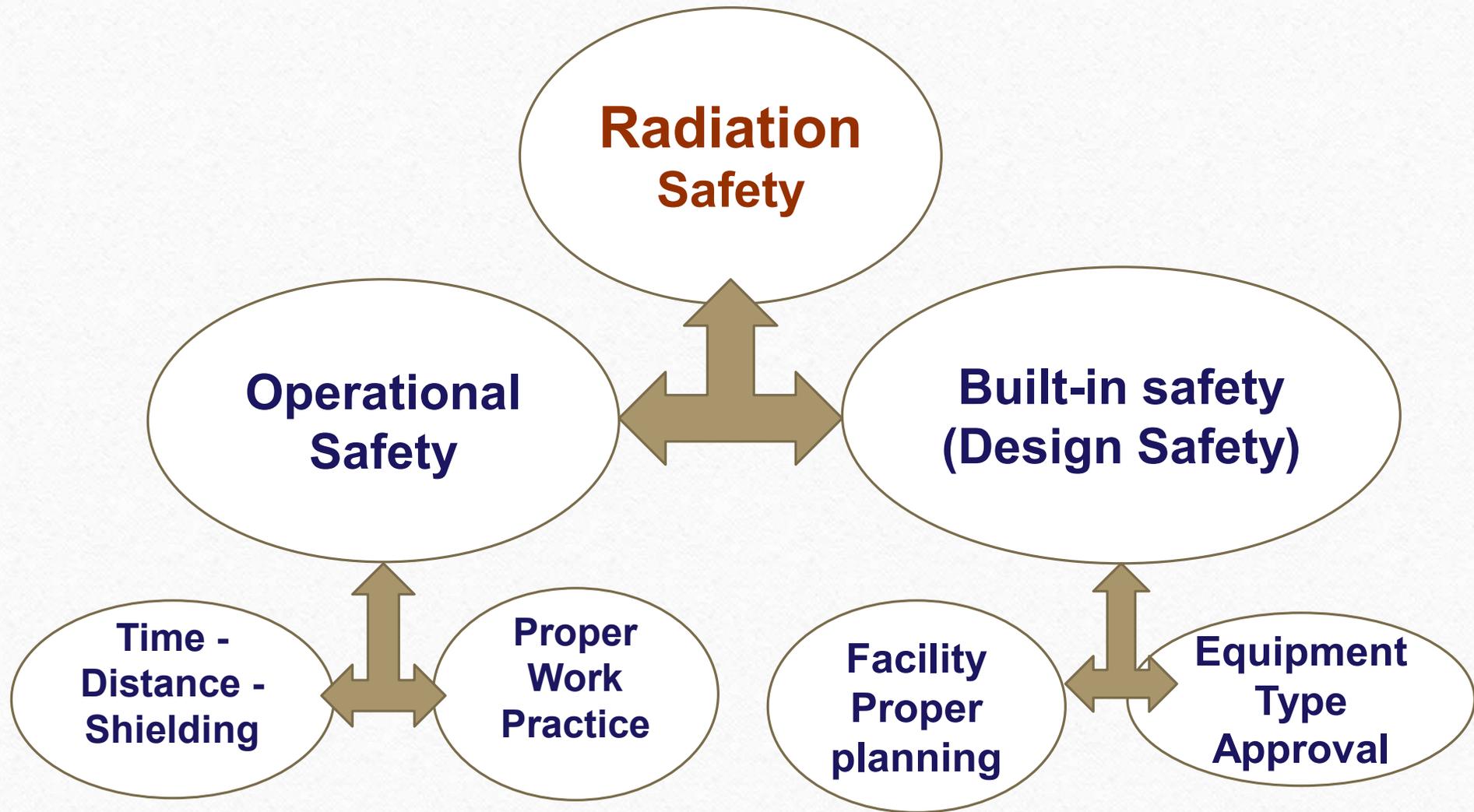
Patient Effective Dose : **0.005 – 0.01 mSv**

Dual Emission X-ray Absorptiometry (DEXA)/ BMD



Patient Effective Dose :
~0.001mSv

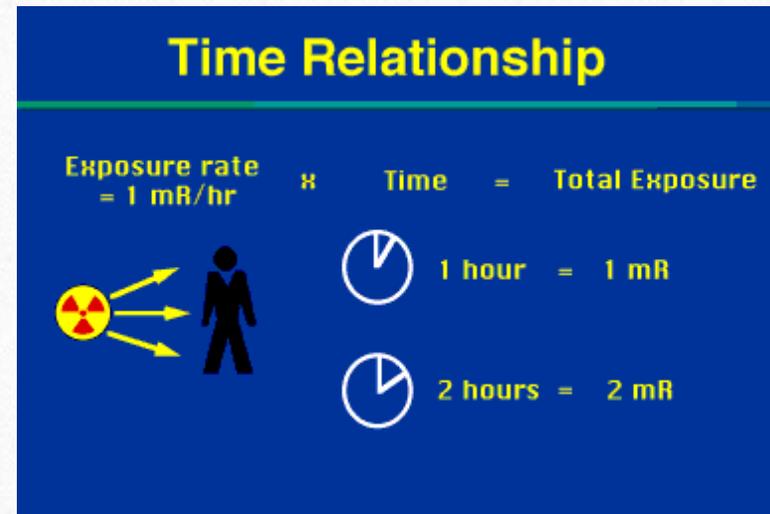




**In this presentation we have considered only operational safety components
Built is safety requirements are elaborated in separate presentation.**

Basic Factors for Radiation Protection

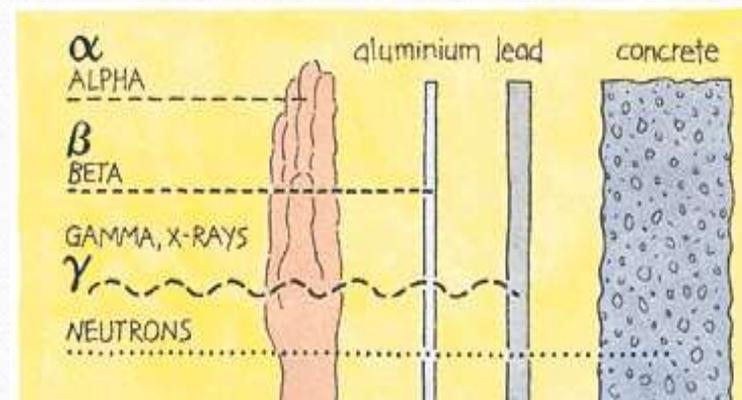
- Time



- Distance

$$I_1 d_1^2 = I_2 d_2^2 \text{ (INVERSE SQUARE LAW)}$$

- Shielding



To reduce the Radiation dose to the individual-

- Reduce the time spent near the X-ray source (reduce fluoroscopy procedure time)
- Increase the distance from the X-ray source
- Interpose a shielding material between X-ray source and Operator- **(Use of radiation protection accessories)**

Operational Safety

Components of operational safety

- Handling of equipment by Qualified persons
- **Use of protective accessories -**
Mobile Protective Barrier, Lead Apron, Organ shield etc.
- Usage of Personnel monitoring devices (TLD)
- Preventive maintenance and periodic QA of equipment
- Updating with the current regulatory requirements

Protection of Staff/Operator

Use protective devices!



- ✓ Advisable skirt type lead apron to distribute weight.
- ✓ use of lead apron (0.25 mm lead equivalent), radiation dose would be reduced by more than 90 %
- ✓ Use ceiling suspended screens, lateral shields and table curtains- must for interventional radiology procedures.



0.25 mm Lead Eqv. glass eyewear with side protection

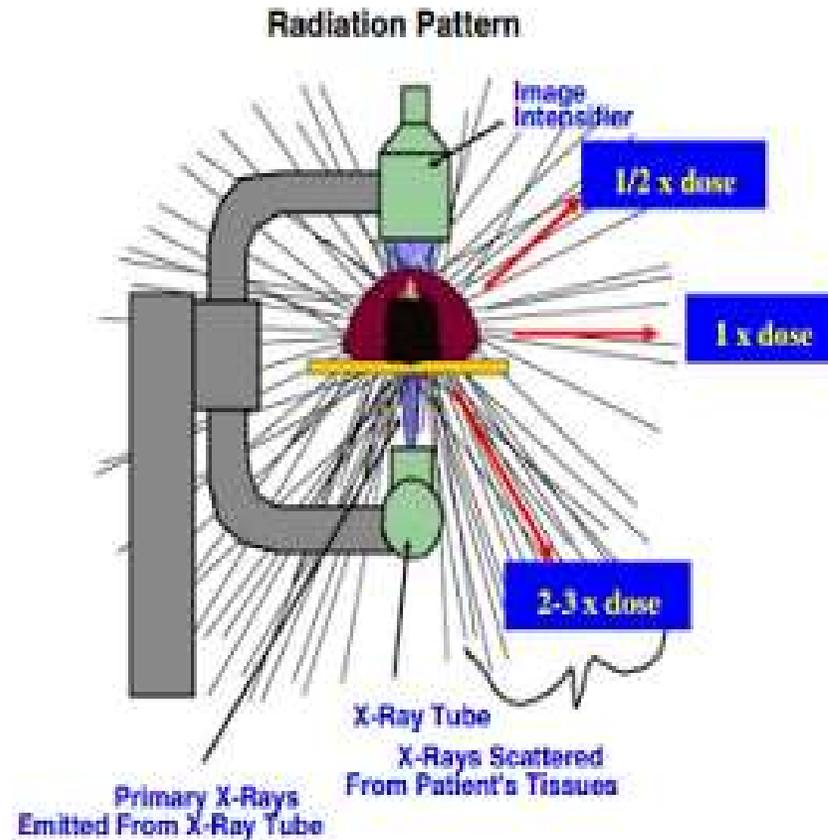


Ways to minimize radiation exposure

- Always collimate to the area of interest, the larger the amount of tissue the beam is allowed to irradiate the more scatter radiation is produced.
- Avoid holding of infirm patient by staff, provide protective apron to the attendant while holding such patients.
- Always operate the equipment from behind the protective barrier or using lead equivalent apron.
- During fluoroscopy exams always make sure that built in safety devices such as flaps /ceiling suspended glass/ couch hanging flaps as applicable are available and use it on routine basis.
- During use of mobile x-ray equipment stand at least 6 feet away from the patient and wear lead apron.
- During c-arm procedures standing on the side of the image intensifier is safest because there is more scatter produced at the entrance surface side of the patient.
- During use of Portable X-ray equipment, ensure that X-ray tube is immobilized on the stand and film cassette shall not be held in hand by any person.

In Fluoroscopy...

- Radiation levels increase as distance from patient decreases. Highest scatter radiation levels are often where the operator stands. Radiation levels are high beneath the table (when X-ray tube below the table) hence couch hanging lead equivalent rubber flaps shall always be used.



- ▶ In general, an operator positioned 3 feet from the X-ray beam entrance area will receive 0.1% of the patient's Entrance Skin Exposure.
- ▶ Staff members positioned further away from patient receive much less exposure due to inverse square law effects.

proper storage of radiation protection devices-Lead apron



Personal Monitoring Badge (TLD)

(Refer guidelines for proper use of TLD badges)

Wear TLD badge inside the Lead apron at chest level –Radiography

For R/F or in Cath Lab

- One inside the apron at chest level
- Additional wrist badge for procedures requiring hands close to primary beam

After work, store TLD badges in radiation free area

Control TLD Card should be kept away from radiation area



TLD below apron



TLD

TLD above apron

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



Radiation Safety...

Carry out Quality Assurance testing of each & every X-ray equipment once in TWO YEARS.

- Improves imaging standard
- Increase the Life of the X-ray tube/ equipment by avoiding retakes
- Useful in reduction of unnecessary patient's Dose & hence dose to the staff

- A good knowledge of equipment specification and characteristics is essential for an effective optimization of radiation protection
- Occupational doses can be reduced by reducing patient dose. The proper use of equipment (including shielding devices) is essential.

- There are no regulatory limits for exposures to patients.

- AERB's design specifications ensure that equipment can deliver correct exposure to patients however optimizing the patient doses in every justified examination is the sole responsibility of physician and technologists involved in referring, conducting, and reporting the findings...!!



Patient dose management

- Quality control protocols –
 - Justify the procedure
 - Ask for records of previous diagnostic procedures
 - Plan the procedure (right patient, right contrast, purpose of scan/investigation)
 - Know well about your equipment settings
 - Ensure only qualified and trained operator should operate the equipment
 - Inform patient about his/her procedure
 - Handover procedure records (CD/disc and reports) including radiation dose records to patient.
 - Ensure that daily and periodic QA are performed and equipment performance is satisfactory.

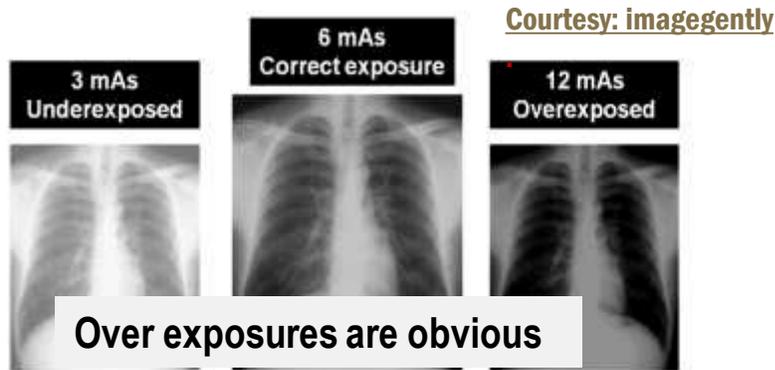
Patient Protection

Radiation safety during x-ray examination of patient is ensured by:

- Limiting the total “beam–on” time
- Avoiding oblique lateral projections
- Prior to exposure, collimate the x-ray beam to the area of interest , AVOID post exposure cropping of the image
- Selecting low dose rate protocol
- Use of correct exposure protocols for patient examinations including paediatric protocols
- Monitoring of DLP in CT and DAP values for IR procedures and
- record- keeping of patient’s doses for CT and IR procedures.

REDUCING UNNECESSARY DOSE TO PATIENTS

Screen film imaging



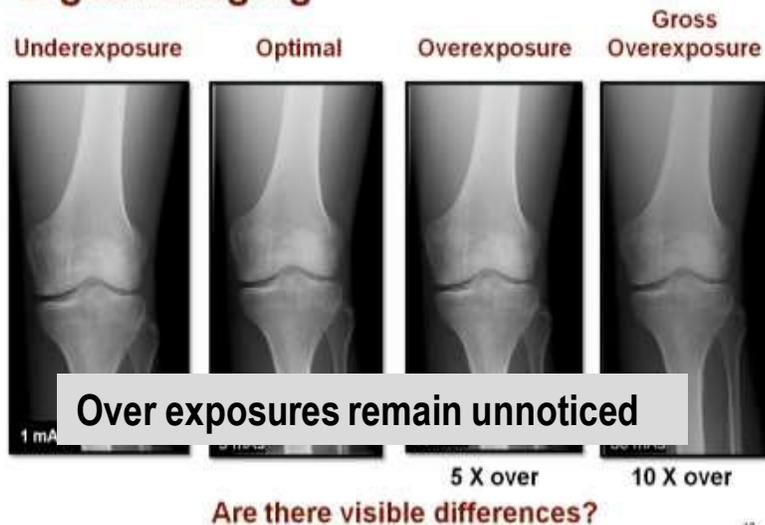
Best quality image is not normally necessary for required diagnosis.

Exposure field should be always collimated to the area of interest

Bucky/grid should be used judiciously

REMEMBER... Small conscious steps go a long way in optimizing doses to patients.

Digital Imaging



Latest equipment are provided with additional Cu filters. Very good in reduction of patient dose

On pregnant patients, always use additional shields, if it is felt that the abdomen is likely to get unnecessarily exposed.

Use Digital imaging correctly to reap its benefits !!

Radiation protection of paediatric patients

Why are children receiving higher doses?

- × Using unsuitable Automatic Exposure systems; in imported equipment, which are not customized to Indian demography before use.
- × Following adult exposure protocols for children
- × Expecting best quality images, even if there is no additional gain in terms of diagnosis
- × Not using dose-minimising features that machine provides.
- × Radiographs taken by unqualified personnel, who do not fully appreciate the implication of their actions.
- × Not considering alternate means of diagnosis (MRI, USG etc).
- × Not asking for previous x-ray records, for the same ailment.



Radiation protection of paediatric patients



Keep in mind for Child examinations....

- Grid should not normally be used
- Use equipment with high power i.e. higher mA and shortest time
- Ensure that for AEC systems, protocols are customized to Indian child.
- Use thyroid, gonad shields & immobilization devices

AVOID “BABYGRAMS”!!!
EXPOSE ONLY AREA OF INTEREST



**Additional considerations for
Computed Tomography and
Interventional Radiology**

- If patient doses are higher than the expected level, but not high enough to produce obvious signs of radiation injury, the problem may go undetected and unreported, putting patients at increased risk for long-term radiation effects.
- Every facility performing CT imaging should periodically review its CT protocols and be aware of the dose indices (such as CTDI, DLP)

Major reasons in increasing dose

1. Seeking Image quality higher than necessary
2. Unjustified examinations,
3. Not using the features that the machine provides for dose reduction

Pediatric CT

- 30% to 40% of CT exams can be managed with alternate modalities (eg USG, MRI etc.).
- Overuse of multiphase exams in pediatric practice.
- Paediatric exams typically use kVp values that are too high
- Same exposure factors used for children as for adult
- Same exposure factors for pelvic (high contrast region) as for abdomen (low contrast region)

Image gently

- **“Child size” the amount of radiation used**
- **Scan only when necessary**
- **Scan only the indicated region**
- **Scan once; multiphase scanning is usually not necessary for children**



Automatic Exposure Control

- Dose increases if one does not select factors properly e.g. Noise index or image quality parameter
- If one selects
 - High noise index- poor image quality, low dose
 - Low noise index- good quality, high dose
- Example: Kidney for stones: unlikely to be missed even in low dose scan, but for appendicitis- higher dose scan is needed
- Heavy patient- upper value may reach



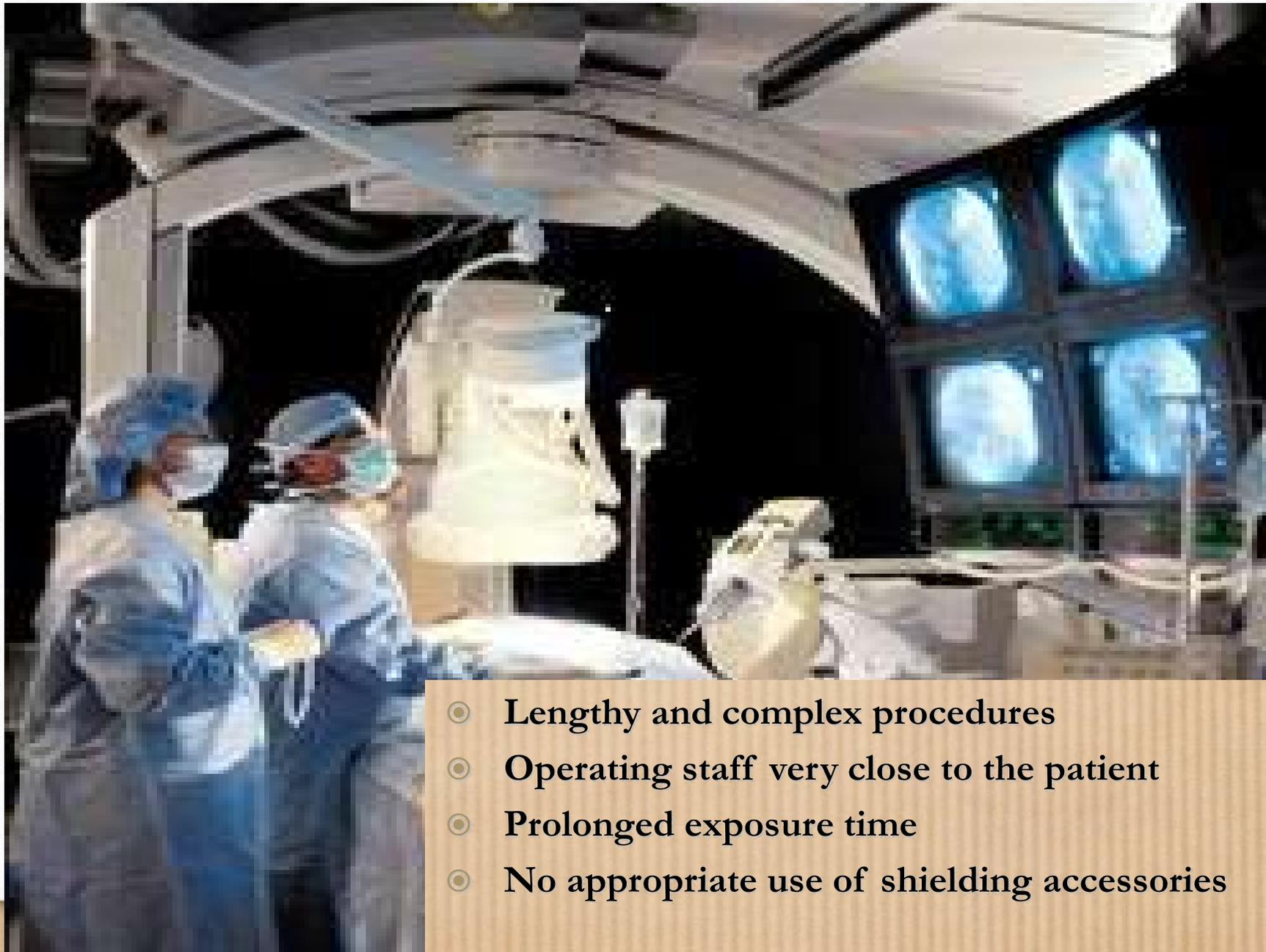
Interventional Radiology

CT

Radiography

Interventional Radiology -History

- Minimally invasive fluoroscopically guided procedures
- Dr. Charles Dotter, MD – Interventional radiologist
- Nobel Prize in Medicine in 1978.
- Invention of Angioplasty using catheter delivered stent
- In some cases this is an alternate option to open surgery



- Lengthy and complex procedures
- Operating staff very close to the patient
- Prolonged exposure time
- No appropriate use of shielding accessories

-
- Many interventionalists are not aware of the potential for injury from procedures, their occurrence or the simple methods for decreasing their incidence utilizing dose control strategies.
 - Many patients are not being counseled on the radiation risks, nor followed up for the onset of injury, when radiation doses from difficult procedures may lead to injury.



**Doses of the order
of 1Gy to 22Gy**



Patient Radiation Dose

- Patient Dose
 - Typical entrance exposure rates for fluoroscopic imaging are
About **1 to 2 R/min** for thin (10-cm) body parts, so skin injury threshold can be reached in approx. **100-200 min**
3 to 5 R/min for the average patient, approx. **40-67 min**
8 to 10 R/min for the heavy patient, approx. **20-25 min**
- The maximum entrance exposure rate for normal fluoroscopy to the patient is 10 R/min
- For specially activated fluoroscopy (audible alarm), the maximum exposure rate is 20 R/min

C-Arm Fluoroscopy-Shielding

- With the C-arm oriented vertically, the x-ray tube should be located beneath the patient with the II above
- In a lateral or oblique orientation, the x-ray tube should be positioned opposite the area where the operator and other personnel are working
- In other words, the operator and II should be located on the same side of the patient
 - This orientation takes advantage of the patient as a protective shield

Distance

- ❖ Rule of thumb (diagnostic energy range):
 - ❖ At 1 m from a patient at 90 degrees to the incident beam, the radiation intensity is $1/1000^{\text{th}}$ the intensity of the beam incident at the patient
- ❖ More precisely: 0.1% - 0.15% (0.001 to 0.0015) of the intensity of the beam incident upon the patient for a 400 cm² area field area
- ❖ The NCRP recommends that personnel should stand at least 2 m from the x-ray tube and the patient and behind a shielded barrier or out of the room, whenever possible

Shielding

Ceiling suspended screen

- Typically equivalent to 0.5 - 1mm lead.
- Very effective if well positioned.
- Not available in all the rooms.
- Not used by all the interventionalists.
- Not always used in the correct position.
- Not always used during all the procedure.



Protective Devices – Quality Control

- All lead equivalent vinyl material (aprons, gloves, etc) should comply with relevant international standards. They should be tested at purchase and regularly thereafter, at least every 2 years.
- **Incorrect storage may lead to cracks in the shielding but this may not be detectable by visual inspection alone**
- **A simple test is to examine the devices using fluoroscopy (at about 60 kVp). The use of automatic dose rate or automatic brightness controls should be avoided.**
- **This test will only detect flaws in the shielding. Faulty devices should be discarded immediately**

CONCLUSIONS

- The majority of the radiation dose received by the operator (provided the primary beam is avoided) is due to scattered radiation from the patient.
- Know your equipment
- Use protective shields (lead apron, mounted shields/flaps, ceiling suspended screens as applicable)
- Avoid holding of patient without adequate protection.
- **Keep hands out of the primary beam**
- **Stand in the correct place: opposite the X ray tube rather than near the X ray tube.(knowledge of iso-dose curve)**
- **Always wear your personal radiation monitoring badge and use them in the right manner**
- **Make sure that x ray equipment is properly functioning and periodically tested and maintained**
- **All actions to reduce patient dose will also reduce staff dose.**
- **Follow Time, Distance, Shielding golden rules**

- While drawing immense medical benefits from the application of X-rays, care need to be taken against the hazards associated with them.
- Use of appropriate protective accessories and equipment specific safety features will ensure optimization of patient and staff dose.
- The prime responsibility for ensuring safety of X-ray installations rests with the user institution.

Questions:

1. 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

2. What are the basic factors for radiation protection in Diagnostic radiology?

Ans: Time, Distance & shielding

3. What is the relation between distance & X-rays exposure?

Ans: X-ray exposure follows inverse square law with distance- $I_1 d_1^2 = I_2 d_2^2$

4. Where TLD control card should be stored?

Ans: in radiation free area such as Admin room, reception room etc

5. 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.

6. What are the recommendatory lead equivalence for Radiation protective barrier, viewing glass window, lead apron and door of the X ray installation room?

Ans: Protective barrier-1.5 mm of Lead Eqv, Viewing glass window-1.5 mm of Lead Eqv,
Lead apron- 0.25 mm of Lead Eqv and door-1.7 mm of Lead Eqv

7. Where to store the TLD badge after the routine work.

Ans: In radiation free area (Outside the X-ray installation room)

8. How to ensure the safe work practice during diagnosis of patients?

Ans: Implementation of following things can ensure the patient safety:

- Limiting the total “beam-on” time

- Avoiding oblique lateral projections

- Collimation to limited beam size

- Selecting low dose rate protocol

- Use of Exposure protocols for patient examinations including paediatric protocols

- use of DLP in CT and DAP values for IR procedures and

- Record keeping of patient’s doses for CT and IR procedures.

9. Why QA tests of the X ray equipment should be carried out periodically?

Ans: Very useful to maintain quality of equipment

Improves imaging standard

Increase the Life of the X-ray tube/ equipment

Useful in reduction of unnecessary patient's Dose & hence dose to the staff

References and sources for additional information:

- The Essential Physics of Medical Imaging (J. T. Bushberg, J.A. Seibert, E.M. Leidholdt, J M Boone)
- The Physics of Radiology (H.E. Johns, J.R. Cunnighnam)
- Introduction to Health Physics (H. Cember)
- Radiation Detection and Measurement (G. Knoll)
- IAEA Presentations on Diagnostic Radiology

List of presentations in the training Module

Basics of Diagnostic X-ray Equipment

Biological effects of Radiations

Medical X-ray imaging techniques

Planning of Diagnostic X-ray facilities

Quality Assurance of X-ray equipment

Quality Assurance of Computed Tomography equipment

Radiation Protection in Diagnostic Radiology Practice

Causes, prevention and investigation of excessive exposures in diagnostic radiology

Regulatory Requirements for Diagnostic Radiology Practice

THANK YOU