PRACTICAL RADIATION PROTECTION IN MEDICAL IMAGING

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Objectives of the Presentation

- To present an update on radiation protection applicable to Medical Imaging:
  - in relation to various aspects of Medical Imaging

- To highlight the practicability of the various approaches to Radiation Protection.

- To reinforce a sense of commitment in radiation protection among the personnel and administration

Recall : Purpose of Radiation Protection

- General purpose of Radiation Protection

  - To reduce the effects of radiation to man and the environment

- Specific purpose of Radiation Protection in Medical Imaging

  - To reduce the effects of radiation to patient, staff and general public.

The rationale for radiation protection

The rationale for radiation protection

- Deterministic and stochastic effects

  - Deterministic effect : may not happen in medical imaging (though some amount of radiation damage has been documented in relation to prolonged exposure to radiation in Fluoroscopic examination.

Radiation Induced burns in Fluoroscopy:

57-year-old, 6-foot-2-inch-(188 cm) tall man weighing 220 lb (99 kg) underwent 2 angioplasty procedures -

1st Angioplasty lasted 173 minutes and multitude of cinefluorographic images

2nd Angioplasty (5 months later) 74 min of fluoroscopy time and more than 2700 cine images

24hours after 2nd procedure he developed developed a painful and erythematous area involving the skin below his right scapula. Over the next 5 months the affected skin went on to ulcerate and then necrose. Eventually, the patient underwent extensive skin grafting . Berlin L, Radiation-Induced Skin Injuries and Fluoroscopy . *AJR* 2001; 177:21-25

- Stochastic effect : somatic or genetic

  - can happen at any doses of radiation

  - probability of effect increases with dose.

  - no difference of severity of the disease (such as cancer) if it occurs.

The rationale for radiation protection

- Increasing trend in Radiation doses attributed to Medical Imaging

  - Medical imaging is the largest contributor of man-made radiation exposure to the population.

  - Studies showed progressive increase in doses attributed to radiological examinations

  For Example: Per capita annual effective dose from diagnostic CT exams was 0.74 mSv in 2006, up from 0.19 mSv in 1991:

    - more than double increase in the examination rate

- - higher radiation dose per procedure from the newer generation of multi-detector CTs.

Chen J, Moir D. An estimation of the annual effective dose to the Canadian population from medical CT examinations. J Radiol Prot. 2010 Jun;30(2):131-7. Epub 2010 Jun 9.

The rationale for radiation protection

- Increasing trend in radiation doses even with advancement in technology.
- For example: Computerised Tomography technology : conventional – Spiral – Multidetector systems

- The increase in doses was justified against possibility of improved diagnostic quality in examinations leading to better management options and outcomes – better quality of life.

The rationale for radiation protection

- Need to reduce radiation doses, especially to children:

  - presence of rapidly dividing cells than adults

  - longer life expectancy, hence chances of developing cancers from x-radiation is higher than adults

Imaging in children - a challenge

- Probability of errors is higher due to:
  - patient cooperation
  - movement
  - understanding of procedure
  - patient preparation
  - body composition or anatomical development has not reached full maturity to give quality images for example the peri-renal fat of the kidneys not well developed resulting in poor contrast.

The rationale for radiation protection

- Accessibility to knowledge: Role of the media

  Practitioners must be aware of the above accessibility ; patients now have knowledge (conflicting or otherwise) concerning the majority of radiation protection practices elsewhere.

- Administrative considerations: Licensing requirements

The rationale for radiation protection

- Professional obligation of Medical Imaging Practitioners to ensure that the service offered is safe.

  "No extra harm to the patient"

Rights of the patient to expect a service that is safe and based on evidence

The rationale for radiation protection

- Both physical and technical factors can influence radiation dose to the patient, staff and general public.
- Physical : in terms of patient considerations (size and patient condition)
- Technical factors : primarily imaging parameters (this is under the control of the practitioner) and equipment specifications (need to be optimised by the practitioner)

Concept of Adequate Imaging

- Relates to the concept of ALARA (As Low as Reasonably Achievable) or ALARP (As Low as Reasonably Permissible).

- Fact: "Good " or "Excellent" images are usually associated with higher radiation dose.

- All possible means to achieve an image that is "acceptable" rather than "good". The term " acceptable" is synonymous with "diagnostic enough".

- Puts special emphasis on the visualisation of specific image quality criteria related to that particular examination.

- To avoid unnecessary repeats should the information for the specific region of interest is already visualised (example: catheter tip visualised but other image quality criteria not met).

- This concept is more significant with Film- Screen technology as opposed to Digital Imaging modalities (Computed Radiography, Digital Radiography, Digital Fluoro and Digital Mammo). Digital images can be manipulated.

General guidelines of Radiation Protection

- **General guideline:**
- **Justification:** The examination must be medically indicated.
- **Optimization:** The examination must be performed using doses that are as low as reasonably achievable (ALARA), consistent with the diagnostic objective.
- **Concept of Dose reference levels**: Establish the dose for the different examinations within a medical imaging department. To compare intra department / inter department.

Practical Radiation Protection

- General

  - Shielding Time and Distance

  - Dosimetry of staff

  - 10 and 28 day rules

  - Avoid repetitions in the examinations

    - optimising patient considerations (eg possibility of movement blurring, preparation of patient –artefacts,)

    - knowledge on Radiographic pathology – knowing how to demonstrate the pathology.)

    - exposure factors for previous examinations need to be documented to ease further examination.

- Use of high speed image receptors is effective to reduce radiation dose
- Carbon Fibre Cassette permits 25 – 30% dose reduction
- Inter-spacer material for grids of Carbon or cellulose fibre for grids used in Pediatric Imaging (lower kV ranges used) rather than aluminium interspacer.
- Collimation reduces formation of scatter radiation and influence image quality.

- Be aware of the advantages and limitations of the equipment:

  Example; Automatic Brigntness Control (ABC) can have its benefits ; less operator dependent BUT

  If left on its own could give rise to higher dose. In cases when the spine comes in dependent on the setting ABC might adjust the exposure rate to improve the image. It might not be necessary especially in Barium Enema studies.

  ~ same consideration with presence of shielding within the collimated area.~

- Technique chart – established through research and / or experience

- Problems with Digital Imaging Technologies : Computed Radiography, Digital Radiography and Computerised Tomography Scanning-

  - High doses of radiation involved in the generation of an image will not be visible on the image as opposed to Film-Screen Radiography.

  - Tendency for practitioners to give higher doses because of :

    - avoid “underexposure “
    - pseudo-confidence in choice of exposure factors
    - unavailability of technique chart to enable correct selection of exposure factors

Hence : “Exposure Factor Creep”

Challenges to Radiation protection

- Different patient characteristics present different radiation protection approaches.
- Different modalities present different radiation protection approaches.
- Different equipment specifications within a given modality present different protection approaches.
- Different centers practicing different radiation protection approaches.

Radiation Protection and Patient Characteristics

- Body Size: Increase in body size generally necessitates more exposure hence more radiation dose to the patient.

  Approach: Reduce body size whenever possible – compression

  - adopting the prone position when permissible for the abdomen.

- Image quality considerations: use the highest kV possible without compromising image quality

Radiation protection and modalities

- Different radiation based modalities require different approaches to radiation protection initiatives.

  For example: Projection radiography may permit increased FFD which CT Scanning do not permit;

  CT scanning permit the use of bismuth latex to shield radiosensitive organs which Projection Radiography might not be possible.

- A wide range of possibilities of radiation protection; some common to the modalities while some are specific.

- Equipment specifications does not permit changes to be made for "direct radiation protection approaches" to be made. Equipment specification enables "optimisation approaches" to be used.

  For example: in Projection Radiography a detailed study into the specifications of the system can help to optimise the system for differing body sizes / patients.

- Discussion pertaining to various modalities in terms of technical, practice and equipment

Optimisation with x-ray equipment / accessories

- Generator waveform : ” Constant Potential” (CP) as opposed to “Pulsating Potential” (PP) generators
- The mean entrance dose and radiographic exposure factors from CP generators were found to be significantly lower than those from PP generators.

Practically : Demarcation of cases

- ‘Pulsating Potential” generators could be used for examinations that does not involve radiosensitive regions: lower and upper extremities.

26

To use Grid or not to use Grid? Stationary Grid or moving Grid?

- Grid : Image quality against dose to patient (& staff)
- Grid usage : kV above 60

  : body thickness more than 10cm
- Whenever possible do not use grid. Use of grids necessitates the use of higher exposures due to grid factor.
- Grids remove scatter radiation. The higher the kV, the higher grid ratio is required.
- Moving Grid requires higher dose compared to stationary grid. To consider choice based on Image quality requirements.

27

Radiation protection and modalities

- Different radiation based modalities require different approaches to radiation protection initiatives.
- Discussion pertaining to :

    - Projection Radiography
    - Fluoroscopy
    - Computerised Tomography Scanning

Projection Radiography

- Technical approach:

  - High kV technique : well known approach towards lowering patient dose

  - Filtration: increase in filtration with increase in kV

- Practice

  - Anode heel effect (Females- head towards cathode for lumbar spine).

  - Using different filters of different material (copper, Yttrium

  - Increased FFD

Projection Radiography

- PA projection instead of AP projection in:

  - For spinal examinations (Scoliosis series) in young female patients – their breast tissue is extremely sensitive to radiation induced cancer. In this position mean glandular tissue can be reduced by 98%.

  - PA of Lumbar. The pelvic bone will act as a natural filter for the ovaries.

  - Breast shielding in lateral view of the thoracic spine – need to develop a means to hold the lead shielding in place.

Not so common Radiation Protection Practice for Projection Radiography

- Optimisation of practice:

  - Lateral view of abdomen (adult – left lateral / child – right lateral) : different radiosensitivity of liver

  - Micturation for women undergoing lower abdominal examinations

- Optimisation of equipment and accessories

  - Lateral view of cervico-thoracic junction would require grids of high Grid Ratio in view of the higher kV range used.

Projection Radiography

- Equipment Specifications

  Difference in equipment specifications can influence the dose to the patient:

  - Generator
  - Grid assembly
  - attenuating properties of the table / vertical bucky

- Accessories specifications: Film screen combination

- Hence for a given patient and examination, patient dose differs
- Implication: Practitioners need to determine the optimal conditions to perform a particular examination on a given patient.

Fluoroscopy

- **Factors influencing dose:**
- **- patient size**
- **- kVp, mA and time**
- **- tube - patient distance (SSD)**
- **- Image Intensifier - patient distance**
- **- use / non-use of grid vs. patient dose**
- **- x-ray field collimation**
- **- obliques vs. perpendicular views**

Not so common Radiation protection in Fluoroscopy

- Added Filtration in Fluoroscopy

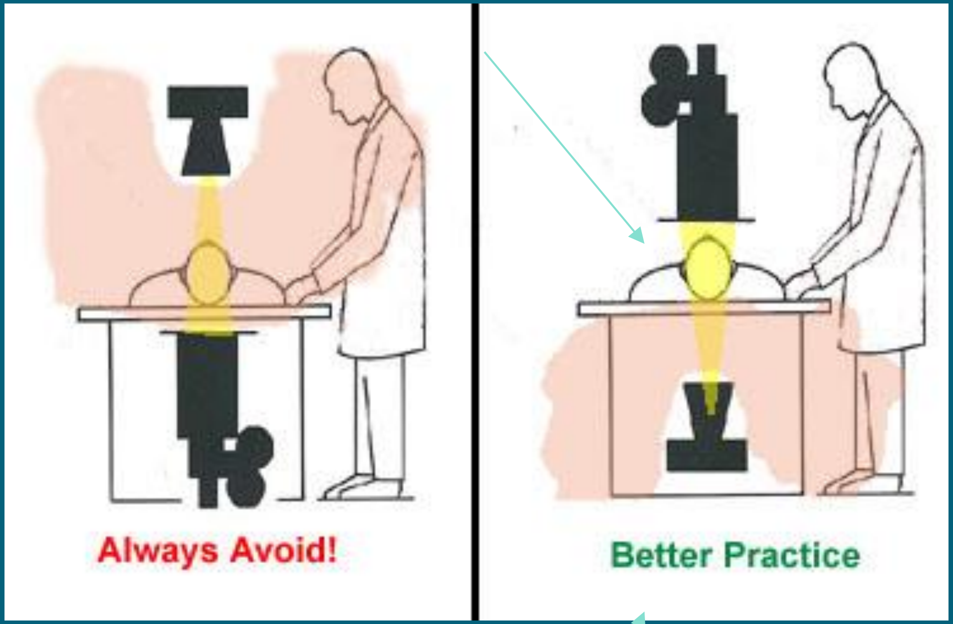
Using 0.3mm copper as added filtration in Double Contrast Fluoroscopy examination

- Adults : reduction in radiation dose of 11%
- Paediatric : reduction of 44% at tube voltage 102 kV
- Additional 0.1mm molybdenum filter decreases exposure to the patient by a factor between 2-3 times for pediatric.

- Omission of Grid in Paediatric Fluoroscopy : can reduce radiation dose to the child by 40%.

X-ray Tube Position

Image Intensifier



X-ray Tube

- Position the X-ray tube under the patient not above the patient.
- The largest amount of scatter radiation is produced where the x-ray beam enters the patient.
- By positioning the x-ray tube below the patient, you decrease the amount of scatter radiation that reaches your upper body.

Factors affecting staff doses in Fluoroscopy

- Height of staff (Can’t change this!)
- Distance from the patient : optimise
- Irradiated patient volume: reduce size (compression) and collimation
- X-ray tube distance : 38 cm for stationary fluoroscopes 30 cm for mobile fluoroscopes
- Imaging parameters (kV, mA, sec)
- Pulsed Fluoroscopy / screening duration
- Reduce II to patient distance
- Appropriate use of shielding materials / accessories

Computerised Tomography Scanning

- Features that is not under the control of the practitioner:

  : Anatomical Modulation or Tube Current Modulation : Software activated: determination of the imaging parameters in relation to anatomic region or projection angle.

Radiation dose issue in CT

- Generally dose in CT in higher than dose in conventional radiography.
- Generally dose in continuous data acquisition is higher than the stop- and-shoot technique.
- Generally, dose using Multidetector CT technology is higher than Single Detector technology for a given scan range due to the difference in beam geometry.
- The use of overlapping scan acquisitions result in higher radiation dose.

Practical radiation protection in CT

- Technique chart for CT

  - Determination of appropriate technical factors (mAs values) based on patient size

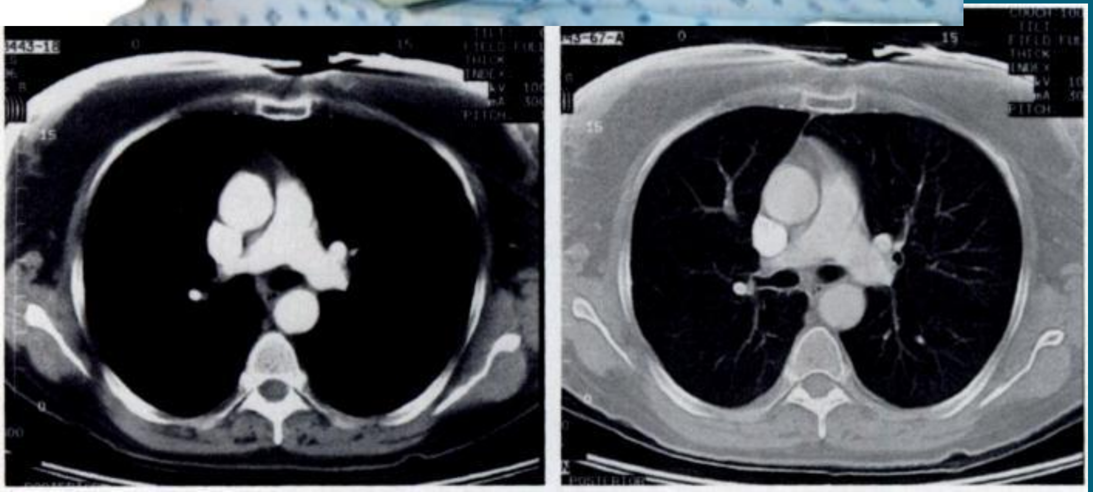
  - Selective in-plane shielding : for eyes, thyroid and breast resulting in dose savings to these organs from 40% - 67%.

Not so common radiation protection initiatives (Radioprotection to the Eye During CT Scanning.

Kenneth D. Hoppera, Joel D. Neumana, Steven H. Kinga and Allen R. Kunselmana American Journal of Neuroradiology 22:1194-1198 (6 2001)

- Shielding using Bismuth latex in CT Scanning:
- For eyes and thyroid

40



Breast shielding in CT Thorax

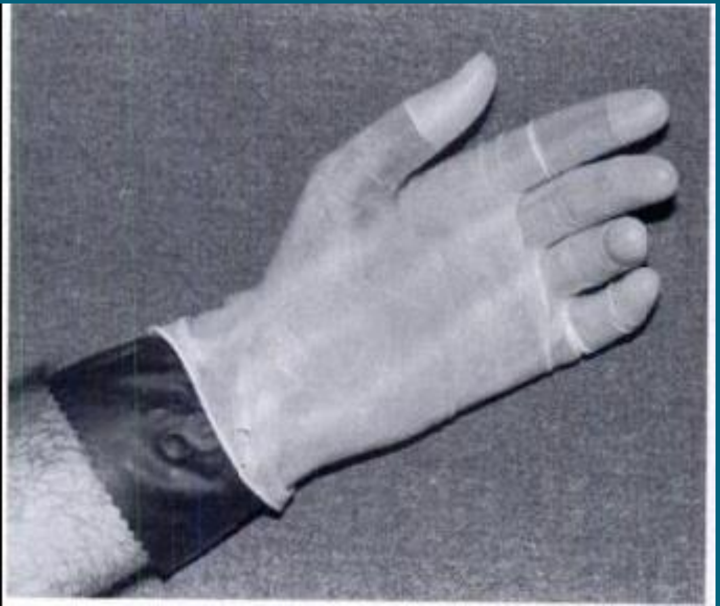
The breast: in-plane x-ray protection during diagnostic thoracic CT--shielding with bismuth radioprotective garments.

Hopper KD, King SH, Lobell ME, TenHave TR, Weaver JS. 1: Radiology. 1997 Dec;205(3):853-8

41

Radiation Protection and the working environment

- Understand the working environment and the radiation protection initiatives that can be carried out.
- For example: the need to protect the Clinician’s hand during interventional procedures under fluoroscopy:



Disposable lead glove after distal part of each finger has been cut off. (2) Altered glove worn beneath regular sterile glove.

Contact and shadow shielding

- Contact shielding is the use of lead sheet or lead rubber placed in contact with the anatomy.
- Shadow shielding is the use of lead sheet or lead rubber placed some distance away from the body, making use of the shadow on the body to determine the appropriate placement of the shielding.

A lead shield is placed on top of the cover of the incubator. The shadow of the lead on the patient's body will determine the correct positioning of the lead sheet.

Reducing the possibility of cross-infection / handling of the baby.

Radiation protection and practice

- To limit possibility of errors that can be attributed to:
  - error in positioning
  - error in imaging parameters
  - error in data entry
  - presence of artefacts
- Changing the practice :
  - PA versus AP (Skull, ? Abdomen ? Lumbar spine)
  - determination of ovary position in Malaysian women (a research area)

Radiation and the personnel

- Use appropriate exposure factors for the part being radiographed.
- Practitoners need to understand how the equipment works
- Variation in user understanding : need for updates or refresher courses
- Need to upgrade operational skills of the personnel
- All approaches taken to reduce dose to the patient will actually result in reduction in dose to the staff as well.

Radiation Protection and administration

- Quality Control and Quality Assurance of all related equipment
- Periodic Maintenance to be carried out.
- Using a radiological team approach for dose management.
- Create avenues for in-house research on optimisation of equipment in relation to patient or examination.
- Responsible to ensure that radiation protection practice is current and is based on Evidence.
- Availability of avenues for staff to be updated of the latest practice in radiation protection.
- ROR (Reward or Reprimand)

Difference in practice between Imaging departments.

- Exist differences in interpreting the 10 and 28 day rules.
- Different practice pertaining to 28 day rule and the types of examinations.

Rule of thumb for studies involving contrast media

- Lower the kV to optimise photoelectric effect especially for positive contrast media (iodinated contrast media). The lower kV will enhance the contrast characteristics, increasing the contrast between the contrast filled region of interest and the surrounding areas.

- Radiation protection in the above case is weighted against the benefit of obtaining quality images enhancing the diagnostic quality (and use of the contrast media) at the expense of increasing dose to the patient.

CONCLUSION

- Efforts to reduce radiation risks:
  - continuous process
  - professional obligation
  - administrative role
  - support from staff

Thank You