Introduction

Why a Clinical Practice Guideline?

The practice of radiology has changed remarkably over the years. Use age of radiological advanced equipment gives a very high radiation exposure to the patient & in turn to the staff. This has caused when exposed to high radiation doses especially in interventional radiology there is a higher risk of getting immediate & delayed effects.
E. g. skin injuries and cataracts

1.1 For whom is this guideline intended?

This is intended to hospital administrators, Radiologists, Physicists, Clinicians & Radiographers & Medical officers.

1.2 Objectives

Provide evidence-based recommendation to clinicians and radiologists, physicists & radiographers to decide on the best practice of radiation protection in order to protect the patients & the staff from hazards of radiation.

1.3 How are the guidelines structured?

Guideline was structured under two different sections for easy application. Radiation control measures in Radiography & Nuclear imaging & for clinicians & radiologists. All the hospitals where Radiological imaging facilities available were considered.

1 RADIATION PROTECTION & MONITORING

1.1 Aim

Is to develop guidelines for Radiation protection for patients & monitoring for the staff who are being exposed to ionizing radiation in Hospitals where Imaging is available. By reducing radiation exposure to the patient the exposure to all the other categories is reduced. Guidelines for Service providers Medical administrators, staff working in the Radiology Department & the clinicians who requests Imaging have a collective responsibility in reducing radiation exposure.

1.2 Introduction:

Exposure to Radiation can cause following effects. e. g. Cataract, skin damage, **A slightly elevated risk for cancer two or more years later in life, but this risk is typically low in comparison to the normal incidence of human cancer.**

The basic goals of the radiation dose limits are

1. To prevent injuries such as cataract and erythema.
2. To reduce the risk of cancer.

Biological effects of radiation vary for different types of radiation e.g. x-rays & γ- rays (Quality) & the type of tissue exposed (Tissue weighting).

- Higher for gonads 0.2
- Bone marrow, colon, lung, stomach 0.12
- Skin 0.01

Effective dose
This is measured in mSv or mGy depends on the type of tissue exposed (Tissue weighting factor) & type of the radiation (Quality factor)

e.g. For the same exposed dose of radiation effective dose is higher when an organ carries a higher tissue weighting factor.

ALARA program

As Low As Reasonably Achievable is to make every reasonable effort to maintain exposures to radiation far below the dose limits as is practical. **Grade X**

Occupational Dose limits (ICRP)

- Effective dose of 20 mSv per year—averaged over a period of 5 years
- Should not exceed 50 mSv in any one year
- Equivalent skin dose of 500 mSv per year—Limit is set on basis of stochastic effects
- Localized limit needed to avoid deterministic effects.
- Dose limits do not apply to radiation dose employee receives as part of personal healthcare

Justify & optimize

The need for the investigation in terms of benefit verses the risk to the patient must be carefully considered. Type of investigation & the technique must be selected to minimize the dose to the patient. **Grade X**

1.3 Radiation protection policies & procedures

Work according to the policies & procedures of a radiation safety program if already implemented. Grade Y

Follow the established acquisition procedure prior to obtaining radiation - producing devices Ref. guidelines for quality assurance. Registration of the machines should be done according to the AEA regulations. **Grade X**

Radiation worker registration should be according to SLMC regulations **Grade X**

Training all the individuals using radiation-producing devices who are not SLMC registered should receive radiation safety training with in four months of using the device. Grade Y

Personal radiation exposure monitoring badges should be available for the staff. Grade Y

1.4 Personnel Radiation exposure monitoring

Introduction

Personal radiation exposure monitoring is estimation of whole body effective dose of radiation exposure of the staff by using a monitoring device.

1.4.1 Monitoring devices

Standard monitoring device is a clip on a badge or a ring badge bearing the Individual's name, date of the monitoring period & a unique identification number

Personnel monitoring badges are to be worn on the trunk under the protective clothing where it will most likely approximate the Radiation exposure to head & feet of the wearer & on the collar or fore head.

- **Thermo luminescent dosimeter (TLD)**
  TLD contains crystalline materials that emit light if heated after being exposed to Radiation. Cost effective.

  Grade X
- **Electronic dosimeters.**
  To be used for monitoring in Interventional Radiology

  Grade Y

Should be provided, processed & reported by the IAEA /AEA or a commercial service or Company approved by the ministry of Health & should meet the requirements of the IAEA/AEA. **Grade X**

- Distributed to relevant personnel by the Radiation safety officer/ Radiation safety supervisor to measure individual's radiation exposure from X-ray source.

  Grade Y

External radiation levels should be kept to less than 0.1millirem/hr at 5c.m.from the source surface or source house and to the levels as low as reasonably achievable (ALARA) Monitoring requirements
Ref. IAEA regulations. **Grade X**

1.4.2 Procedure for personnel monitoring

Radiation protection officer/ supervisor should file a radiation Worker registration form for each individual who are working with Radiation sources.

Should include

- Basic information regarding training
- Basic information regarding experience
- Monitoring needs

Initial personnel monitoring **decisions** will be based **on this information**.
Further evaluations should be based **on** the personnel monitoring **reports**.

- Should be done monthly & quarterly
- Should include
  - name
  - monitoring period date
  - dose for the immediate past period
- Current calendar quarter & calendar year
- Reports should be considered as medical records & should not be released with out a written request

  Grade Y

1.5 Radiation control measures in Radiography

1.5.1 For general radiography

Exposure is from Low energy X-rays
(Diagnostic range)

Primary radiation

Primary radiation is radiation produced by the X-ray tube. It is of a higher intensity & emission is in one direction. Proper installation procedures & thicker shields can easily stop the primary radiation.
Should be considered in designing of the room (Ref. AEA regulations) Primary radiation produced by the equipment can be stopped within by thicker shielding, design of tube housings, collimation systems & shielding features of intensifier housings.

Scatter radiation

Scatter radiation is produced by the irradiated patient & directed in various directions & is of low energy & of different energies & is more difficult to control. Production of scatter radiation depends on several factors e.g. fat patients produce more scatter than thin patients, scatter radiation production decreases when Kvp is increased & tube distance from the patient increased. Radiation workers should be aware of the scatter radiation.

radiation production. **Grade X**

A. Diagnostic X-ray machines

a. Technique chart

This should be available near the control panels of each X-ray machine. This chart will provide specific examination information. Availability of this chart will help to reduce the patient exposure by limiting unnecessary higher exposures.

The chart shall include

i. The patient's anatomical size versus technique factors to be utilized

ii. The type & size of the film or film screen combination to be used

iii. The type & the focal distance of the grid to be used, If used

iv. The source to image receptor distance to be used

V Type & location of gonadal shielding to be used. **Grade X**

B. In ward mobile X-ray examinations

Personnel in X-ray room or ward

Except for patients who cannot be moved out of the room only staff & the **personnel required for the medical** procedure or training no other person should be in the room during radiographic exposure.

Ideally there should be a separate side room or ward for radiography.

Grade X

Other patients & personnel who are inside the room should position behind a protective screen or should wear a protective lead apron of 0.25m.m.Lead equivalent to be protected from scatter radiation.

Grade Y

Patients who cannot be moved from the room should be protected from the direct scatter radiation by a protective Lead apron 0.25 mm lead equivalent or positioned that the nearest portion of the body is at least 2 meters from the tube head

Grade Y

Radiographer has to make every effort to keep the radiation exposure to levels that are as low as reasonably achievable by using fastest film /screen combinations & maximum feasible length of the hand switch cable. Orientation of the primary beam should be directed to an unoccupied area.

Grade X

C. Fluoroscopic procedures under couch & over couch fluoroscopy equipment

Fluoroscopy performed by Radiographers should be under the direction of a Radiologist. Spot film images shall be obtained only under the direction of the clinician when a non-Radiologist uses a radiation producing equipment

Grade Y

Protective gloves at least 0.25 lead equi valent should be readily available to the Fluoroscopist during each examination Protective aprons of at least 0.25 m.m. lead equivalent should be worn by the Fluoroscopist & by persons in the fluoroscopic room except the patient during the examination. Fluoroscopic X-ray systems designed strictly for fluoroscopy should not be used for spot filming or Radiography & Dental fluoroscopic X-ray systems with out image intensification should not be used.

Grade X

When performing over couch fluoroscopy with remote control operator is behind a protective screen during the examination.
When using C arm units Operator is exposed to 20 times higher radiation than under couch fluoroscopy.
Non- Radiologist Fluoroscopists should have training.

D. Radiation control measures in Interventional procedures

Carries a high radiation risk

Occupational doses in interventional procedures guided by fluoroscopy are the highest doses registered among medical staff using X-rays. If protection tools and good operational measures are not used, and if several complex procedures are performed per day, radiation lesions may result after several years of work. e.g. cataracts, skin injuries

Minimize Exposure Time

Everything done to minimize exposure time reduces radiation dose

- Minimize fluoro and cine times
- Whenever possible, step out of the room.
- Step behind a barrier (or another person) during fluoro or cine.
- Use pulsed fluoroscopy– minimizes time x-ray tube is producing x rays.

Grade X

Stay away from the patient

When move from 20 cm to 40 cm, or 1 m to 2 m, from patient, dose rate decreased 4 times or to 25% Patient is the source of scattered radiation.

- Do not stand next to patient during fluoroscopy.
- Step back during cine runs

Grade X

Measurements of entrance dose, scatter dose and image quality should be performed at regular intervals decided by the facility

- Scatter dose detector (phantom) at lens level of the intervention list's position
- Test object to measure image quality at the centre.
- Flat ionisation chamber (Dap meter) to measure patient entrance dose

Grade X

Select operation modes

Change from low fluoroscopy to cine, scatter dose rate could increase in a factor of 10 (from 2 to 20 mSv/h for normal size) Use low fluoroscopy when ever possible

Different C-arm angulations can modify the scatter dose rate in a factor of 5

1.6 Radiation control measures in nuclear imaging

It is the responsibility of the Radiation safety committee, Radiation safety Officer & Radiation safety supervisor to ensure the following. Approval of the use of radioactive materials should be obtained from the AEA and should be renewed annually. Approval may be obtained by submitting a brief application describing the Isotope, quantity to be used, the location it is used, individuals who will handle the material, the training and experience of the applicant, the training of the staff and the protective measures to be used.

New applications are required for the use of a new radionuclide or for an experimental procedure, which has an impact on safety.

1.6.1 Responsibilities of staff members

i. Each staff member must have training, which includes radiation and chemical safety unless they are staff members who are registered in the SLMC. Other staff members should not be allowed to handle radioactive materials until the training is completed. Radiation workers should attend regular refresher courses. Staff members should be aware of

ii. Staff members are responsible for adhering to all laws, rules, regulations & license conditions pertaining to the use of Radioactive materials.

iii. Workers shouldn't wear their assigned radiation dosimeter during uses of radioactive materials

iv. Staff members should practice ALARA program during their work and minimize the potential for exposures, contaminations or release of radioactive material

Grade X

A. General Radiation laboratory protection regulations

Effective dose to the patient depends on the characteristics of radioactive substance used. (Type of disintegration & energies, physical half-life & Biological half-life)

Procedure in accidental contamination

Following are usual causes of accidental contamination. Accidental spill from a source container, during an injection or from patient excretions e.g. urine, saliva etc.

These should be reported to the radiation safety committee when there is need for a change in the program.

B. Disposal of radioactive waste

Waste that contain material of short half-life Take precautions not to be contaminated. Wear gloves & use forceps. Put the waste in a labeled bag & seal it. Collect the bags in a bin & once a week check the bags for the surface radiation. If the surface radiation emission is below 2 Gy/hr it can be disposed as ordinary contaminated waste. Before disposal the bag should be sealed & labeled contaminated waste

Waste that contain material of long half- life should be collected & sealed & labeled the same way as for the short half - life material. A radiation-warning sticker should be pasted. Should be collected by the Radiation safety officer for disposal by the special waste disposal system for disposal of radio active waste

Grade X

C. Administration of radionuclides in pregnancy

For women of reproductive age

Following investigations need delaying pregnancy. Pregnancy should be avoided for

- Fe59 4months
- Selenocholesterol 75- 12 months
- I131 MIBG tumour imaging - 2 months
- I131 Iodide for thyroid metastasis 4 months

For Pregnant women

- Justify the procedure after discussing with a nuclear imaging specialist & if decided optimize the exposure.
- Counsel the patient regarding low-level risk from exposure.
- Most radiosensitive period of pregnancy is 8wks - 15 wks of gestation (10-17 wks of menstrual age).

For Breast feeding women

i. Consider delaying the examination after the mother has ceased breast-feeding
ii. Most appropriate radio pharmaceutical has to be used bearing in mind the secretion of activity in milk.

Following are examples of substitutes that would reduce the dose to the infant

i. The use of Te99m DTPA or gluconate instead of pertecnatate in brain scans.
ii. The use of In 111 leucocytes instead of Ga67 for sites of infection
iii The use of pure I123 instead of I125 or I131

Recommended time before resumption of breast-feeding after radionuclide investigation. These recommendations does not apply during early lactation when colostrums is being secreted

Grade X

Radiopharmaceuticle	Activity administered to mother (MBq)	Feeding interruption time (hrs)
P32 Phospate	Any	Stop
Ga67Ga3+	Any	Stop
I125 fibrinogen	Any	Stop
I125 human albumin	Any	Stop
I131-iodide	Any	Stop
Tc - pertecnatate	80 800	24 48
-macroaggregates	80	12
-macroaggregates+ -technigas	100+20	14
-microspheres	100	18
-erythrocytes	800	18
I123 iodide	20	27
-o-Iodohippurate	20	11
-MIBG	400	21

For children & young persons

The biological distribution, uptake & retention of radiopharmaceuticals vary considerably through out child hood & need to be taken into account.

In addition to basic considerations of radiation protection in nuclear imaging consideration should be given as to minimizing the doses. The activity should be the minimum consistent obtaining a diagnostic result.

The patient's body weight should always be measured. Adult doses are used as a guide. Scaling down

the adult administered activity in simple proportion to body weight will give the same count density as for an adult patient although the effective doses will be higher. Scaling factors for use in administration of radio nuclides to children

Weight (kg)	Fraction of adult administered activity
3	0.1
4	0.14
6	0.19
8	0.23
10	0.27
12	0.32
14	0.36
16	0.40
18	0.44
20	0.50
22	0.53
24	0.56
26	0.58
28	0.62

Caution should be taken when using radiopharmaceuticals that concentrate differently in children e.g. uptake of iodide in thyroid gland in the new born & uptake of Tc 99m phosphates & Ga 67 in growing bones of children.

1.7 Radiation Safety Committee

Established committee should be available in all the provinces either in a TH or PGH

The Radiation Safety Committee is responsible for establishing policies governing the procurement, use & storage & dispenses of Radiation producing devices, & protects patients &workers in the hospitals according to the IAEA/AEA regulations. Grade Y

When there is no established radiation safety committee in the hospital it is necessary to maintain a policy document, which establishes specific methods and procedures to develop and maintain safety and compliance. **Grade X**

Safety is the practice of set of rules, guidelines and procedures, which protect workers & patients. Compliance is the maintenance of procedures, documents and records, which demonstrate that the local laws and regulations are not compromised.

1.7.1 Members of the Radiation safety Committee

Hospital Director
Radiologist
Physicist
Superintendent Radiographer
Radiation safety supervisor/supervisors
Non-Radiologists who are involved with radiation may called to represent work when ever necessary.

1.7.2 Assigned duties of the radiation safety committee

i. **Monitor** the program to maintain the occupational doses as low as reasonably achievable (ALARA)

ii. Review
Review & approve proposed uses of Radiation equipment & Radiation safety program changes prior to submittal to the AEA.
Quarterly review of the occupational radiation exposure records.
Quarterly review of Radiation incidents **& annual review of the** Radiation safety program.

iii. **Establish a table of occupational dose levels** that, if exceeded needs investigations & action by the Radiation safety officer.

Grade Y

1.7.3 Radiation safety officer

Should be a Physicist or Radiologist when there are machines other than plain radiography in the department. When there are only radiography machines a trained radiographer can perform radiation safety officer's duties.

Duties of radiation safety officer

- Supervise radiation protection procedures in order to ensure radiation safety & to minimize exposure to patients & to the staff.
- Training of staff who works in the Hospital in radiation protection.
- Ensure all monitoring equipments are maintained & calibrated & personnel monitoring devices are issued to & worn by all radiation workers & returned to AEA for dose assessment. **Grade X**
- Recommends purchase of radiation producing devices to the radiation safety committee.
- Provides technical advice, prepare local safety working rules & provide training & instructions to staff.
- Review reports together with any necessary recommendations to improve radiation safety.
- Performance of periodic radiation surveys.

- Record & report to the AEA any unsafe practices & accidents.
- Investigate potentially hazardous situations & ensure remedial actions being taken. Keeps an inventory record of radioactive material & arrange for the safe storage. Record all work carried out by each radiation worker. Ensure all licenses & certificates of registration are renewed before the expiry of validity & all records are properly maintained. **Grade Y**

1.7.4 Radiation safety supervisor

Radiographer who have training in radiation safety procedures

Duties of radiation safety supervisor

- Monitor survey & inspect regularly the equipment, work areas & work carried out in the department & prepare reports when instructed by Radiation safety officer.
- Perform checks of radiation producing equipment, survey instruments & other safety equipment.
- Keep copies of records & reports required by AEA
- Assist the Radiation Safety officer & Radiation safety committee in the performance of duties

Grade X

1.7.5 Surveying instruments

Thin window Geiger –Muller meter (end window or pancake type) that will detect very low energy X-rays or an Ion chamber meter.
Instruments must be calibrated annually & should be done by the radiation safety officer

Appropriately calibrated survey meter be available in each Hospital where Radiation safety committees are implemented. (TH & PGH)

If not available in the hospital Radiation Safety supervisors from the other Hospitals in the province should be able to use the same equipment on regular basis for purposes of surveying.

Radiation warning signs should be pasted outside & within the Radiation areas

Periodic inspection & regular checks of the machines – by the AEA

Grade X

1.8 For referring clinicians & radiologists

Reducing radiation exposure to patients will reduce exposure to the staff working in the Department. Recent concepts consider, reducing the radiation exposure to the patient the most important measure in radiation protection.

Check
Whether already done? Avoid repeats

Whether investigating too early? Delay if too early

Whether this is the best investigation for management? Discuss with Radiologist at regular Clinico-radiological meetings

Whether too many investigations performed?
Reduce the number when ever possible

Refer Table for Typical effective doses from Diagnostic Medical exposure & compare the doses with the dose of a Chest Radiograph before requesting an investigation, which is expected to give a high radiation exposure especially in patients of childbearing age & children. **Grade X**

Reasons for the request & the clinical condition should be clearly stated in the request form.

This enables the Radiologist to select the proper images & the technique. All imaging departments should have protocols for the common imaging examinations.
Report should be clearly written or preferably in print
Grade X

Typical effective doses (mSv) of ionizing radiation from common imaging procedures

Band Score		Effective dose
0.	US, MRI	0
I.	X-ray chest, limb & pelvis	<1
II.	IVU, X-ray lumbar spine, Isotope scanning (skeletal survey)	1-5
III.	CT chest or abdomen, NM (e.g. cardiac)	5-10

Women of reproductive age referred for an examination that irradiates the pelvic area from diaphragm to the knees or for a procedure, involving radioactive isotopes should be questioned whether they are or may be pregnant. If a patient cannot exclude the possibility of pregnancy, she should be questioned whether her period is over due. Irradiation of a fetus should be avoided when ever possible.

The Radiologist & the referring Clinician should review justification for the proposed examination. Whether to defer the Investigation or if decided, as justified Radiologist must ensure that exposure is the minimum required to acquire the necessary information.

The most radio sensitive period of the foetus is 8^{th} & 15^{th} weeks of pregnancy. Radiological investigations should be performed within 28 days of LMP. Limited 10 day rule applies for the investigations which give a higher radiation dose to the pelvis e.g. Ba enema, abdominal or pelvic CT. **Grade X**

1.8.1 Typical effective doses from Diagnostic Medical exposure

Diagnostic procedure	Typical effective dose (mSv)	Equivalent of Chest X-rays	Approximate equivalent period of natural back ground Radiation
Radiographic examinations Limbs & joints (except hips)	**0.01**	**<0.5**	**<1.5 days**
Chest (single PA film)	**0.02**	**1**	**3 days**
Skull	**0.06**	**3**	**9days**
Thoracic spine	**0.7**	**0.7**	**120days**
Lumbar spine	**1.0**	**50**	**150days**
Hip	**0.4**	**20**	**60days**
Pelvis	**0.7**	**35**	**120days**
Abdomen	**0.7**	**35**	**120days**
IVU	**2.4**	**120**	**14 months**
Barium swallow	**1.5**	**75**	**240days**
Barium meal	**2.6**	**130**	**15 months**
Barium follow through	**3**	**150**	**16 months**
Barium enema	**7.2**	**360**	**3.2years**
CT head	**2**	**100**	**10 months**
CT chest	**8**	**400**	**3.6 years**
CT abdomen &pelvis	**10**	**500**	**4.5 years**

Radionuclide studies

Diagnostic procedure	**Typical effective dose (mSv)**	**Equivalent of Chest X-rays**	**Approximate equivalent period of natural back ground Radiation**
Lung ventilation (Xe 133)	**0.3**	**15**	**7 weeks**
Lung perfusion (Tc99m)	**1**	**50**	**6 months**
Kidney (Tc99m)	**1**	**50**	**6 months**
Thyroid (Tc99m)	**1**	**50**	**6 months**
Bone (Tc99m)	**4**	**200**	**1.8 years**
Dynamic cardiac (Tc99m)	**6**	**300**	**2.7years**
PET head(F-18FDG)	**5**	**250**	**2.3years**

References

1. Diagnostic radiology – Grainger & Allison, forth edition Volume one

2. UK X-ray safety manual 2006

3. Appointment of radiation protection officers and safety supervisors – AEA 1999 regulations

4. ICRP workshop 2006 – Radiation protection in interventional cardiology

5. Making best use of a department of clinical radiology – (Guideline for doctors) The Royal College of Radiologists London NRPB website at http//www.nrpb.org