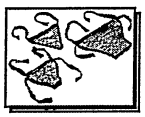
Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Techniques to Reduce Patient Dose

Shielding:

- Radiological examinations of the abdomen or pelvis of women of reproductive capacity should be planned so as to deliver the minimum radiation dose to any embryo or fetus that might be present
- Whenever feasible, shielding of radiosensitive organs such as the gonads, lens of the eye, breast and thyroid should be considered.



J. DAMILAKIS, Assistant Professor of Medical Physics

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Techniques to Reduce Patient Dose

Radiography or Fluoroscopy

The total filtration of the x-ray beam should be 2.5 mm Al; of which 1.5mm should be permanent

Dental

Total Filtration : 70 KVp, < 1.5 mm
> 70 KVp, 2.5 mm

Mammography

Total Filtration > 0.5 mm AL

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Techniques to Reduce Patient Dose

Distance:

Mobile Radiography:

A minimum source-skin distance of at least 30 cm must be used.

Dental

Source to end of Cone (position indicating device)
50 KVp , 10 cm
> 50 KVp , 18 cm

Cephalometry shall be performed at a source-skin distance of at least 1m

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Techniques to Reduce Patient Dose

Size of the Field and the alignment of the X- Ray Beam

Important measures by which the radiation dose to the patient (and operator) can be minimized include:

- **reducing the size of the x-ray beam** to a practicable minimum consistent with the clinical requirements of the examination, and
- accurately **centering the x-ray beam and positioning the patient.**

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Persons Supporting the Patient

Management should take steps to ensure that:

- persons acting as **"Comforters"** do not receive a radiation dose exceeding 5 mSv during the period in which they might assist with a patient during diagnostic examinations.
- However, such exposures must be minimized bearing in mind that the person(s) involved could possibly receive further exposures in similar situations at other times.

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Persons Supporting the Patient

The regulatory authority:

- should require Management to have **written procedures** for the optimization of protection measures for individuals who hold patients (comforters).
- The protocol should include:
  - methods to avoid the need for holding patients
  - criteria specifying which persons are allowed to hold patients
  - methods for positioning and protecting the comforter so his / her exposure is low as reasonably achievable.

Dose limitation for comforters and visitors of patients (I)

- **The dose limits should not apply to comforters of patients, i.e., to individuals exposed while voluntarily helping (other than in their employment or occupation) in the care, support and comfort of patients undergoing medical diagnosis or treatment, or to visitors of such patients.**



Dose limitation for comforters and visitors of patients (II)

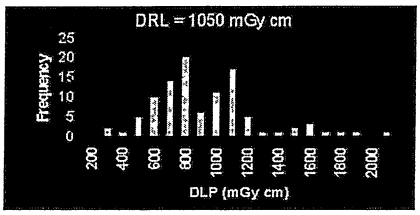
- **However, the dose of any such comforter or visitor of patients should be constrained so that it is unlikely that his or her dose will exceed 5 mSv during the period of a patient's diagnostic examination or treatment. The dose to children visiting patients who have ingested radioactive materials should be similarly constrained to less than 1 mSv.**



Guidance Levels

- are values of dose or dose rate selected by professional bodies in consultation with the Regulatory Authority **to indicate a level above which there should be a review by medical practitioners** in order to determine whether or not the value is excessive, taking into account the particular circumstances and applying sound judgment.

It is intended that Guidance Levels (reference dose values) should serve as **thresholds for investigation** and to prompt improvements in poor practice when appropriate.



CT- SKULL

Guidance Levels

Management should ensure that:

- **levels are revised** as technology improves
- **corrective action** is taken as necessary if doses fall substantially below the guidance levels and the exposures do not provide useful diagnostic information and do not yield the expected medical benefit to patients;
- reviews are considered if doses exceed the guidance levels as an input to ensuring optimized protection of patients and maintaining appropriate levels of good practice

Guidance Levels

- In the absence of large scale surveys, the performance of diagnostic radiographic and fluoroscopic x-ray equipment should be assessed on the basis of comparison with the guidance levels specified in the **IAEA Basic Safety Standards (BSS 115).**
- Levels should not be regarded as a guide for ensuring optimum performance in all cases, as they are appropriate only for typical adult patients .

GUIDANCE LEVELS OF DOSE FOR DIAGNOSTIC RADIOGRAPHY FOR A TYPICAL ADULT PATIENT

Examination	Projection	Entrance surface dose per radiograph[a] (mGy)
Lumbar spine	AP LAT LSJ	10 30 40
Abdomen, intravenous urography and cholecystography	AP	10
Pelvis	AP	10
Hip Joint	AP	10

Notes: PA: posterior-anterior projection LAT: lateral projection
LSJ: lumbo-sacral-joint projection. AP: antero-posterior projection.

GUIDANCE LEVELS OF DOSE FOR DIAGNOSTIC RADIOGRAPHY FOR A TYPICAL ADULT PATIENT

Examination	Projection	Entrance surface dose per radiograph (mGy)
Chest	PA LAT	0.4 1.5
Thoracic spine	AP LAT	7 20
Dental	Periapical AP	7 5
Skull	PA LAT	5 3

Notes: PA: posterior-anterior projection LAT: lateral projection.
LSJ: lumbo-sacral-joint projection. AP: antero-posterior projection

DOSE RATE GUIDANCE LEVELS FOR FLUOROSCOPY

Mode of operation	Entrance surface dose rate[a] (mGy/min)
Normal	25
High level[b]	100

a In air with backscatter.

b For fluoroscopes that have an optional "high level" operational mode, such as those frequently used in interventional radiology.

DOSE GUIDANCE LEVELS FOR COMPUTED TOMOGRAPHY

Examination	Multiple scan average dose[a] (mGy)
Head	50
Lumbar spine	35
Abdomen	25

a Derived from measurements on the axis of rotation in water equivalent phantoms, 15 cm in length and 16 cm (head) and 30 cm (lumbar, spine and abdomen) in diameter.

DOSE GUIDANCE LEVELS FOR MAMMOGRAPHY

Average mammary glandular dose per cranio-caudal projection[a]
1 mGy (without grid) 3 mGy (with grid)

a Determined in a 4 5 cm compressed breast consisting of 50% glandular and 50% adipose tissue, for film-screen systems and dedicated Mo-target Mo-filter mammography units.

Dose Limits

- **The use of dose limits is not used (recommended) for patient medical exposure. Dose constraints and guidance levels should be used.**

Optimization For Diagnostic Procedures :

Management should ensure that:

- each type of x-ray equipment is operated by appropriately trained staff only, and images are interpreted only by medical practitioners trained in those techniques

Optimization For Diagnostic Procedures :

Management shall ensure that:

- the total filtration of the useful x-ray beam is sufficient to ensure that the half value layer for a given x-ray tube and collimator is not less than the recommended values of IEC Standards.

Mammographic

kVp	Minimum HVL (mm of Al)
20	0.20
25	0.25
30	0.30

Radiographic

kVp	Minimum HVL (mm of Al)
40	0.4
49	0.5
50	1.2
60	1.3
70	1.5
71	2.1
80	2.3
90	2.5
100	2.7
110	3.0
120	3.2

Optimization For Diagnostic Procedures :

Film and Processing

- **Film/screen combinations used shall be as sensitive as possible,** without compromising image quality.
- Film should be processed according to the manufacturer's instructions. Optimized film processing will reduce patient doses and improve image quality.
- Automatic film processing is preferred.

Optimization For Diagnostic Procedures :

Radiographic

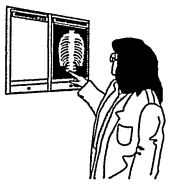
- Appropriate clinical and radiographic **protocols** for all examinations shall be prepared and used
- In radiographic installations there shall be a comprehensive **quality control** of the generator and imaging system

- It is advisable to use the **highest kVp** (and the lowest mAs) compatible with the image that one expects to obtain. In this way the patient irradiation will be lower, although it might get lower image contrast. Therefore the optimization is to find the proper balance between contrast and dose
- **The shortest exposure time** as possible should be selected, above all when examining non collaborating patients (shorter time means reduction in kinetic blurring)

- It is very important to have **viewing boxes in areas with correct environmental light,** enough brightness and uniformity over the surface and, for certain applications (e.g. mammography) complementary high intensity light sources. Hence, periodic cleaning of the internal and external surfaces and replacement of the fluorescent tubes are essential
- Make sure that the illuminated area coincides with the radiograph size, so that **diaphragmable viewing boxes** are recommended

Existing past images

- Before beginning an examination, it is advisable to compile the existing past images of similar examinations in or outside the institution, in order to minimize the number of radiological examinations that the patient has to bear.



Periodic measurement of the entrance patient dose

- The **periodic measurement** (at least once a year) **of the entrance patient dose** (or similar quantity) and the comparison with the guidance (or reference) levels and with values from previous controls will permit the detection of equipment malfunctions
- **When the entrance doses (or other dosimetric parameters) are clearly in excess of the guidance levels (or of those previously obtained), it is necessary to check the generator and associated devices, as well as the procedures and techniques used for the examination.**

Periodic evaluation of the image quality

- A periodic evaluation (at least once a year) of the image quality obtained in each room allows the detection of malfunctioning in the imaging chain or in the generator (almost always associated to high patient doses and poor image quality)
- A periodic evaluation of the number of **rejected and repeated radiographs** and the analysis of the causes of rejects and retakes allow the detection of failures in the X-ray equipment, associated image devices, as well as in the examination procedures and in the skill and training of the staff

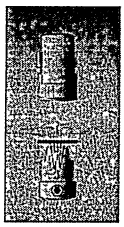
Optimization For Diagnostic Procedures :
Radiographic

- **Patients shall be fully instructed** as to their actions during a particular procedure, for example to avoid movement during the exposure.
- **Automatic exposure control (AEC)** should be incorporated in radiographic equipment and should be used
- If an AEC is not used, technique charts for each x-ray unit including tube voltage (kV peak), radiographic exposure (mAs), focus to skin distance, dimensions of the patient, etc shall be used.
- **Protocols should take into account** the image receptor being used (for example film-screen sensitivity), use of a grid or air gap, AEC chamber, appropriate collimation and protection of radiosensitive organs .
- **No exposure should be repeated** unless the diagnostic value of the examination is compromised as assessed, where practicable, by the relevant medical practitioner.

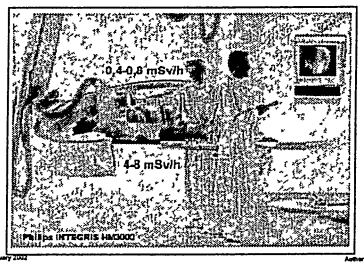
Optimization For Diagnostic Procedures :
Fluoroscopy

- Direct (i.e. unintensified) fluoroscopy shall not be performed.
- In fluoroscopy installations there shall be a comprehensive **quality control** of the generator and imaging system
- Fluoroscopy shall not be used as a substitute for radiography.
- Whenever possible, automatic exposure control **(AEC)** should be selected. If protection of radiosensitive organs is used, and if the protective shield obscures part of the image, the automatic exposure control should be disabled to avoid high dose rates.

- The patient entrance air kerma rate **should not usually exceed 50 mGy/min.**
- In modern image intensifiers, this value should be much lower depending on patient size and projection
- The use of devices for memorizing the last image (**last image hold**) is recommended

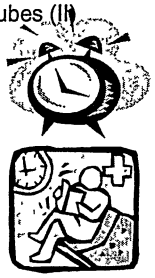


Example of scattered dose rate



Scattered dose is higher at the X-ray tube side

With reference to generators and x-ray tubes (II)



- In examinations with fluoroscopy, a **clock** should be available allowing the measurement of the **fluoroscopy elapsed time**, with audible indications at 10 or 5 minutes.
- Fluoroscopy should be controlled with a switch of a **"dead man"** type.

Angiography - Patient Protection

- **Patients should be counseled on radiation risks if the procedure carries a significant risk of such injury.**
- **Records of exposure should be kept if the estimated maximum cumulative dose to skin is 3Gy or above.**
- **All patients with estimated skin doses of 3 Gy or above should be followed up 10 to 14 days after exposure.**
- **The patient's personal physician should be informed of the possibility of radiation effects.**
- **If the dose is sufficient to cause observable effects, the patient should be counseled after the procedure.**
- **A system to identify repeated procedures should be set up.**

Optimization For Diagnostic Procedures :
Computed Tomography

- In CT installations there shall be a comprehensive **quality control** of the generator and imaging system
- The examination parameters such as **scanned region, number of slices, slice thickness, slice spacing (or scan pitch), tube voltage (kVp) and tube current (mAs)** should be optimized and established in clinical protocols.
- It is easy to administer an unnecessarily high radiation dose to patients if a rigorous and comprehensive quality assurance programme is not in operation, and procedure protocols are not used.

Optimization For Diagnostic Procedures :
Mammography

- In mammography installations there shall be a comprehensive **quality control** of the generator and imaging system
- **Special viewing boxes** (with high brightness and collimation) installed in a low ambient light level environment should be used.
- **Dedicated** high sensitivity, high resolution mammography **film-screen combinations** or equivalent digital imaging systems shall be used to produce the image quality required at a low dose.

Optimization For Diagnostic Procedures :
Mammography

- Breast compression shall be used to maximize image quality and minimize mean glandular dose. **Automatic exposure control** shall be used.
- A **grid** should be used except where a thin compressed breast thickness is being examined.
- All films taken in breast screening programmes should be read independently by two radiologists.
- The positioning of the patient is critical for the clinical outcome of the examination and **mammography radiographers and radiologists should be specially trained in mammography techniques**

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Optimization For Diagnostic Procedures : **Pediatric**

- In pediatric radiology installations there shall be a comprehensive **quality control** of the generator and imaging system
- Wherever possible, **dedicated pediatric x-ray systems** should be used for babies and small children because they have special features such as special grids, higher beam quality **(special filtration)** and they also have the ability to use very short exposure times and thus to avoid a degradation of the image quality by patient movement,.
- If conventional (adult) x-ray equipment is to be used for babies and small children, the **grid** should be removed where possible.
- The **automatic exposure control** for non-dedicated pediatric equipment should be able to accommodate the different size and stature of children of a range of ages.

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Optimization For Diagnostic Procedures : **Pediatric**

- Radiographers should undergo some **specific training** in managing pediatric patients, in the appropriate radiographic techniques, and use of the immobilization devices.
- In pediatric radiology a film should not be repeated unless a radiologist considers that the image obtained is not of sufficient diagnostic quality.
- Use of **additional filtration** should be considered for dedicated pediatric equipment, as this can reduce dose.

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
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Optimization For Diagnostic Procedures : **Dental**

- In dental radiology installations, there shall be a comprehensive **quality control** of the generator and imaging system
- Intra-oral dental radiology shall be performed on dedicated equipment operating at **tube potentials above 50 kVp**, preferably 70 kVp.
- The collimator should provide a **focus to skin distance of at least 20 cm** and a **field size no more than 6 cm** in diameter at the collimator end, and preferably limited to the image receptor dimensions.
- Film holders should be used.

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Optimization For Diagnostic Procedures : **Dental**

- **Panoramic dental radiography** (often referred to as orthopantomography or OPG) shall only be performed on dedicated x-ray equipment. The vertical dimension of the x-ray beam in these devices shall not exceed the film width.

Authorization and Inspection of Radiation Sources in Diagnostic Radiology
Radiation Protection of Patients (Module 3.4)

Reporting Accidents and Incidents :

- Accident and incident reports shall be kept for a period specified by the Regulatory Authority and made available, as required, to allow retrospective dose assessment, including the number of radiographic exposures, the duration of fluoroscopic examinations, etc.