Elements of required physical infrastructures: space, shielding, and patient flow…..

Following the IAEA guidelines, adapted by Anna Benini for workshop on Health Technology
IUPESM Task Group, Porto Allegre, Brasil
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Topics

- Equipment design and acceptable safety standards
- Availability of space and use of dose constraints in X Ray room design
- Barriers and protective devices
- Patients’ waiting space and flow
- Qualification and training of personnel
- Choice of equipment
- Planning regular radiation protection and QA/QC
Purpose of Shielding

• To protect:
  • the X Ray department staff
  • the patients (when not being examined)
  • visitors and the public
  • persons working adjacent to or near the X Ray facility
Radiation Shielding - Design Concepts

- Data required include consideration of:
  - Type of X Ray equipment
  - Usage (workload)
  - Positioning
  - Whether multiple tubes/receptors are being used
  - Primary beam access (vs. scatter only)
  - Operator location
  - Surrounding areas
Shielding Design (I)

Equipment

• What equipment is to be used?
  • General radiography
  • Fluoroscopy (with or without radiography)
  • Dental (oral or OPG)
  • Mammography
  • CT
*...and which kind of equipment???

- Do we plan for all health stations to have also X Ray equipment??
- Only simple basic investigations will be performed?!
- Which kind of investigations... chest....and??
- Qualification of staff???
- Evaluation of required investment and infrastructures!
* Equipment evaluation

- Once decided to have an X Ray equipment....
- Definition-evaluation of kinds of investigation
- Staff training.....telemedicine might be a good alternative
- It is very important to choose the right kind of equipment.... purchase evaluation, considering the working condition and environment!!
- Strong and simple equipment!!!
The type of equipment is very important for the following reasons:

- where the X Ray beam will be directed
- the number and type of procedures performed
- the location of the radiographer (operator)
- the energy (kVp) of the X Rays
Shielding Design (III)

Usage

• Different X Ray equipment have very different usage.
• For example, a dental unit uses low mAs and low (~70) kVp, and takes relatively few X Rays each week.
• A CT scanner uses high (~130) kVp, high mAs, and takes very many scans each week.
Shielding Design (IV)

• The total mAs used each week is an indication of the total X Ray dose administered.

• The kVp used is also related to dose, but also indicates the penetrating ability of the X Rays.

• High kVp and mAs means that more shielding is required.
Positioning

• The location and orientation of the X Ray unit is very important:
  • distances are measured from the equipment (inverse square law will affect dose)
  • the directions the direct (primary) X Ray beam will be used depend on the position and orientation
Radiation Shielding - Typical Room Layout

A to G are points used to calculate shielding
*Evaluation of setting*

- In case of heavy workload????? Adequate patients’ waiting space (large enough), with optimization of flow

* Possibility to have two change cabines in order to reduce waiting time

- In this case both cabines should be shielded in order to avoid unnecessary patient exposures and opened, inside by operator
*Patients flow*

- The patients’ waiting room should be chosen in order also to optimize the shielding
- For example…avoid to put chairs in the ”hot spots”
- Optimize the patients’ changing time accordingly to the technical time of the investigations
Shielding Design (VI)

Number of X Ray tubes

- Some X Ray equipment may be fitted with more than one tube
- Sometimes two tubes may be used simultaneously, and in different directions
- This naturally complicates shielding calculation
Shielding Design (VII)

Surrounding areas

- The X Ray room must not be designed without knowing the location and use of all rooms which adjoin the X Ray room.
- Obviously a toilet will need less shielding than an office.
- First, obtain a plan of the X Ray room and surroundings (including level above and below).
Must consider:

- appropriate calculation points, covering all critical locations
- design parameters such as workload, occupancy, use factor, leakage, target dose (see later)
- these must be either assumed or taken from actual data
- use a reasonable worst case more than typical case, since undershielding is worse than overshielding
Radiation Shielding Parameters (I)

P - design dose per week

• usually based on 5 mSv per year for occupationally exposed persons (25% of dose limit), and 1 mSv for public

• occupational dose must only be used in controlled areas i.e. only for radiographers and radiologists
Radiation Shielding Parameters (II)

- Film storage areas (darkrooms) need special consideration
- Long periods of exposure will affect film, but much shorter periods (i.e. lower doses) will fog film in cassettes
- A simple rule is to allow 0.1 mGy for the period the film is in storage - if this is 1 month, the design dose is 0.025 mGy/week
Radiation Shielding Parameters (III)

- Remember we must shield against three sources of radiation
- In decreasing importance, these are:
  - primary radiation (the X Ray beam)
  - scattered radiation (from the patient)
  - leakage radiation (from the X Ray tube)
U - use factor

• fraction of time the *primary* beam is in a particular direction i.e.: the chosen calculation point

• must allow for realistic use

• for all points, sum may exceed 1
Radiation Shielding Parameters (V)

- For some X Ray equipment, the X Ray beam is always stopped by the image receptor, thus the use factor is 0 in other directions
- e.g.: CT, fluoroscopy, mammography
- This reduces shielding requirements
 Radiation Shielding Parameters (VI)

• For radiography, there will be certain directions where the X Ray beam will be pointed:
  • towards the floor
  • across the patient, usually only in one direction
  • toward the chest Bucky stand

• The type of tube suspension will be important, e.g.: ceiling mounted, floor mounted, C-arm etc.
Radiation Shielding Parameters (VII)

T - Occupancy

• $T = \text{fraction of time a particular place is occupied by staff, patients or public}$
• Has to be conservative
• Ranges from 1 for all work areas to 0.06 for toilets and car parks
**Occupancy (NCRP49)**

<table>
<thead>
<tr>
<th>Area</th>
<th>Occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work areas (offices, staff rooms)</td>
<td>1</td>
</tr>
<tr>
<td>Corridors</td>
<td>0.25</td>
</tr>
<tr>
<td>Toilets, waiting rooms, car parks</td>
<td>0.06</td>
</tr>
</tbody>
</table>

A critical review proposes new values for Uncontrolled and Controlled areas: See R.L. Dixon, D.J. Simpkin
Radiation Shielding Parameters (VIII)

W - Workload

- A measure of the radiation output in one week
- Measured in mA-minutes
- Varies greatly with assumed maximum kVp of X Ray unit
- Usually a gross overestimation
- Actual dose/mAs can be estimated
Workload (I)

- For example: a general radiography room
- The kVp used will be in the range 60-120 kVp
- The exposure for each film will be between 5 mAs and 100 mAs
- There may be 50 patients per day, and the room may be used 7 days a week
- Each patient may have between 1 and 5 films

SO HOW DO WE ESTIMATE W?
Workload (II)

- Assume an average of 50 mAs per film, 3 films per patient
- Thus $W = 50 \text{ mAs} \times 3 \text{ films} \times 50 \text{ patients} \times 7 \text{ days}$
  - $= 52,500 \text{ mAs per week}$
  - $= 875 \text{ mA-min per week}$
- We could also assume that all this work is performed at 100 kVp
**Examples of Workloads in Current Use (NCRP 49)**

<table>
<thead>
<tr>
<th></th>
<th>Weekly Workload (W) mA-min at:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 kVp</td>
</tr>
<tr>
<td><strong>General Radiography</strong></td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Fluoroscopy (including spot films)</strong></td>
<td>750</td>
</tr>
<tr>
<td><strong>Chiropractic</strong></td>
<td>1,200</td>
</tr>
<tr>
<td><strong>Mammography</strong></td>
<td>700 at 30 kVp (1,500 for breast screening)</td>
</tr>
<tr>
<td><strong>Dental</strong></td>
<td>6 at 70 kVp (conventional intra-oral films)</td>
</tr>
</tbody>
</table>

More realistic values include CT: see ref. Simpkin (1997)
Workload - CT

- CT workloads are best calculated from local knowledge
- Remember that new spiral CT units, or multi-slice CT, could have higher workloads
- A typical CT workload is about 28,000 mA-min per week
Tube Leakage

- All X Ray tubes have some radiation leakage - there is only 2-3 mm lead in the housing
- Leakage is limited in most countries to 1 mGy.hr-1 @ 1 meter, so this can be used as the actual leakage value for shielding calculations
- Leakage also depends on the maximum rated tube current, which is about 3-5 mA @ 150 kVp for most radiographic X Ray tubes
Radiation Shielding Parameters

Wall 1

Wall 2

Wall 3

Wall 4

X-Ray tube

dsec

dsca

dpri

Patient

Chest stand

Control

Calculation points

IAEA
Shielding - Construction I

Materials available:

• lead (sheet, composite, vinyl)
• brick
• gypsum or baryte plasterboard
• concrete block
• lead glass/acrylic
Shielding - Construction Problems

Some problems with shielding materials:

- Brick walls - mortar joints
- Use of lead sheets nailed to timber frame
- Lead inadequately bonded to backing
- Joins between sheets with no overlap
- Use of hollow core brick or block
- Use of plate glass where lead glass specified
Problems in shielding - Brick Walls & Mortar Joints

- Bricks should be solid and not hollow
- Bricks have very variable X Ray attenuation
- Mortar is less attenuating than brick
- Mortar is often not applied across the full thickness of the brick
Problems in shielding - Lead inadequately bonded to backing

- Lead must be fully glued (bonded) to a backing such as wood or wallboard.
- If the lead is not properly bonded, it will possibly peel off after a few years.
- Not all glues are suitable for lead (oxidization of the lead surface).
Problems in shielding - Joins between sheets with no overlap

- There must be 10 - 15 mm overlap between adjoining sheets of lead
- Without an overlap, there may be relatively large gaps for the radiation to pass through
- Corners are a particular problem
Problems in shielding - Use of plate glass

• Plate glass (without lead of specified quantity as used in windows, but thicker) is not approved as a shielding material
• The radiation attenuation of plate glass is variable and not predictable
• Lead glass or lead Perspex must be used for windows
• Continuity and integrity of shielding very important
• Problem areas:
  • joins
  • penetrations in walls and floor
  • window frames
  • doors and frames
Penetrations

- “Penetrations” means any hole cut into the lead for cables, electrical connectors, pipes etc.
- Unless the penetration is small (~2-3 mm), there must be additional lead over the hole, usually on the other side of the wall.
- Nails and screws used to fix bonded lead sheet to a wall do not require covering.
The doors shall be rebated such that there is a minimum overlap of 15mm. of the lead contained within each door.
Shielding - Verification I

• Verification should be mandatory
• Two choices - visual or measurement
• Visual check must be performed before shielding covered - the actual lead thickness can be measured easily
• Radiation measurement necessary for window and door frames etc.
• Measurement for walls very slow
Shielding Testing

The transmission factor $T$ as an indication of the effect of the primary barrier

$T = \frac{D_1 \text{ with shield}}{D_2 \text{ without shield}}$
Records

- It is very important to keep records of shielding calculations, as well as details of inspections and corrective action taken to fix faults in the shielding.

- In 5 years time, it might not be possible to find anyone who remembers what was done!
*Comments 1*

- Shielding might look complex but in reality is "simple" as it is usually done using tables and computer.
- The evaluation should be done by a RPO or QE, (consultant?) as part of the installing cost.
- It is a work done at the beginning when installing the equipment and than it has to be checked regularly (simple).
- The same RPO or QE taking care of personnel dosimetry, etc.... might do also this once a year.
Main problems remain the identification of requirements and needs at the beginning and than the evaluation of results and quality of diagnostic.

Integration of radiation protection and quality assurance/quality control is essential for good results.