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

Following the IAEA guidelines, adapded 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 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!!!

Shielding Design (II)

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.

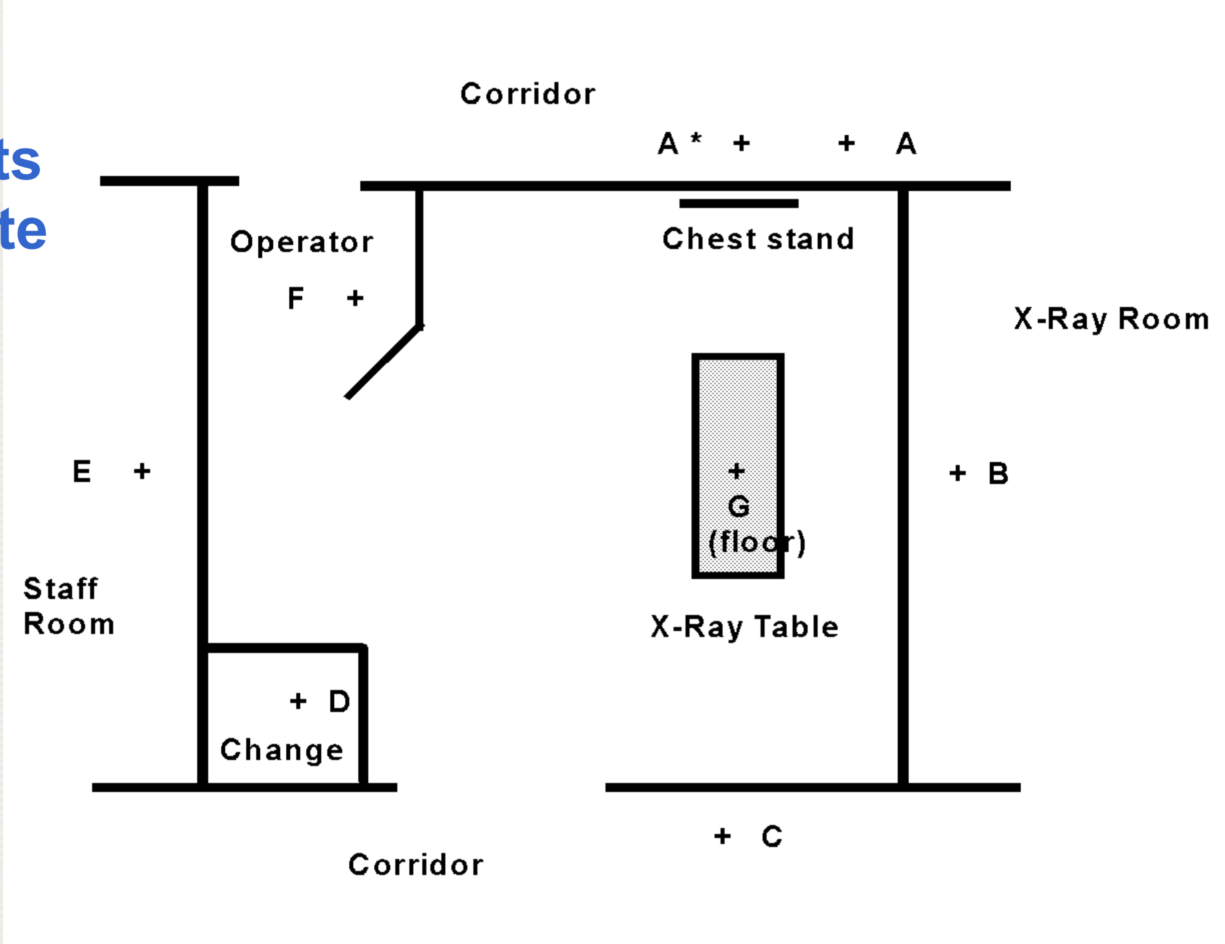
Shielding Design (V)

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 unecessary patient exposures and opened, inside by operator

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*Patients flow

- *The patients' waiting room should be choosen in order also to optimize the schielding*
- *For example…avoid to put chairs in the "hot spots"*
- *Optimize the patients' changing time accordingly to the technical time of the investigations*

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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)

Radiation Shielding - Design Detail

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)

Radiation Shielding Parameters (IV)

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 = 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)

Area	Occupancy
Work areas (offices, staff rooms)	1
Corridors	0.25
Toilets, waiting rooms,car parks	0.06

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 mAs x 3 films x 50 patients x 7 days

  = 52,500 mAs per week

  = 875 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)

	Weekly Workload (W) mA-min at:		
	100 kVp	125 kVp	150 kVp
General Radiography	1,000	400	200
Fluoroscopy (including spot films)	750	300	150
Chiropractic	1,200	500	250
Mammography	700 at 30 kVp (1,500 for breast screening)		
Dental	6 at 70 kVp (conventional intra-oral films)		

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

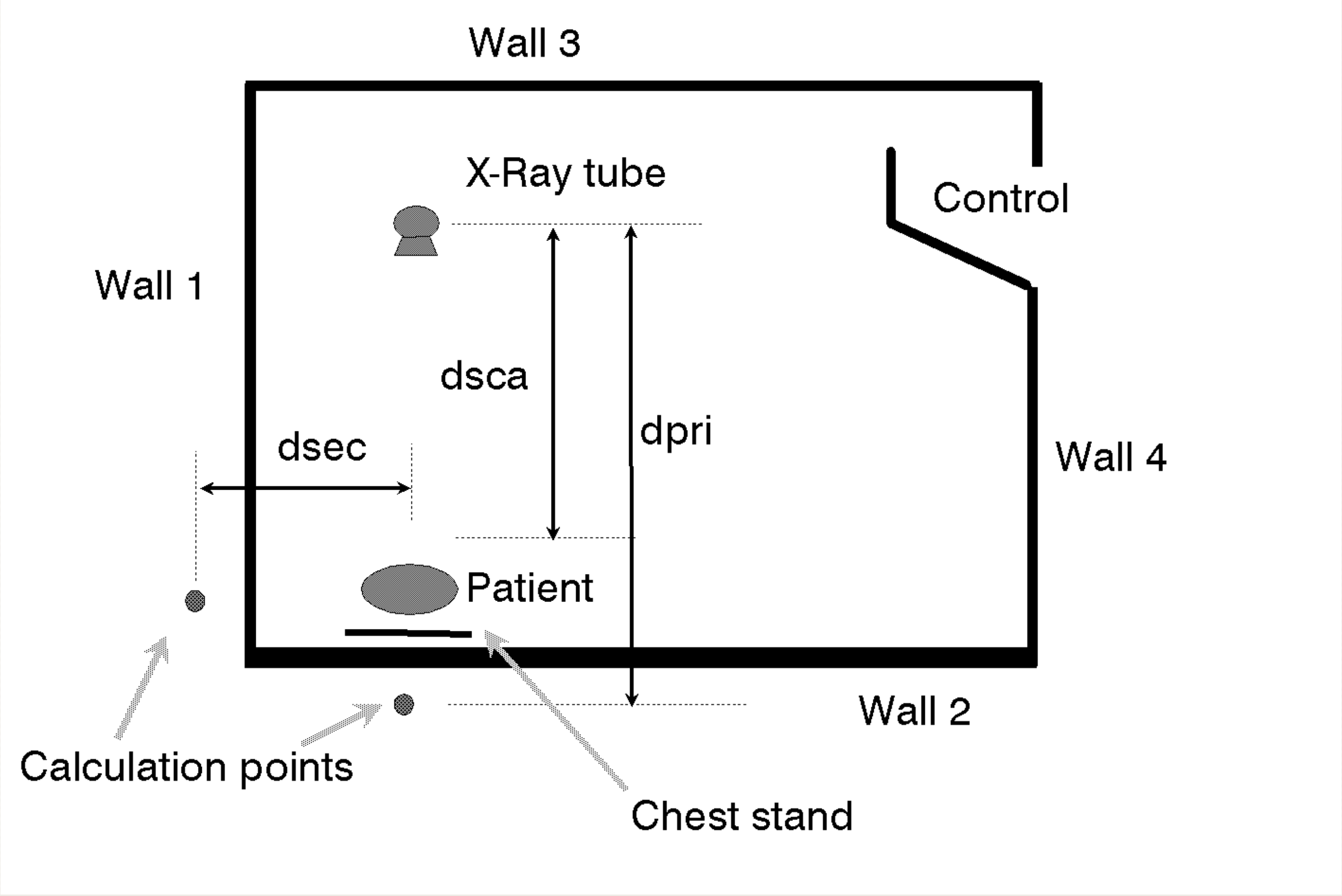
Workload - CT

- 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



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

Radiation Shielding - Construction II

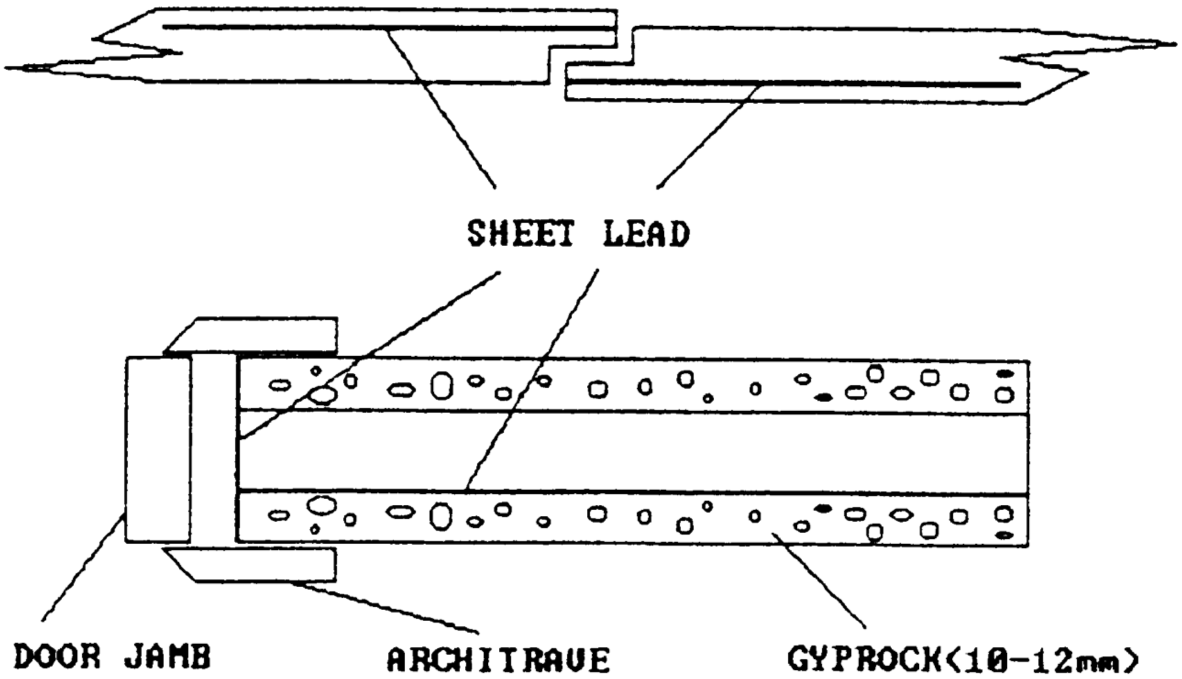
- Continuity and integrity of shielding very important
- Problem areas:
  - joins
  - penetrations in walls and floor
  - window frames
  - doors and frames

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

Shielding of Doors and Frames

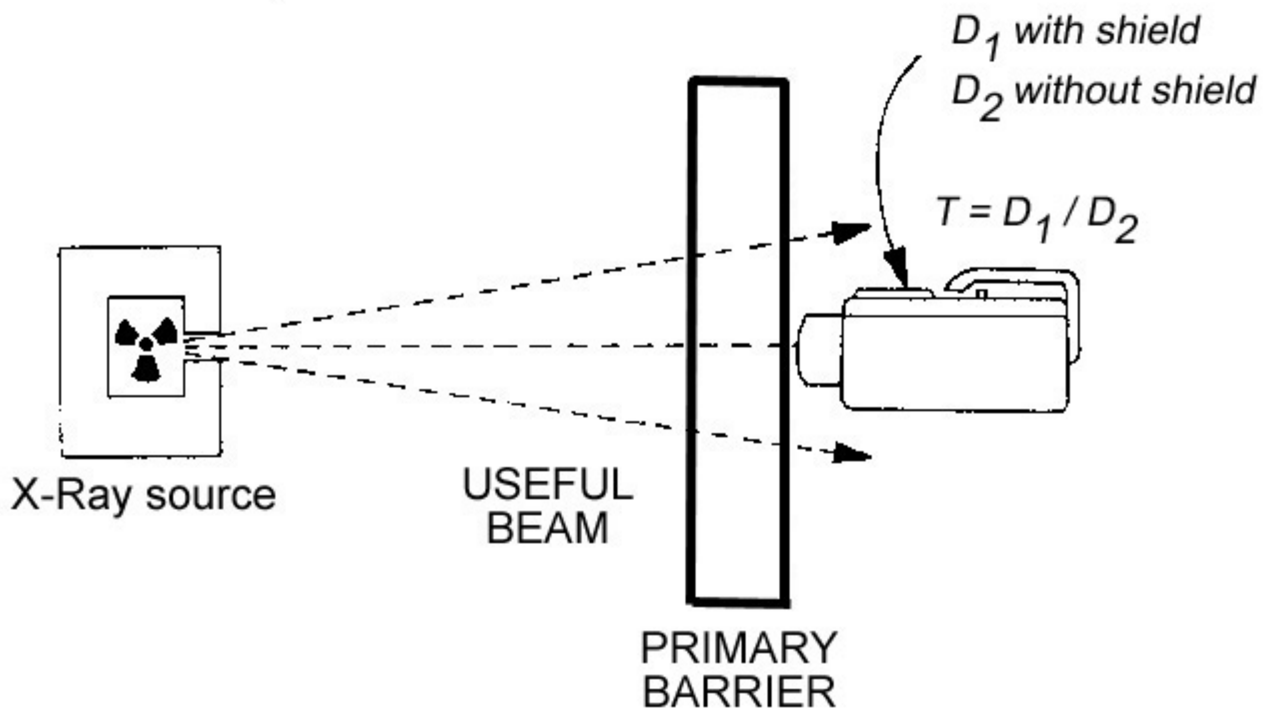
The doors shall be rebated such that there is a minimum overlap of 15mm. of the lead contained within each door.



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

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 cheked regularly (simple)
- The same RPO or QE taking care of personnel dosimetry, etc…. might do also this once a year

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* Comments 2

- **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 an quality assurance/quality control is essential for good results**