Radiation Shielding for Diagnostic X-rays
Principles behind Recommendations in BIR Report

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Introduction

In 2000 the British Institute of Radiology (BIR) published a report from a joint BIR and Institute of Physics and Engineering in Medicine (IPEM) working party on Radiation Shielding for Diagnostic Radiology [1]. This was the first UK report on this topic covering all X-ray modalities including dental radiology.

A second edition of the report has been commissioned by the BIR with a Working Party (WP) comprising the authors of this poster. A major addition to the revised report has been the inclusion of PET/ CT. The WP have made substantive changes to the methodology used for the assessment scatter dose in CT. The contribution of tertiary scatter from ceilings and walls has been considered with particular applicability in CT and interventional radiology. Other changes have been included to reflect the influence of changing technologies and clinical practices in X-ray imaging and also to reflect developments in building practice.

The purpose of this poster is to summarise the basis of the recommendations concerning dose constraints, occupancy and assessment of workload.

Dose constraints

An X-ray room or at least part of the room is invariably designated as a controlled area. Designation is required because special procedures have to be put in place to ensure that no individual receives a significant radiation dose. Shielding to the external structure of the room (walls, floor, ceiling, etc) is required to ensure that access to areas outside the room can be unrestricted both for staff and for members of the public. This could be interpreted as a requirement for doses to be less than 1 mSv per year, the public dose limit. However, there is also a requirement in legislation to restrict radiation exposure as far as is reasonably practicable to all persons. Since shielding is relatively inexpensive in comparison to the overall cost of an X-ray facility, the Working Party do not consider shielding to the dose limit to be an ALARP (as low as reasonably practicable) solution.

For a single source of radiation the National Radiological Protection Board recommended a dose constraint for the public equal to three-tenths of the dose limit, i.e. 0.3 mSv [2]. The dose limit (and consequently the dose constraint given above) is a limit on effective dose. However, that is not a pragmatic dosimetry quantity; it depends on several factors including radiation energy and more significantly irradiation geometry. In practical terms the dosimetric quantity used for the quantification of the primary and secondary sources of radiation is air kerma.

For these reasons the WP recommends an annual air kerma constraint of 0.3 mGy. This is an inherently conservative approach since the maximum air kerma behind a barrier is invariably greater than the effective dose to an individual at that location for the radiation energies used for diagnostic X-rays.

Dose constraint an CR

The dose constraint discussed above applies to people. It is also important to consider the accumulated dose to storage type detectors in particular imaging plates (IP) for computed radiography (CR).

IPs are commonly stored behind the protected screen in a general X-ray room. If not in frequent use, any additional radiation may impair image quality. The dose to the region of the image on the IP is typically in the range 1 to 10 μGy. Generally the acceptable dark noise on a plate corresponds to a dose of 0.1 μGy. The WP recommend a daily dose constraint equal to the dark noise be applied. This corresponds to an annual dose constraint based on a 250 working day year of 0.025 mGy.

Occupancy factors

Dose constraints apply to the individual not groups of individuals. They can therefore be adjusted by dividing by an occupancy factor defined as the maximum proportion of the working year that an individual is likely to be in that area.

For example, a patient waiting room will be occupied for most of the working day. However, you would not expect any individual patient or accompanying person to be present for more than about one or two hours in any working day and for no more than a few days in the year. Patient occupancy may therefore be considered very low. However, a member of staff may be required not only to fetch patients from the waiting room but may also spend some time with patients throughout the day and throughout the year.

Therefore the use of an occupancy factor of 5 to 20% seems reasonable depending on the extent to which a member of staff is likely to be in attendance. Some typical occupancy factors are given in Table 1.

One caveat applies to occupancy factors. The Ionising Radiations Regulations 1999 specify that an area must be designated as a classified area if any person working in the area is likely to receive an annual dose that is 6 mSv or greater. An occupancy factor of less than 5% linked to a dose constraint of 0.3 mSv would indicate that doses in that area could be greater than 6 mSv per year and would therefore require to be designated as a controlled area. The WP therefore recommend that occupancy factors less than 5% are not used.

Occupancy and location	Suggested range
Full Occupancy	100%
Control rooms	
Reception Areas, Nurses stations	
Offices, shops, living quarters, children's indoor play areas, occupied space in nearby buildings	
Partial Occupancy	20-50%
Staff rooms	
Adjacent wards, clinic rooms	
Reporting areas	
Occasional Occupancy	5-12.5%
Corridors	
Store rooms, stairways	
Changing rooms, unattended car parks	
Unattended waiting rooms	
Toilets, bathrooms	

Workload

In its first report, the WP recommended dose area product as the parameter to be used for workload assessment for radiographic and fluoroscopic X-ray facilities. In this report the term kerma area product (KAP) is preferred. The basis of this recommendation is:

- scatter is the predominate source of radiation when calculating the required shielding,
- the dose from scatter radiation is proportional to KAP, and
- KAP data are readily available from recommended national dose reference levels, from national reference doses based on UK wide dose surveys and from local dose audits.

The WP rejected the use of mAs as a workload parameter since the major factors influencing scatter intensity are dose and beam area. Dose is influenced not only by mAs, it also depends critically on kV and filtration and the influence of beam area is ignored.

The scatter factor (S) is defined as:

$$S = \frac{K_s}{KAP}$$

Where K_S is the scatter air kerma at 1 m from the centre of the irradiated beam in the patient.

S is a function of angle and kV. Using the original scatter data from [3], the WP showed that the As the scattering angle increases above 90°, S increases. In a situation in which the central axis of the beam is parallel to the barrier, the WP have shown that the maximum scatter factor for a wall at a distance of 1 m (S_{max}) as a simple function of kV.

$$S_{max} = (0.031 \times kV + 2.5)\,\mu Gy\,(Gy\,cm^2)^{-1}$$

With additional copper filtration, as is commonly used in interventional radiology, higher scatter factors are appropriate and these are included in the revised report.

In the revised WP report a similar methodology has been recommended for CT scanning in which scatter dose is derived from the patient dose parameter dose length product (DLP) [4].

References

1: BIR (2000) Radiation Shielding for Diagnostic –rays. Eds Sutton DG, Williams JR. BIR: London.

2: NRPB (1993) Board Statement on the 1990 Recommendations of the ICRP. Docs of the NRPB, 4(1).

3: Williams (1996) Scatter dose estimation based pm dose-area product and the specification of radiation barriers. Br J Radiol, 68, 1032-7.

4: Wallace H et al (2012) Establishment of scatter factors for use in shielding calculations for |CT facilities. J Rad Prot 32(2).