IRPA guideline protocol for eye dose monitoring and eye protection of workers

INTRODUCTION

In April 2011, the International Commission on Radiological Protection revised its eye dose threshold for cataract induction. The Commission specified a limit of 0.5 Gy, compared with the previous threshold doses for visual-impairing cataracts of 5 Gy for acute exposures and > 8 Gy for highly fractionated ones. Further, ICRP recommended a reduction in the dose limit for occupational exposure in planned exposure situations (in terms of equivalent dose) for the lens of the eye from 150 mSv to 20 mSv in a year, averaged over defined periods of 5 years, with no dose in a single year to exceed 50 mSv(1). This revised dose limit is incorporated into IAEA International Basic Safety Standards(2), and into the Council Directive Euratom(3) which must be implemented by the Member States by February 2018.

The reduction of the limit for occupational exposure for the lens of the eye has significant implication in view of the application to planned exposure situations for the different areas of occupational exposure(4,5) and needs adequate approaches for eye protection and eye dose monitoring.

IRPA initiated a process in 2012 to survey the views of the Associate Societies worldwide and to provide a medium for discussion on the implications of implementation of the new limits for the lens of the eye in occupational exposure(6-9).

Within the IRPA key scope of supporting the RP professionals; the purpose of this guideline is to provide practical recommendations about when and how eye lens dose should be monitored in the framework of the implementation of the new ICRP dose limit for the lens of the eye, as well as guidance on use of protective devices depending on the exposure levels.

WORKERS FOR WHOM LENS OF THE EYES MONITORING MIGHT BE NEEDED

Ionising radiation as neutron, photon and beta radiation can result in exposure to the lens of the eye, while an exposure to alpha particles are in general not considered in relation to the very low penetration depth in tissue. Exposure to neutron, as to heavy ions, are unlikely to be as an important contribution to the lens of the eye dose in general, since they may be restricted to astronauts or accidental conditions.

Risk assessments should be carried out to identify workers for whom exposure of the lens of the eyes might be important. These will require the use of information available on the tasks undertaken and the level of involvement in the procedures.

1. Workers exposed to a relatively uniform whole-body radiation field, shall not need any specific eye lens monitoring. The whole body dosimeter will provide a good estimate of the eye-lens dose. This is the most frequent situation, and thus in most cases no special monitoring or procedures shall be required.

2. Workers exposed to weakly penetrating radiation in a non-uniform radiation field producing a significant dose to the lens but a low effective dose. This might be the case for contaminated areas or in the vicinity of high levels of directional dose-equivalent rate produced by beta radiation.

3. Workers exposed to highly non-uniform radiation fields in which the eyes may be especially exposed, such as the case of interventional radiologists and cardiologists who work close to the radiation source but with a part of their body protected with a lead apron or similar situations.

For categories 2 and 3, estimation of potential doses to the eyes is required. For weakly penetrating radiation it is recommended that the radiation field is characterized and the maximum energy of beta radiation determined, so that the appropriate protection methods can be used. Within category 3, fluoroscopically guided procedures in medicine are likely to be the most frequent situations where special eye lens monitoring is required.

Occupational exposure to the lens of the eye is considered in the nuclear industry mainly in the use of hot cells, decommissioning of nuclear facilities or in case of handling Pu or depleted U.

Occupational exposure to the lens of the eye is considered in the medical field mainly in fluoroscopically guided procedures in interventional radiology and cardiology, preparation of radiopharmaceuticals and manual brachytherapy[10].

PROPOSED DOSE LEVELS FOR IMPLEMENTATION OF DOSE MONITORING

Prior to routine monitoring, for category 2 and 3 workers, it is important to assess the dose levels to the lens of the eye in a workplace field situation in order to decide which method, if any, and interval of routine monitoring is necessary. The potential eye doses can be obtained from workplace monitoring, whole body dosimetry, literature data, simulations or confirmatory (pilot) measurements[(4,5)]. For interventional clinicians, a number of studies involving multiple centres and meta-analyses of published data have been reported, and these can be helpful in estimation of potential doses to the eyes based on other parameters or doses measured in other parts of the body[(11, 12)]. Data on the number of procedures performed, the kerma-area product workload, the interventional access route and proximity to the x-ray tube should be considered for risk assessment[(13)].

The dose limit for the eye is expressed in terms of equivalent dose to the lens – H_{lens}[(1-3)]. This quantity cannot be measured but it is well estimated using the operational quantity, individual dose equivalent at 3 mm depth – $H_p(3)$. The depth of 3 mm was selected as it corresponds to the depth at which is located the part of the lens sensitive to ionising radiation. If the radiation field is well known, $H_p(3)$ can be estimated by the use of dosemeters type tested and calibrated in terms of other quantities, such as the individual dose equivalent at 0.07 mm depth - $H_p(0,07)$ and at 10 mm depth - $H_p(10)$ [(4,5)].

Recommendations for dose monitoring based on potential doses are given in Table 1.

Table 1 Proposed dose levels for implementation of dose monitoring[(16)]

Tissue	Dosimeter position	Dose quantity*	Annual dose (mSv)	Monthly dose (mSv)	Protection / Dose monitoring recommendations
Eyes	Collar or headband	Hp(3)	1–6	0.2–0.5	Initial monitoring with collar or head dosimeter to establish dose levels. Regular monitoring recommended
Eyes	Collar or headband	Hp(3)	> 6 (15)**	> 0.5	Regular monitoring with collar or head dosimeter is required.

* In photon fields, characteristics of fluoroscopically guided procedures Hp(0.07) or Hp(10) may also be used

** dose constraint in brackets

EYE LENS MONITORING PROCEDURES

The most accurate method for monitoring the equivalent dose to the lens of the eye is to measure the personal dose equivalent Hp(3) with a dosimeter worn as close as practicable to the eye.

In a homogeneous radiation exposure, an unshielded whole body dosimeter worn on the thorax provides a good estimate both of the effective dose and the dose eye equivalent dose.

In cases of non-homogenous exposures, such as clinical procedures, where workers protect part of their body with a lead apron, requires a better policy. A dosimeter worn under the lead apron will yield a reasonable estimate of effective dose but will not provide an indication of the eye exposure. In this situation a second unprotected dosimeter is recommended. Personal dose equivalent measured with dosimeters worn on collar or head could be considered to provide a satisfactory estimate for annual eye lens doses. The closest is the position of the dosimeter to the eyes the better is the estimate.

When using a single unprotected dosemeter worn at the collar or thorax, especially for measured annual doses above 6 mSv, it is recommended to perform a pilot study to determine a conversion factor between this measurement and $H_p(3)$ measured close to the eye. Such study can provide an objective criterion for ensuring compliance with the dose limits[4,17].

The ICRP recommends the use of one dosimeter worn on the trunk of the body inside the apron, and a second dosimeter worn outside the apron at the level of the collar for interventional radiologists, and cardiologists, vascular surgeons and other groups undertaking interventional procedures[18-19].

For other users of fluoroscopy, and staff present during interventional procedures, but larger distance from the patient, the need for an assessment of dose to the eye must be borne in mind[20]. Use of a collar badge should be based on practice patterns and workload. In some cases, initial collar monitoring will support the desirability of continuing requirements for the collar dosimeter. In institutions where all staff always wear lead aprons, it may only be necessary for the interventional clinician performing the procedure to wear two dosimeters, while other staff only wear a collar or eye dosimeter.

GUIDANCE ON USE OF EYE PROTECTIVE DEVICES

In the occupational exposure setting, radiation exposure to the eyes can be broadly divided into three categories:

- i) exposure to beta radiation that can be effectively shielded by wearing protective eyewear containing plastic lens (Perspex™ or equivalent);
- ii) exposure to x-rays that can be shielded by wearing protective eyewear with lead-glass lenses;
- iii) exposure to gamma radiation that is so penetrating that protective eyewear would be too heavy or bulky to wear.

It should also be noted that for item ii) above, that the radiation protection factor published by the manufacturer of the glasses is not a real description of the effectiveness for reduction of dose to the lens of the eye, since important factors such as the fit and shape of the glasses and the angle of exposure are typically need to be taken into account.

In the medical field

The lead apron is the most essential component of personal shielding in an x-ray room, and must be worn by all those present. It should be noted that the level of protection of the lead apron depends on the x-ray energy, which is represented by the voltage applied across the x-ray tube (kV). Staff working close to the patient should wear a thyroid collar. Since the risk of radiation induced thyroid cancer is higher for those under 30 y, especially females, use of a thyroid collar should be considered for all staff under 30 y who are present in the interventional room. It has to be remembered that the lead apron and thyroid collar are extremely good in reducing levels of radiation scattered by the patient that reach the chest, neck and the other protected parts of the staff member's body, but do not provide any protection for the lens of the eye.
Doses to the lens of the eye of the staff can be important during interventional radiology and cardiology and in nuclear medicine(14, 15). As regards protection of the eyes in the medical field, Table 2 summarizes the protection recommendations depending on the annual dose.

Since effective use of ceiling suspended screens and tolerance of lead glasses both depend on the operator, individuals must be involved in decisions on options for protection that suit them.

Table 2 Proposed dose levels for guidance on use of protective devices (16)

Tissue	Annual unprotected dose (mSv)	Protection recommendations
Eyes	3–6	Ceiling suspended screens should be used where available. Protective eyewear may be considered where there is no other protective device.
Eyes	6–10	Training in use of ceiling-suspended screens recommended. Protective eyewear should be considered, particularly where no other protective devices are available.
Eyes	> 10	Protection essential. Both ceiling suspended shield and protective eyewear should be considered and at least one form used.

Ceiling suspended screens

Staff should be trained in optimal use of ceiling suspended screens, before commencing interventional work. The training should include correct positioning linked to the different positions of the x-ray tube with respect to operator position.
The ceiling suspended screen is more effective when positioned close to the skin of the patient and to the x-ray field. The ceiling suspended screen can provide good protection

for the whole head, but this depends on effective use through repositioning whenever the x-ray tube or patient couch are moved, so that dose reduction factors in practice are usually only of the order of two, although diligent positioning could give reductions of 4-5 times[21].

Protective eyewear

Use of properly designed[1] protective eyewear should be considered if the measured annual eye dose exceeds 6 mSv. Lead glasses can provide dose reduction factors of 4-5, although since the doses depend on the glasses design, only factors of 2-3 can be guaranteed[22]. Different models of protective eyewear with various shapes, sizes and lead thickness should be evaluated before their use against penetrating and higher energy gamma rays. The evaluation should include radiography to confirm that the side shielding is adequate. If there is no specific data available for measurements of the dose reduction, then a factor of 2 may be applied provided the eyewear is of an approved design. However, systems must be in place to ensure that the protective eyewear is worn consistently.

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