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COMMENTARY

Occupational dose constraints for the lens of the eye for interventional radiologists and interventional cardiologists in the UK

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ABSTRACT

The International Commission on Radiological Protection (ICRP) has recommended a 20 mSv year^{-1} dose limit for the lens of the eye, which has been adopted in the European Union Basic Safety Standards. Interventional radiologists (IRs) and interventional cardiologists (ICs) are likely to be affected by this. The effects of radiation in the lens are somewhat uncertain, and the ICRP explicitly recommend optimization. Occupational dose constraints are part of the optimization process and define a level of dose which ought to be achievable in a well-managed practice. This commentary calls on the professional bodies to review a need for national constraints to guide local decisions. Consideration is given to developing such constraints using maximum expected doses in high-workload facilities with good radiation protection practices and application of a factor allowing for attenuation by lead glasses (LG). Doses are based on a Public Health England survey of eye dose in the UK. Maximum expected doses for ICs are approximately 21 mSv year^{-1} , neglecting LG. However, the extent of IR exposure is not yet fully known, and further evidence is required before conclusions are drawn. A Health and Safety Laboratory review of LG established a conservative dose reduction factor of 3 for models available in 2012. Application of this factor provides a dose constraint of 7 mSv year^{-1} to the eye for ICs. To achieve this constraint, those employers with the most exposed ICs will have to provide and ensure the correct use of a ceiling-suspended eye shield and LG.

INTRODUCTION

The 20 mSv year^{-1} dose limit for the lens of the eye, recommended by the International Commission on Radiological Protection (ICRP), has been included in the European Union (EU) Basic Safety Standards Directive for Ionising Radiation.¹ Member states must implement this by 6 February 2018. Interventional radiologists (IRs) and interventional cardiologists (ICs) receive significant occupational exposure to the eye and are staff on whom the limit reduction, from $150 \text{ mSv year}^{-1}$, may have the greatest impact.² Publications suggest that interventionalist doses may exceed 20 mSv year^{-1} if protection measures, including both a ceiling-suspended eye shield (CSS) and lead glasses (LG), are not utilized.²⁻⁵

Evidence of radiation effects in the lens suggests a dose threshold for cataract formation of 0.5 Gy for acute, fractionated and protracted exposure. However, for chronic exposure, much of the evidence refers to opacities rather than cataracts.⁶ To prevent a tissue reaction, it is usually sufficient to maintain dose below the threshold. In the case

of the eye, optimization is explicitly recommended to account for uncertainties in the value and even existence of a threshold. Some studies provide evidence which is not inconsistent with a linear no-threshold model.⁶

Dose constraints can help restrict occupational doses by ensuring that appropriate consideration is given to protection. Use of constraints when planning protection measures is required, where appropriate, by current legislation,⁷ but exceeding a constraint will not in itself result in regulatory action.⁸ Guidance states that constraints are appropriate only where individual doses from a single source are a significant fraction of the limit.⁹ As the EU directive¹ requires the undertaking to establish constraints, and eye doses for interventionalists are a significant fraction of a 20 mSv limit,^{2-5,10} it is expected that UK implementation may require employers to develop and use constraints.

Constraints define a level of dose which ought to be achievable in well-managed practices. They are an upper bound on the dose expected for an individual undertaking

a particular role, when working with a given radiation source, notwithstanding the principle that all doses should be as low as reasonably achievable, economic and societal factors being taken into account. Constraints do not represent a boundary between safe and dangerous levels of dose, nor a step change in the associated health risk.¹¹ However, they do mark a boundary between acceptable and unacceptable levels of protection and are in place to limit inequity between individuals.⁸ The ICRP expect constraints, which can be based on experience or recommendations from professional bodies, to be used to address variations in the level of protection afforded to the most highly exposed.¹¹ There are currently no such recommendations for eye dose in the UK. This commentary hopes to generate discussion and calls on the professional bodies to review a need for national constraints which could guide local decisions.

Development of constraints

Public Health England (PHE) carried out an assessment of eye dose for interventionalists at three high-workload UK hospitals with well-managed radiation protection practices.⁴ The study was carried out over 4 weeks in 2013 and suggested that, neglecting attenuation by LG, 2 out of 61 individuals would be at risk of reaching the 20 mSv limit (maximum 20.8 mSv year⁻¹). Maximum individual workloads at each of the hospitals during the study were 45, 50 and 75 procedures.

A 6-month study in interventional cardiology at the University Hospital of South Manchester (UHSM) in 2012/2013 monitored nine cardiologists, including three electrophysiologists, using thermoluminescent dosimeters placed over the left eye.¹⁰ The maximum extrapolated annual eye dose was 17.3 and 3.0 mSv, respectively, neglecting LG. The associated whole-body doses were 1.2 and 0.8 mSv, respectively. All nine cardiologists used CSSs and complied with monitoring during the study. UHSM is a high-workload department with four catheter labs and a good radiation protection culture. In 2012, the catheter lab was used predominantly for electrophysiology procedures delivered at 10,500 Gy cm². The other labs delivered on an average 45,600 Gy cm² (maximum 66,500 Gy cm²); this is at the upper end of UK catheter lab workloads.¹² The most exposed individual was a registrar who performed 65 procedures a month on average. Registrars at UHSM may do four or five sessions per week in the catheter lab (four patients per session). Given their large individual workloads, it may be safe to assume their exposure would not underrepresent the exposure of cardiologists at other centres. X-ray equipment used during the study was 5 and 10 years old. UHSM was one of the sites included in the PHE report. The longer study confirmed PHE findings.

A separate study of 204 interventional staff at 8 UK hospitals found that several individuals would have exceeded the 20 mSv limit.⁵ There were a variety of radiation protection conditions with non-uniform uptake of CSSs and LG, which is currently typical.^{4,5} Nonetheless, for IRs and ICs monitored on the head, in departments that always used CSSs, the respective maximum doses were approximately 24 and 20 mSv year⁻¹, neglecting LG. The publication does not state the age of the X-ray equipment used but is likely to include a range of specifications.

Constraints should be set at the upper end of the distribution of reasonably achievable doses.¹³ At this stage, it would seem

unwise to use anything other than the maximum expected dose, with application of a correction factor for LG. However, the PHE study⁴ may not have fully captured the extent of IR doses. A recent study in Ireland gave maximum eye dose as 44.9 mSv year⁻¹ in a department with modern equipment and well-utilized CSS.¹⁴ There is currently not enough evidence to draw conclusions on the most exposed IRs in well-managed practices in the UK. For ICs, it can be said with reasonable confidence that they could expect up to 21 mSv year⁻¹, neglecting LG, in well-managed practices. Setting a constraint now comes down to a discussion about which factor to use for LG attenuation.

A review of CSSs and LG established a conservative dose reduction factor (DRF) (being the ratio of the unshielded to shielded doses) for the eye of 5 and 3, respectively.² If correctly positioned, CSSs effectively shield the upper body.¹⁵ Despite claims that modern LG are light and easy to wear,⁴ they are not uniformly popular owing to weight and “steaming up”.¹⁶ Those who wear corrective eyewear have the option of prescription LG or lead overglasses (LOG). Most styles are available in single vision, bifocal and progressive focus lenses; however, cost will need to be balanced with practicality and comfort. LG should fit closely to the contours of the face^{15,16} and it is important that individuals choose glasses that are right for them, to encourage full compliance. The author has been assured by a number of suppliers that they are seeking better designs, increased wearer comfort and technical advancement.

Magee et al¹⁶ have advocated a conservative DRF of 2 for LG or LOG that have not been specifically assessed for their level of protection (provided they meet certain criteria). The majority of the pairs tested in that study provided DRFs of 3–5, with only the least favourable angle of scattered radiation incident on a pair of LOG, giving a DRF <2. Monte Carlo simulations suggest that wraparound LG are more protective than those with separate front and side shielding (average DRF of 3.8 and 1.7, respectively).¹⁵ Using a DRF of 2 assumes a minimum level of protection. This would not be appropriate for the most exposed interventionalists, especially given the availability of glasses providing greater protection. Therefore, a DRF of 3 has been used in line with the Health and Safety Laboratory review.² Application of this factor provides a constraint of 7 mSv year⁻¹ for ICs; this is significantly below the expected 15 mSv year⁻¹ classification level.

Meeting a constraint

A number of individuals will need close attention, to ensure their exposure is below any constraint set. The constraint should identify situations where optimization with existing equipment is not sufficient and when the employer, who has the responsibility to ensure doses are as low as reasonably practicable, must take action. To reduce eye dose, employers may have to purchase CSSs and effective LG or even upgrade X-ray equipment. The work performed by interventionalists is of great benefit to society. To ensure the most exposed do not incur unreasonable detriment from an imbalance in the distribution of cost–benefit, it is reasonable to expect an employer to invest in protection. Employers will have taken steps to ensure a public

dose constraint is not exceeded outside their controlled areas; so, this concept should be familiar. A national constraint would ensure that a similar level of protection is provided across the UK. The cost of a CSS (with installation) and a number of pairs of LG will be dwarfed by initial and ongoing costs of an interventional facility. Given the ICRP recommendation to optimize eye dose,⁶ CSSs and LG should already be available. Employers who have reviewed protection measures and concluded that the X-ray equipment should be upgraded are unlikely to have systems with modern dose-saving features such as advanced optimization of parameters and real-time image processing. All equipment should be replaced within a reasonable time from the point it is known to be unsuitable. Owing to the high capital cost of new X-ray equipment, it may be sufficient that employers have considered meeting a constraint within their equipment replacement strategy.

CONCLUSION

All occupational doses should be as low as reasonably practicable, and a suitable constraint may be required to comply with UK implementation of the EU directive.¹ This commentary calls on the professional bodies to review a need for national constraints, which could guide local decisions. A constraint for IRs requires further consideration, and meeting it may be a significant challenge for some. Using data from well-managed practices and accounting for attenuation by LG suggests a 7 mSv year⁻¹ dose constraint for ICs. This is strict, but given the philosophy behind optimization and evidence that it is achievable, it should be seen as a manageable challenge. It should not lead to a reduction in the number of life-saving procedures performed; however, it will require employers to ensure that protection is optimized for those performing these procedures. For those with high workloads, a CSS and LG are essential to meet this constraint.

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