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Protecting interventional radiology and cardiology staff: Are current designs of lead glasses and eye dosemeters fit for purpose?

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The Ionising Radiations Regulations (IRR 2017) have implemented a new annual radiation dose limit for the lens of the eye of 20 mSv. This change has focussed attention on the protection requirements for interventional radiologists and cardiologists. They undertake complex procedures that involve the placement of devices within the body through catheters to treat a variety of conditions under the guidance of X-ray imaging. In order to accomplish this, clinicians needs to stand close to patients to perform the manipulations while viewing the X-ray images, and as a result they are exposed to radiation scattered from the patients' tissues. Clinicians with medium or high workloads could receive doses to the eye that would exceed the new dose limit, if protective measures were not in place. A number of ophthalmological studies have been conducted recently on interventional staff attending congresses in various parts of the world, a number of which have reported higher frequencies of lens opacities confirming the risk to interventional staff. For example Vañó et al (2013) reported that in a group of 127 staff 50% of cardiologists and 40% of nurses and technicians working in interventional laboratories had posterior subcapsular opacities compatible with injury from exposure to ionising radiation and it was estimated that the lifetime lens doses for some of these individuals were several grays. The incidence rate of opacities was four to five times higher than the rate for an unexposed control group. The number of interventional procedures has expanded steadily over the last two decades as new interventions of increasing complexity have been developed. This increases the risk of the eye lens doses approaching or even exceeding the new limit. The International Commission on Radiological Protection have prepared guidance, drawing together recommendations on methods for protection and personal dosimetry for interventional staff (ICRP 2018). The publication aims to provide guidance to personnel involved in the interventions, but also to hospital administrators, medical physicists, and others with an involvement in occupational protection, to assist hospitals in meeting the challenge presented by these developments.

Interventional staff wear lead/rubber aprons to protect the trunk against scattered radiation, so effective doses to the whole body are unlikely to approach the effective dose limit (IRR 2017). However, the aprons do not shield the head, neck, arms, hands, and legs. Ceiling-suspended lead acrylic shields are the most important devices for protecting the upper body and can reduce doses to the head and neck by factors of 2–5. However, success depends on how well they are positioned and efficient protection requires continual repositioning whenever the couch or X-ray tube are moved. An additional level of protection for the eyes can be achieved from use of lead glasses. Protective collars are worn to shield the thyroid, and these are vital for younger staff as the risk of thyroid cancer depends strongly on age. Thyroid collars should be worn by all female staff under 40 years of age working in interventional laboratories and males under 30 years, as well as interventional clinicians performing the procedures. There are also risks that the hands carrying out manipulations, and legs that are nearer to the X-ray tube receive significant doses, if not protected. In this editorial some of the issues involved in protection of the eyes and measuring doses to the eyes are highlighted.

Protective eyewear can reduce dose to the lens of the eye substantially, but will not provide complete protection. Since issues relating to protection of the eye have only recently begun to receive more attention, it is worth considering the design of current models. When interventional clinicians are carrying out procedures, they will usually be viewing images on a display monitor while X-rays are being emitted, rather than looking at the patient who is being irradiated. Scattered radiation can pass through gaps behind the lenses to irradiate the eyes directly, but a significant part of the eye lens exposure is from radiation scattered from tissues surrounding the eyes that are irradiated. There are two types of lead glasses: a “wrap around” style with lenses angled to the front of the face, or ones with flat lenses and lead glass side shields. The protection provided by the lenses of current models is usually equivalent to a lead thickness of 0.75 mm. However, the protection factors offered by equivalent thicknesses of 0.5 mm and 0.35 mm are only about 5% and 12% less (Hu et al 2017), so 0.75 mm is probably more than is needed. *A priori* one might assume that the opaque frames would be shielded. However, those of many models are made of plastic and so there is often a gap in the protection between the front lens and the side shield in the direction from which X-rays are incident. The size of the lenses is important because not only do larger lenses reduce the risk of direct exposure of the eye from radiation scattered from a patient, they also provide better shielding for tissues surrounding the eyes and scatter from these tissues makes a major contribution to the dose to the eye lens. Increasing the size of the lens from 17 cm^2 to 27 cm^2 could reduce the eye dose by over 40%. The weight of glasses is obviously an issue, as heavy spectacles would be uncomfortable, but by judicious choice of lead equivalence for the lenses (0.4 – 0.5 mm), lens size including a metal frame surround with some shielding capacity (24-27 cm^2), and the use of metal shielding in the front section of the side arms, it should be possible to achieve a better level of protection with a similar weight. Other options might be lead acrylic goggles with lead equivalences of 0.4 mm to 0. 5 mm or whole face visor style shields with a lead equivalence of 0.1 mm.

It is impossible to ensure that staff are using proper protective measures and to know whether doses to staff comply with the dose limit without measuring them. Guidelines on requirements for personal dosimetry in the UK will be published later this year (Martin et al 2018). Interventional operators in the UK who are classified radiation workers will need to wear a dosemeter under their lead apron to measure personal dose equivalent Hp(10) to give an assessment of effective dose, and a dosemeter adjacent to the eye to measure Hp(3). Since other staff in the interventional room will receive doses to their eyes, a dosemeter is required that will provide information on this and a dosemeter worn at the collar outside the lead apron should provide sufficient data to allow a radiation protection service to decide whether additional dedicated eye and/or body monitoring is necessary (ICRP 2018, Martin et al 2018). There have been problems in the past with compliance in the wearing of dosemeters by some staff and it may be useful to compare personal dosemeter results with estimates based on other measures of radiation levels. This could be done through use of area dosimeters attached to the frame of the C-arm X-ray unit to measure the level of scatter radiation near the patient or monitoring of kerma-area product measurements associated with patient doses, which have a close link to the amount of scatter produced (ICRP 2018, Martin et al 2018). However, since the relationships between these quantities and staff doses depend on the type of procedure and X-ray tube geometry, conversion coefficients would be required to provide the link to levels of eye dose.

If operators wear eye protection, this will only be taken into account if the eye dosemeter is worn behind the lead glasses. But how good a representation of the dose to the eyes will this give? If the dosemeter is worn on the skin surface at the side of the eye, then the result may be reasonable. However, if a dosemeter is incorporated into lead glasses immediately behind the protection or clipped onto the inside of the lead glass lenses it may be shielded from X-rays coming from the side that will be incident on the eye, and so underestimate the dose to the eye lens significantly. A dosemeter attached to the frame of the lead glasses outside the protection provides a possible option (Silva et al 2017), but this will overestimate the dose from incident radiation, while not recording all the radiation scattered back from tissues in the head, so the net result may be closer to the eye lens dose but the uncertainties will be large. The dose measured with a dosemeter attached to a head band is the simplest option and should give a reproducible result, but will overestimate the eye lens dose. However, if a dosemeter is worn on the skin surface near to the eye, but not shielded by the lead glasses, a protection factor could potentially be applied to take account of the dose reduction. Current models of protective eyewear provide protection equivalent to factors between 0.2 and 0.4, so application of an adjustment factor of 0.5 to the measured result would be a reasonable conservative value for the majority of users (ICRP 2018, Martin et al 2018). In the UK this would require the factor to be included in the statement of service provided by the Approved Dosimetry Service and to be approved by the Health and Safety Executive, and the employer would need to have a system in place to confirm that the dosemeter was always worn in the designated position by each staff member.

Methods for protection of the eyes of interventional radiologists and cardiologists are still developing. More efficient use of ceiling suspended screens is perhaps the best way of keeping doses to the eye lens low. Therefore there is a continuing need for staff involved in interventional procedures to have periodic education and training to ensure that protection facilities are used effectively as well as emphasising the importance of dose monitoring. However, there is also a need for companies that supply radiation protection devices and services to make improvements through evaluating the designs of protective eye wear that are appropriate for the future, and supplying eye dosemeters that are easy to use, reliable, and give accurate measures of eye lens doses. Through following the protection methods described in ICRP (2018) and use of appropriate dosimetry methods (Martin et al 2018) within a coherent safety culture framework, it should be possible to keep eye doses of interventional staff below the new regulatory limit, but this is not something that can be left to chance.

Colin J Martin, Honorary clinical senior lecturer, University of Glasgow, Scotland, United Kingdom.

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