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Where is the best position to place a dosemeter in order to assess the eye lens dose when lead glasses are used?

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HIGHLIGHTS

- The best position to place an eye lens dosemeter on lead glasses was evaluated.
- The optimal position found is over the lead glasses, close to its bridge.
- Single dosimetry, compared to double dosimetry, is enough to assess eye lens dose.

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ABSTRACT

The objective of this study was to evaluate the feasibility of assessing the eye lens dose when lead glasses are used, by attaching a small radiophotoluminescent (RPL) glass dosemeter to the lead glasses. RPL dosemeters were placed over and under the shielding of the glasses and their response was evaluated for a range of parameters, including irradiations in a standard X-ray beam and Monte Carlo simulations of a cardiac/radiologic intervention (scattered beam). For the specific situations taken into account in this study, the optimal position was found to be a dosemeter placed close to the bridge of the lead glasses, over its shielding.

1. Introduction

Because of the increasing concern related to the development of lens opacities among workers occupationally exposed to ionising radiation (IR), several studies on the dose received by the eye lens have been performed (Jacob et al., 2013; Sanchez et al., 2014; Vanhavere et al., 2011). Following indications that lens opacifications could occur at doses lower than previous considered (Worgul et al., 2007), the International Commission on Radiation Protection (ICRP) has recommended a new dose limit to the lens of the eyes (ICRP, 2011), which was included in the International Basic Safety Standards (European Comission, 2014). Special attention has been devoted to interventional cardiologists/radiologists, due to the high doses their eye lenses may receive. A higher occurrence of lens opacification in these group of workers compared to control groups has been reported in the literature, as well as in nurses and technicians exposed to IR in the interventional suite (Ciraj-Bjelac et al., 2010). In order to protect their eye lenses, the use of protection devices, such as lead glasses and shielding suspended screens, are advised (ICRP, 2012). Currently, dosemeters dedicated to assess $H_p(3)$ are available (Bilski et al., 2011; Ferrari et al., 2016; Gilvin et al., 2013; Mariotti et al., 2011), enabling the assessment of the eye lens dose. Nevertheless, these dosemeters are usually big in size and might be uncomfortable to be worn together with lead glasses. Assessing eye lens doses when lead glasses are worn is still a

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problem, because most dosemeters cannot be worn under the glasses, and wearing them above or beside the glasses can result in large overestimates, due to the need of applying a correction factor to account for their shielding properties (Magee et al., 2014). A dosemeter under the shielding of the glasses, on the head, close to the eyes, should assess the eye lens dose with good accuracy because the same shielding efficiency would be provided both to the eye lens and to the dosemeter. This approach has, however, practical issues, such as the need of a headband to hold the dosemeter, which in turn may not allow the glasses to fit properly in the face of the operator, decreasing its shielding efficiency (Koukorava et al., 2014). In addition, this is not comfortable for the user, who prefers smaller dosemeters, without extra holders (Principi et al., 2015). In order to provide only one set of protection device that would enable protection and dose assessment of the eye lens, the feasibility of assessing the eye lens dose by employing a small radiophotoluminescent glass dosemeter attached to lead glasses was evaluated in the present study.

2. Materials and methods

2.1. Dosimetry system

A radiophotoluminescent (RPL) glass dosemeter, DoseAce GD-352M (AGC Techno Glass), was chosen for this study, thanks to its good dosimetric properties in terms of $H_p(3)$ and small size (Silva et al., 2016). Detailed information about this dosimetry system and its readout procedure are presented elsewhere (Silva et al., 2016).

2.2. Experimental measurements in a standard beam

Two models of lead glasses (Pulse Medical Inc, Blue Ridge GA,USA), which have proven to provide reasonable shielding (Magee et al., 2014) were considered, Fig. 1, to account for the presence and absence of side shielding protecting the eyes. Both models have frontal lenses equivalent to 0.75 mm of lead and one has also side shielding equivalent to 0.50 mm of lead, as stated by the manufacturer. Dosemeters were placed in 10 different positions, under and over the shielding of the lead glasses, as shown in Fig. 2. Positions were chosen taken into account the rod shape of the dosemeter and in order to not hinder the sight of the user. To compare the response of RPL dosemeters with currently used EyeD dosemeter (Bilski et al., 2011) (with a lithium fluoride detector MCP-N, Radcard, Poland), the eye lens dose was also measured by attaching the EyeD to the arm of the lead glasses as reported in literature (Dabin et al., 2016).

In the secondary standard dosimetry laboratory at SCK·CEN, irradiations were performed with four energies (ISO 4037 narrow series N-40, N-60, N-80, N-100 (ISO, 1996)), chosen to be representative for the typical range of energies found in interventional cardiology/radiology (Bushong, 2016; Clairand et al., 2011), at three different angles in transverse plane (0°, 45° and 75°), using the head of an anthropomorphic Rando phantom (Alderson Research Laboratories, USA). The eye of the Rando phantom was kept at a fixed distance of 1.0 m from the X-ray source. Reference dose $H_p(3)$ to the eye lens was measured using an EyeD dosemeter, placed on the eye socket, under the shielding of the glasses. EyeD dosemeters used on the eye sockets and attached to the arm of the glasses were calibrated in the ORAMED proposed cylindrical phantom, with an ISO S-Cs source (ISO, 1996).

Fig. 1. Models of lead glasses used. In detail, RPL glass dosemeter GD-352M.

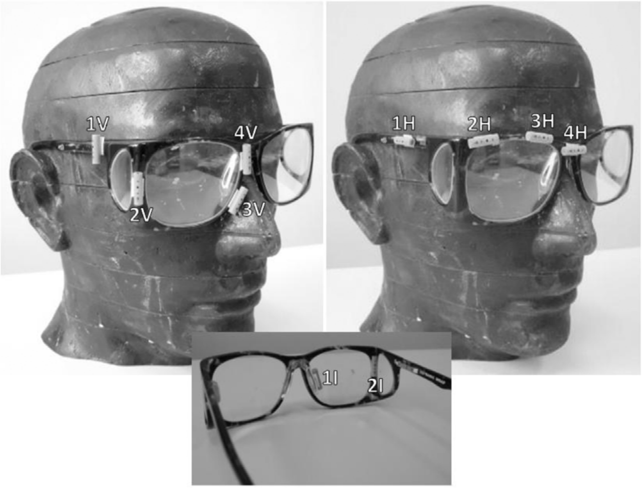

Fig. 2. Positions where RPL dosemeters were placed, over and under the shielding of lead glasses.

Irradiations were performed in four steps: (1) RPL dosemeters placed over and (2) under the glasses, (3) EyeD attached to the arm of the glasses and (4) EyeD on eye socket, to assess $H_p(3)$ under the shielding of the glasses. Each setup was irradiated twice, and the average over the two irradiations was used for data analysis.

2.3. Monte Carlo simulation of an interventional cardiac/radiologic procedure - scattered beam

To evaluate the response of the dosemeters in different positions on the glasses in an interventional setup, Monte Carlo calculations using MCNPX (Pelowitz, 2011) code were performed. A mathematical phantom made of ICRU 4-elements tissue was used both as patient and as operator (Behrens and Dietze, 2011). Body and neck of the operator were covered with 0.5 mm of lead, to simulate the use of lead apron and thyroid shield. Furthermore, the operator was also equipped with detailed eyes of specific material composition, as defined by Behrens *et. al.* (Behrens et al., 2009). As the fitting of lead glasses on the operator's face has an important role on its shielding efficiency (Koukorava et al., 2014), two models of lead glasses based on the ones experimentally used were added to the operator. Lenses size, curvature of the frame and lead thickness were carefully modeled to be the same as those from the physical glasses. An improved version of the dosemeter used experimentally, with lower angular dependence (paper under preparation) was placed in the same positions on the glasses as those experimentally studied. The difference between the current GD-352M and the optimized dosemeter simulated is the shape of the tin filters. All the materials and reading volume of the glass dosemeter (Kadoya et al., 2012) remained the same and were modeled as such in the simulations. An X-ray spectrum of 80 kVp, 3 mm Al was used to simulate a thorax irradiation. Field size at the entrance of the flat panel detector was 25 cm. Source-skin distance was 60 cm and the distance between patient's skin and flat panel detector was 10 cm.