ORIGINAL ARTICLE

Occupational Exposure of the Eye Lens in Interventional Procedures: How to Assess and Manage Radiation Dose

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Abstract

Occupational exposure from interventional x-ray procedures is one of the areas in which increased eye lens exposure may occur. Accurate dosimetry is an important element to investigate the correlation of observed radiation effects with radiation dose, to verify the compliance with regulatory dose limits, and to optimize radiation protection practice. The objective of this work is to review eye lens dose levels in clinical practice that may occur from the use of ionizing radiation. The use of a dedicated eye lens dosimeter is the recommended methodology; however, in practice it cannot always be easily implemented. Alternatively, the eye lens dose could be assessed from measurements of other dosimetric quantities or other indirect parameters, such as patient dose. The practical implementation of monitoring eye lens doses and the use of adequate protective equipment still remains a challenge. The use of lead glasses with a good fit to the face, appropriate lateral coverage, and/or ceiling-suspended screens is recommended in workplaces with potential high eye lens doses.

Key Words: Eye lens, radiation dose, interventional procedures, occupational exposure, fluoroscopy

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INTRODUCTION

After the results of a number of studies on radiation cataractogenesis, the International Commission on Radiological Protection reevaluated the dose limit for lens of the eye, based on the new findings that at relatively high exposures (> 1 Gy) lens opacities may occur within a few years; however, at lower doses and dose rates (similar to those that might be encountered in occupational practice in medicine) visually disabling cataracts may occur over many years [1,2]. It has been shown that the duration of the latency period is inversely dependent on dose, and the new threshold ranges from zero to 0.8 Gy [2]. Consequently, the International Commission on Radiological Protection has set the threshold dose for radiation-induced eye cataracts to be 0.5 Gy for both acute and fractionated exposures [1], and they recommended a reduction of the dose limit for the eye lens for workers from 150 mSv to 20 mSv per year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv [2,3]. This new 7.5-fold reduction has become the subject of intense scientific debate, including authors who justified [4,5] and challenged [6] this issue. As new evidence on eye lens injuries associated with exposure to ionizing radiation has become available, eye lens dosimetry is now a very active research area [7-9].

The objective of this work is to review eye lens dose levels in clinical practice that may occur from the use of ionizing radiation in fluoroscopy-guided interventional

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procedures. Current and future eye lens dose monitoring arrangements and dose assessment methods are also discussed, including the impact of potential dose reduction factors.

EYE LENS INJURIES DUE TO OCCUPATIONAL EXPOSURE IN INTERVENTIONAL PROCEDURES

Occupational exposure in medicine is one area in which increased eye lens exposure is likely to occur. There are numerous studies on the high staff eye dose levels from fluoroscopy-guided procedures in radiology, cardiology, and other areas such as orthopedic surgery, urology, gynecology, neurology, anesthesiology, vascular surgery, pulmonology, CT fluoroscopy, and gastroenterology [7,10-17].

Pilot studies performed in collaboration with the International Atomic Energy Agency and professional cardiology societies have investigated the relationship between such occupational exposure and subsequent eye lens changes [7,8]. The studies included a detailed questionnaire regarding exposure history as well as a comprehensive dilated slit-lamp examination of interventional cardiologists, nurses, and technicians working in cardiac catheterization laboratories. Post-subcapsular cataract opacities were found in 38% of examined cardiologists and 21% of paramedical personnel, compared with 12% of controls. Cumulative occupational mean eye lens doses were estimated at 6.0 Sv for cardiologists and 1.5 Sv for associated staff when eye lens protection was not used [7,8]. A strong dose-response relationship between occupational x-ray exposure and detectable posterior eye lens changes in interventional cardiologists was reported. Similarly, post-subcapsular cataract lens changes likely induced by radiation exposure were found in interventional cardiologists and nurses (50% and 41%, respectively, compared with findings of similar lens changes in <10% of controls), suggesting an urgent need for improved radiation safety and training [18]. Another large study included prospective analysis accompanied by a 20-year follow-up of more than 35,000 radiological technologists who were assessed in terms of risk for eye lens opacification and cataract [19]. The study provided evidence that exposure to relatively low doses of ionizing radiation (lifetime dose up to 60 mGy) may be harmful to the eye lens and increases the long-term risk of cataract formation. The findings suggested that the likelihood of cataract formation increases with increasing exposure to ionizing radiation with no apparent threshold level.

The above-mentioned studies highlighted the need to assess eye lens dose in clinical practice. However, one of the main limitations of the current literature is the large uncertainty in estimated occupational doses.

APPROACHES TO EYE LENS DOSE ASSESSMENT IN CLINICAL PRACTICE

Contrary to whole-body dosimetry, eye lens dosimetry is currently not well established and numerous recent studies have been carried out to investigate its various aspects [7-9,19-23]. Furthermore, clinical studies have been conducted to review the methodology for assessing eye lens dose levels, to investigate monitoring arrangements using different types of dosimeter, to study correlation of eye lens dose with patient dose indices, and to perform retrospective eye lens dose assessment [13,15,16,20].

Eye Lens Dose Assessment

According to the International Commission on Radiation Units and Measurements, the operational quantity "personal dose equivalent at depth 3 mm; Hp(3)" is the most appropriate quantity to monitor the eye lens dose as the lens is covered by about 3 mm of soft tissue [24]. Recently, several important initiatives were undertaken to develop eye lens dosimeters calibrated in terms of Hp(3). Generally they employ a thermoluminescent chip as a passive dosimeter with certain material covering it to mimic the necessary thickness and assure coherence with the defined quantity [23,25,26]. All of these new devices should conform to recommended calibration procedures and type tests [22]. If a specific dosimeter is not available, Hp(3) can be estimated through dosimeters calibrated in terms of the International Commission on Radiation Units and Measurements quantities Hp(10) and Hp(0.07) by using proper correction factors [5,26]. It is important to emphasize that such evaluation can be quite inaccurate; for example, if a collar dosimeter is used to evaluate the eye lens dose, the correction factor can vary from 0.4 [27] to 1.4 [28], owing to the difference in radiation field characterizing the measuring point where the dosimeter is placed, with respect to the operator's head. Indeed, it is impossible to determine the eye lens dose from a single whole-body dosimeter, if it is worn under the lead apron [7,8].

It has been demonstrated that active personal dosimeters can be an effective tool for reduction of occupational doses; however, they must meet certain requirements to be suitable for the assessment of the occupational exposure in medical applications [29-31].