Radiological Physics and Technology (2019) 12:26–29
https://doi.org/10.1007/s12194-018-0487-9

Risk of radiation-induced lens opacities among surgeons and interventional medical staff

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Received: 10 January 2018 / Revised: 21 October 2018 / Accepted: 1 November 2018 / Published online: 26 November 2018

Abstract

The main effect of ionizing radiation on the eyes is the onset of posterior cortical and subcapsular cataracts. Recent studies have raised questions about the mechanism of ocular damage and the threshold dose for the onset of such effects. Currently, operators may be exposed to ionizing radiation during surgical procedures. It has been estimated that urologists can be exposed to an annual dose close to or above 20 mSv/year. The aim of our study was to evaluate the frequency of cataracts in a group of professional radiological operators to verify their possible association with the radiation dose to the crystalline lens and the tasks performed. The records of 73 health workers exposed to ionizing radiation were reviewed. The average annual dose to the crystalline lens, the number of years of exposure, and the presence of radiation-compatible opacities were assessed for all operators. Lenticular opacities were observed in 16.4% of subjects. The presence of alterations was associated with exposure doses below 10 mSv and > 10 years' experience in fluoroscopically guided procedures. Based on our results, protection of the crystalline lens against exposure to ionizing radiation by means of goggles is recommended. In addition, examination of the lens via slit lamp examination is recommended for all operators involved in interventional procedures with the current levels of radiation exposure.

Keywords Lens opacities · Ionizing radiation · Occupational cataract · Occupational exposure · Interventional radiology · Radiation protection

1 Introduction

The main effect of ionizing radiation on the eye is the loss of transparency of the lens, as documented by studies on survivors of the atomic explosions of Hiroshima and Nagasaki [1, 2]. The pathogenic mechanisms leading to this alteration are well-known and involve direct changes in the lenticular cells, which, due to the particular architecture of the tissue, are easily damaged. This results in specific alterations in the cells' water and protein content, accompanied by variations in the ability to conduct optical radiation. Many factors affect the tissue response to radiation, including the type of radiation, the manner of exposure, the individual genetic susceptibility, and the forms of cataracts with respect to the visual axis [3, 4]. The onset of cataracts is considered to be a deterministic having a threshold dose below which the effect does not occur [2]. The relationship between exposure to high doses of radiation > 2 Gy and the onset of lenticular opacities has been well-documented in the literature for many years [2, 3]. However, reports on the possibility of damage at low doses of exposure are relatively recent, as are the assumptions regarding the absence of an effect threshold [5, 6]. Epidemiological studies performed so far indicate a positive association between exposure to ionizing radiation and posterior subcapsular, cortical, and mixed cataracts at different levels of exposure. The main imitations of these studies are the short observation period and the experimental models used. In fact, it is not possible to identify with certainty an effect threshold for acute and chronic exposures [7].

Recent studies have shown a greater frequency of lenticular opacity among health professionals exposed for many years to relatively low doses of ionizing radiation during the course of vascular procedures, and also for exposure below the occupational exposure limit established by

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the International Commission on Radiological Protection (ICRP). It has been shown that in the absence of radiological protection devices, the workloads typical to interventional radiology practices can lead to an exceedance of the current threshold for deterministic effects on the crystalline lens after several years of work [8–11]. Urological procedures such as ureteroscopy and urethral stent insertion can result in significant exposure of the operators to radiation; published studies have determined the radiation dose to the lens to be between 0.05 and 0.66 mSv per procedure [12].

Actual radiobiological uncertainties related to the mechanism underlying the development of lenticular damage have revealed the need for a re-evaluation of the radiosensitivity of the lens. This has resulted in a change in the previous recommendation of the ICRP of a dose limit of 150 mSv/year for professional exposure. The ICRP currently recommends the dose limit for the crystalline lens to be 20 mSv per year, or 100 mSv in 5 years, provided that the value for a single year does not exceed 50 mSv. In fact, based on the available evidence, it is believed that an acute exposure lower than 100 mSv does not induce damage to the lenticular cells, but the use of a deterministic model with threshold dose remains uncertain [13].

The aim of our retrospective cross-sectional study was to evaluate the association between lenticular opacities defined according to the Lens Opacities Classification System (LOCS) and radiation dose to the crystalline lens in a group of health professionals with occupational exposure to radiation in a university teaching hospital [14].

2 Materials and methods

We reviewed the dosimetric and clinical documentation of a group of professionals with occupational exposure to ionizing radiation (73 participants; 51 men and 22 women), operating in the departments of traditional radiology, interventional radiology, interventional cardiology, vascular surgery, urology, and orthopedics of a university hospital. The workers had been examined during a study carried out at the occupational health department in 2015. During screening, they underwent an examination of the crystalline lens using biomicroscopy or slit lamp examination with a backlighting technique and photographic relief in pharmacological mydriasis. The latter technique was conducted by instillation of 1 gtt of tropicamide (Tropimil) 0.5% eye drops in the conjunctival sac. The examinations were performed using a slit lamp (CSO SL 980) connected to image acquisition software (Epsilon Lyrae camera.)

Possible opacities detected were classified according to the LOCS criteria into nuclear, cortical, or posterior by comparing slit lamp images with standard photographic slides. The opacities were then further rated on a scale of 1– 5 according to severity. The system guarantees a standardized classification of clinical pictures. All the findings were analyzed by an ophthalmologist who is an expert in the health surveillance of workers exposed to ionizing radiation and in the use of LOCS scoring. Participants who were at a major risk for the development of lenticular opacities, such as those with diabetes mellitus, myopia, protracted corticosteroid use, radiotherapy treatments, ocular traumatism, congenital cataract, or otherwise diagnosed prior to the first exposure, were excluded from the study. The radiation dose to the crystalline lens was assessed using a calculation algorithm developed by an expert in medical physics. For traditional radiologist operators, the dose to the lens was considered to be equal to the total body dose. For interventional radiologists and surgeons, the dose to the lens was calculated as follows:

$$\mathrm{Di} = \mathrm{Do} \times \left(d_0^2 / d_1^2 \right)$$

where Dl is dose to the lens, Do is dose registered by the total body dosimeter − out of coat, d_1 is distance between patient and operator's lens (about 76 cm), d_0 is distance between patient and total body dosimeter (about 30 cm)

The patient-operator lens and patient-total body dosimeter distances were obtained by direct accurate measurements in the interventional room. The total body dose was registered using a thermoluminescent dosimeter, GR 200A LIF (Mg, Cu, P) model (Solid Dosimetric Detector and Method LAB DML-SAN).

The interventional radiology personnel did not wear protective goggles during the medical procedures they performed.

3 Results

Opacities were observed in 12 (16.4%) of the participants. The most important results are presented in Table 1.

The average (± SD) annual dose to the lens was 7.7 ± 38.2 mSv (range 0.3–190.6 mSv). The mean cumulative dose was 163.4 ± 415.3 mSv (range 0.3–2287.6 mSv); the median value was 12.20 mSv. The cumulative dose varied among the different work tasks: surgeons and occupational radiologists (mean 359.7 mSv; range 0.3–2257 mSv);

Table 1 Types of lens opacities in the study population

Clinical picture	Classification LOCS III	Number	Percentage (%)
Crystal clear	N0, C0, P0	61	83.5
Cortical opacity	N0, C1, P0	7	9.6
Nuclear opacity	N1, C0, P0	4	5.4
Rear subcapsular opacity	N0, C0, P1	1	1.5

Table 2 Distribution of lenticular opacities in the study population according to annual radiation dose, years of radiation exposure, and job description

	No. of persons	Lenticular opacity% (95% CI)
All	73	10.5
Years of exposure		
< 10	26	7.2 (2–22.6)
≥ 10	47	12.5 (5.8–24.7)
Cumulative dose (mSv × years)		
< 10	24	0.0
10–30	24	14.3 (4.9–34.6)
> 30	25	17.8 (7.8–35.6)
Job description		
Surgeons and radiologists (interventional)	14	28.6 (11.7–54.6)
Technicians	31	12.9 (5.1–38.8)
Nurses	10	10.0 (1.8–40.4)

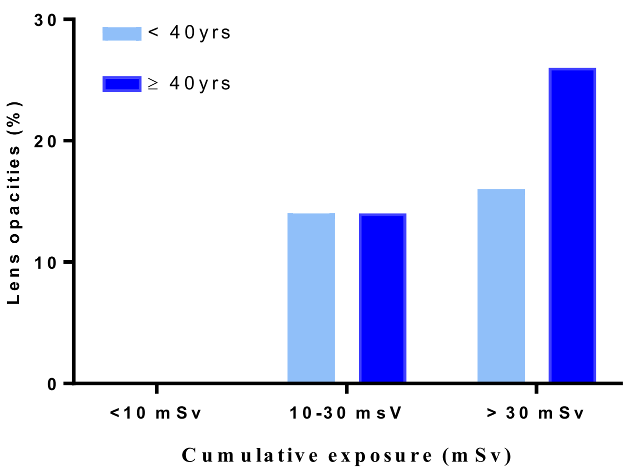

Fig. 1 Distribution of lenticular opacities in the study population by cumulative dose

technicians (mean 173.3 mSv; range 0.3–1392.0 mSv); nurses (mean 44.0 mSv; range 0.8–86.3 mSv), and students (mean 12.4 mSv; range 0.3–64.4 mSv).

The frequency of lenticular opacities was analyzed in relation to years of employment, cumulative lens dose (greater than 100 mSv), and occupation. The results are presented in Table 2.

Surgeons and physicians involved in interventional procedures were found to be at a higher risk of cataracts than other medical professionals (nurses, technicians).

All the cases of opacity detected in the study were classified as stage 1 (initial).

By correlating lenticular opacity and cumulative radiation dose to the crystalline lens, we observed no opacity for cumulative radiation doses below 10 mSv (Fig. 1). This analysis excludes the framework characterized by nuclear opacities, which are not correlated with occupational exposure to ionizing radiation [3].

4 Discussion

This study highlights an association between the presence of lenticular opacities and exposure to ionizing radiation exceeding the cumulative dose of 10 mSv.

The frequency of opacity among surgeons and physicians involved in interventional procedures appeared to be higher than that in other professionals investigated in our study. The results were in agreement with those of previous studies [15, 16], although the doses recorded in our sample were, on average, lower.

It should be noted that all lenticular opacities observed in our study population were classifiable as LOCS stage 1, and therefore did not lead to an actual damage to vision. The limited sample size, the heterogeneity in the study sample, and the relatively low age of the participants might be important limitations of our study, hence limiting the reliability of our results. Nevertheless, our results indicate a surprising effect at even low doses of radiation.

Furthermore, the use of a standardized investigation procedure and a specialist with experience in the scoring of ophthalmological images, as well as the availability of precise dosimetric data, are strengths of our study compared to previously published works [9, 15, 17]. It is interesting to note that, in our sample, no lenticular opacity was observed for radiation doses below 10 mSv and most of the operators were exposed to radiation doses lower than this. The lack of reliable data regarding the mechanism of development of radiation-induced damage to the crystalline lens, and the recent experimental evidence in favor of a stochastic mechanism open up new scenarios in terms of reduction in exposure doses [17, 18].

In previous studies, assuming a threshold dose of 200 mSv/year for the onset of cataracts, it was estimated that urologists, without using specific protection for the crystalline lens, could work for up to 50 years without any harmful effects on their crystalline lenses [12]. Our results indicate that this may not be true and lenticular opacities may develop with a shorter duration of radiation exposure even when the exposure does not exceed the annual professional exposure limit (20 mSv), as defined by Directive 59/2013 Euratom. Therefore, our study confirms the need to adopt a more prudent approach to reduce individual radiation doses and to promote exposure optimization policies, as well as favoring the use of dedicated eye protection screens.

5 Conclusions

In this study, we observed a greater frequency of lenticular opacities in participants exposed to a radiation dose higher than 10 mSv to the crystalline lens.

Surgeons and interventional radiologists appeared to be at a higher risk of development of lenticular opacities than other operators. Common urological procedures may result in radiation exposure exceeding this limit, and consequently, risk of the development of lenticular opacity. In light of our results, we reiterate the need for the use of specialized protective eye wear by professionals in the field of radiology. It is also essential that the medical examinations of these professionals include evaluation of the crystalline lens in drug-induced mydriasis, with an objective registration of the outcomes according to a standardized classification system.

Compliance with ethical standards

Conflict of interest Authors declares that they no conflict of interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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