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ARTICLE

Lens dose and risk of radiation-induced early lens opacities among hospital staff. A cross-sectional study

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Abstract – The main health effect of exposure to ionizing radiation on the eyes is lens opacities and cataracts. Recent findings have raised questions about the pathogenesis of lenticular damage and the exact threshold dose for the onset of this effect. Occupational dose limits for the lens have been therefore recently reduced to 0.02 Gy/year averaged over 5 years with no single year exceeding 0.05 Gy/year. Healthcare workers can be exposed to ionizing radiation during interventional and other medical procedures. The aim of our study was to evaluate the annual dose to the lens in a large group of healthcare workers exposed to ionizing radiation who are working in a university hospital in Rome and to evaluate a dose-response relationship between lens exposure and the onset of lenticular opacities. We reviewed the exposure data of 702 subjects; the average annual dose to the crystalline lens was calculated using a physical algorithm. Moreover, the clinical records of 107 radiation exposed workers were reviewed: the presence of radiation-compatible opacities were assessed for all operators according to the Lens Opacities Classification System (LOCS) III and Merriam-Focht classification. Annual doses exceeding 0.02 Gy were found in 2.1% of the exposed population. Incipient lenticular opacities were observed in 18.6% of the study population. The presence of alterations was associated with higher lens dose (>0.0092 Gy). Based on our results, optimization of procedures and protection of the lens from ionizing radiation by means of personal protection equipment are strongly recommended in higher exposure scenarios.

Keywords: lens opacities / ionizing radiation / occupational cataract / occupational exposure / interventional radiology / radiation protection

1 Introduction

Occupational exposure to ionizing radiations is a well-known risk factor for cataract and lens opacities but the exact mechanism is not clear. Based on studies in Japanese atomic-bomb survivors and in other exposed populations about the opacification of eye lens occurred following exposure, radiation induced cataract has been classified as tissue reactions (formerly called deterministic effect) (Nakashima *et al.*, 2006; Minamoto *et al.*, 2004). The pathogenetic mechanisms leading to this alteration have been explained and involve some direct changes in the lenticular cells (Ainsbury *et al.*, 2016; Hamada *et al.*, 2019). The specific tissue architecture of the lens makes this organ easily damaged by both acute and chronic exposure to ionizing radiations. Specific alterations in crystallin proteins and other contents in the lens may lead to variations in the ability to conduct optical radiation in the tissue resulting a possible visual impairment (Hamada *et al.*, 2014; Uwineza *et al.*, 2019). Tissue response to radiation is affected by many factors such as the type of radiation, the dose rate, the individual susceptibility (Ainsbury *et al.*, 2009). As discussed below, cataract has been classified as a deterministic effect, occurring at acute lens dose >2 Gy (ICRP, 1984). However, recent findings have reported the possibility of damage at lower doses raising questions about the deterministic nature of the effect and the absence of a threshold level (Blakely, 2012; Dauer *et al.*, 2016). Current radiobiological uncertainties regarding to the pathogenesis of the lenticular damage have showed the need for a revision of the actual knowledge on the radiosensitivity of the lens. Based on the available evidence, it is supposed that threshold dose for cataracts have been judged as 0.5 Gy independent of dose rate, although the presence of threshold dose remains uncertain. Based on the actual evidences, ICRP has changed the previous recommendations of a dose limit of 0.15 Gy/year for professional exposure and currently recommends the dose limit for the crystalline lens to be 0.02 Gy in 1 year, or 0.1 Gy in 5 years, with the value for a single year not exceeding 0.05 Gy. Recent studies (Little *et al.*, 2018) have documented an increased frequency of lens opacities among hospital workers performing vascular procedures that exposed them to doses of

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Table 1. Distribution of lens dose (mSv/year) by working area.

Department	Number	Mean value	Standard deviation	Minimum	Maximum
Anesthesiology	100	3.93	2.774	0	15
Cardiosurgery	7	3.45	0.710	3	5
Cardiology	60	4.42	0	27	3.647
Endoscopy	24	3.42	1.451	1	8
Radioimmunoassay	12	2.83	0.202	3	3
Neurosurgery	33	2.85	1.481	0	5
Nuclear medicine	29	16.47	15.170	2	61
Interventional radiology	27	7.67	6.842	0	27
Orthopedic	72	4.04	2.342	0	13
Traditional radiology	162	4.46	3.337	0	23
Radiotherapy	36	5.49	9.609	0	52
Surgery	125	3.38	1.104	0	7
Vascular surgery	15	3.11	3.279	0	14
Total	702	4.64	5.369	0	61

ionizing radiation below the occupational exposure limit established by the International Commission on Radiological Protection (ICRP) (Little *et al.*, 2018). Considering the individual workload, interventional radiologists can receive a dose exceeding of the current threshold for deterministic effects on the crystalline lens after several years of work in the absence of radiological protection devices. (Taylor *et al.*, 2013; Vano *et al.*, 2013; Elmaraezy *et al.*, 2017; Haga *et al.*, 2017). Nevertheless, routine evaluation of lens dose is not performed among exposed population, in fact the previous 0.15 Gy limit will unlikely be exceeded in the typical interventional scenario.

The aim of this retrospective cross-sectional study was to evaluate the lens dose in a group of health professionals (interventional radiologists, radiologists, radiological technologists, interventional cardiologists, surgeons) in a university polyclinic and to evaluate the prevalence of lenticular opacities among those subjects with respect to their lens dose.

2 Materials and methods

In order to assess lens dose, we reviewed the dosimetric records of a group of 702 healthcare workers (interventional radiologists, radiologists, radiological technologists, interventional cardiologists, surgeons) occupationally exposed to ionizing radiation during the year 2018.

The radiation dose to total body was directly assessed by using a thermoluminescence dosimeter while the crystalline lens dose was reconstructed using a calculation algorithm by an expert in medical physics.

All the 702 subjects received TLD measurements during the whole work task, and the annual doses have been evaluated for 15 years.

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 follow:

$$Dl = Do \times (d02/d12),$$

where:
- Dl = dose to the lens;
- Do = dose registered by the total body dosimeter−out of coat;
- $d1$ = distance between patient and operators lens (about 76 cm);
- $d0$ = distance between patient and total body dosimeter (about 30 cm).

For all subjects included in the study, we collected the area of employment.

Subsequently, we reviewed the clinical data of all workers who underwent the occupational periodical ophthalmological visit during the same year. All operators occupationally exposed to ionizing radiations are received an eye examination every 2 or 5 years (as a part of the annual occupational health screening) according to his radiation risk classification so during the year 2018, 107 workers were screened.

During the screening, they were examined using a slit lamp connected to an Epsilon Lyrae camera, with a backlighting technique and photographic relief in mydriasis by instillation of one drop of 0.5% tropicamide (Tropimil) in the conjunctival sac.

Lens opacities, if present, were classified according to both the LOCS III (Bencić *et al.*, 2005) and Merriam-Focht method (Merriam and Focht, 1957). According to LOCS III criteria, opacities were classified as nuclear, cortical, or posterior by comparing slit-lamp images with standard photographic slides and then further rated on a scale of 1 to 5 according to severity. The system guarantees a standardized classification of clinical pictures (Bencić *et al.*, 2005).

Merriam-Focht method (Merriam and Focht, 1957) is a grading system in which increasing numerical scores are assigned to opacities as they progress in severity (Tab. 1).

All the findings were analyzed by an ophthalmologist expert in the health surveillance of radiation exposed workers and in the use of both scoring systems.

Participants who were at a major risk of lenticular opacities for medical conditions, such as diabetes mellitus, myopia, ocular trauma, radiotherapy treatments, protracted corticosteroid use, congenital cataract, or who had received diagnosis of lens impairment prior to the first exposure, were excluded from the study.

3 Results

The mean annual dose to the lens was 0.046 Gy based on calculation from the whole body TLD dose (range: 0.25–61.50) with 15/702 (2.1%) exceeding the annual threshold limit of 0.02 Gy of the EURATOM directive 59/2013. All the subjects receiving an annual dose above 0.02 Gy worked in interventional radiology or nuclear medicine.

Interventional cardiology, hemodynamics and nuclear medicine were the setting with a higher lens dose level (Tab. 1).

Regarding clinical evaluation, the group included in the screening received a mean dose of 10.0 ± 10.7 mSv; opacities were observed in 20/107 (18.6%) of the participants. Using the LOCS classification, all the opacities detected in the study were classified as stage 1 (initial) and the localization was cortical (LOCS grade: N0, C1, P0) in 12/20 (60%) and posterior subcapsular (LOCS grade: N0, C0, P1) in 8/20 (40%).

According to Merriam-Focht grading system, all opacities were classified on the grade 0.5 (between score 0 "Lens without opacities" and score 1 "Lenses showing the beginning of opacities in the posterior pole").

Subsequently, we divided the subjects receiving lens examination in three group defined by the growing tertile of lens dose and compared the prevalence of opacities in each group. According to dosimetric values, 36 workers received less than 0.00426 Gy (first terile), 36 subjects were exposed to a dose between 0.0046 and 0.0092 Gy and 35 were exposed to a dose >0.0092 Gy in the year 2018.

In picture 1, is reported the prevalence of lens opacities by tertile of exposure. Alterations were present in 2/36 (5.5%), 6/36 (8.8%) and 12/35 (35.2%) of the first, second and third tertiles, respectively ($p < 0.05$ according to a Chi^2 test).

4 Discussion

This study clearly shows that a relevant percentage of HCWs can exceed the annual professional exposure limit (0.02 Gy) defined by directive 59/2013 EURATOM in the actual hospital framework. The dose among HCWs employed at nuclear medicine or involved in interventional procedures was higher than that in other professionals investigated in our study (12.27 mGy *versus* 3.98 mGy; $p < 0.05$ at ANOVA test).

Moreover, we found an association between the tertile of lens dose and the presence of lens opacities among exposed subjects (5.5% in first tertile, 8.8% in second tertile and 35.2% in third tertile; $p < 0.01$ at Chi^2 test): our findings are in agreement with previous studies (Ciraj-Bjelac *et al.*, 2012; Coppeta *et al.*, 2019; Jacob *et al.*, 2013), although the doses recorded in our population were, on average, lower: there was no difference in the types of cataracts (cortical or posterior subcapsular) among three dose categories.

We found that the risk of lens opacities is related to the annual lens dose and is significant above 0.0092 Gy. It should be noted, however, that all lens opacities found in our study population were classified as early stage opacities that do not impair vision.

Main limitation of the study was related to the lack of information regarding the use of visual eye protection device in the study population that could lead to overestimate the effective dose to the lens.

Regarding clinical data the study design (cross-sectional), the limited sample size, the lack of cumulative exposure data and the relatively low age of the participants are also important limitations of the study, limiting the reliability of our results. Despite this, in our opinion, our findings remain impressive, mainly in relation to the relatively low doses recorded in the study population.

The availability of dosimetry data and the use of two different grading systems to evaluate lenticular changes among medical workers appears to be the strength of our work compared to previously published studies, because of the use (Blakely, 2012; Ciraj-Bjelac *et al.*, 2012; Jacob *et al.*, 2013).

Our findings and the lack of reliable data regarding the pathogenesis of onset of radiation-induced lens opacities raise question about the exact stochastic mechanism of the damage (Hamada *et al.*, 2014), opening up new scenarios and confirms the need to have a prudent approach to reduce annual radiation doses and to promote exposure optimization procedures, also favoring the use of eye protection devices (Chauhan *et al.*, 2019).

The main limitation of this study is that the cumulative lens dose was not given. ICRP consider that the relationship between radiation exposure and the onset of minor lens opacities follows a linear model although vision-impairing cataract follows a threshold-type dose-response relationship (Zakeri *et al.*, 2017).

5 Conclusions

Our study shows that in the actual operating scenarios a significant number of HCWs performing interventional procedure can exceed the annual threshold dose to the lens established by EURATOM CE 59/2013 directive. Moreover, the frequency of lenticular opacities in the study population was statistically related to the annual lens dose.

In relation to the risk of developing lens opacities, we strongly suggest the use of personal protective eyewear in all subjects employed at interventional radiology. Medical examinations of these workers should include the use of standardized diagnostic evaluation system for lens opacities.

References

Ainsbury EA, *et al*. 2016. Ionizing radiation induced cataracts: recent biological and mechanistic developments and perspectives for future research. *Mutat. Res.* 770(Pt B): 238–261. https://doi.org/10.1016/j.mrrev.2016.07.010.

Ainsbury EA, *et al*. 2009. Radiation cataractogenesis: a review of recent studies. *Radiat. Res.* 172(1): 1–9. https://doi.org/10.1667/RR1688.1.

Benćić G, *et al*. 2005. Clinical importance of the lens opacities classification system III (LOCS III) in phacoemulsification. *Coll. Antropol.* 29(Suppl. 1): 91–94.

Blakely EA. 2012. Lauriston S. Taylor lecture on radiation protection and measurements: what makes particle radiation so effective?

Health Phys. 103(5): 508–528. https://doi.org/10.1097/HP.0b013e31826a5b85.

Chauhan V, *et al*. 2019. The use of *in vitro* transcriptional data to identify thresholds of effects in a human lens epithelial cell-line exposed to ionizing radiation. *Int. J. Radiat. Biol.* 95(2): 156–169. https://doi.org/10.1080/09553002.2019.1539883.

Ciraj-Bjelac O, *et al*. 2012. Radiation-induced eye lens changes and risk for cataract in interventional cardiology. *Cardiology* 123(3): 168–171. https://doi.org/10.1159/000342458.

Coppeta L, *et al*. 2019. Risk of radiation-induced lens opacities among surgeons and interventional medical staff. *Radiol. Phys. Technol.* 12 (1): 26–29. https://doi.org/10.1007/s12194-018-0487-9.

Dauer LT, *et al.* 2016. Status of NCRP Scientific Committee 1–23 commentary on guidance on radiation dose limits for the lens of the eye. *Health Phys.* 110(2): 182–184. https://doi.org/10.1097/HP.0000000000000412.

Elmaraezy A, *et al*. 2017. Risk of cataract among interventional cardiologists and catheterization lab staff: a systematic review and meta-analysis. *Catheter. Cardiovasc. Interv.* 90(1): 1–9. https://doi.org/10.1002/ccd.27114.

Haga Y, *et al*. 2017. Occupational eye dose in interventional cardiology procedures. *Sci. Rep.* 7(1): 569. https://doi.org/10.1038/s41598-017-00556-3.

Hamada N, *et al.* 2019. An update on effects of ionizing radiation exposure on the eye. *Br. J. Radiol.* 20190829. https://doi.org/10.1259/bjr.20190829.

Hamada N, *et al*. 2014. Emerging issues in radiogenic cataracts and cardiovascular disease. *J. Radiat. Res.* 55(5): 831–846. https://doi.org/10.1093/jrr/rru036.

ICRP. 1984. Nonstochastic effects of ionizing radiation. *Ann. ICRP* 14(3): 1–33.

Jacob S, *et al*. 2013. Interventional cardiologists and risk of radiation-induced cataract: results of a French multicenter observational study. *Int. J. Cardiol.* 167(5): 1843–1847. https://doi.org/10.1016/j.ijcard.2012.04.124.

Little MP, *et al*. 2018. Occupational radiation exposure and risk of cataract incidence in a cohort of US radiologic technologists. *Eur. J. Epidemiol.* 33(12): 1179–1191. https://doi.org/10.1007/s10654-018-0435-3.

Merriam GR Jr, Focht EE. 1957. A clinical study of radiation cataracts and the relationship to dose. *Am. J. Roentgenol. Radium Ther. Nucl. Med.* 77(5): 759–785.

Nakashima E, *et al*. 2006. A reanalysis of atomic-bomb cataract data, 2000–2002: a threshold analysis. *Health Phys.* 90(2): 154–160. https://doi.org/10.1097/01.hp.0000175442.03596.63.

Minamoto A, *et al*. 2004. Cataract in atomic bomb survivors. *Int. J. Radiat. Biol.* 80(5): 339–345. https://doi.org/10.1080/09553000410001680332.

Taylor ER, *et al*. 2013. Ocular radiation exposure in modern urological practice. *J. Urol.* 190(1): 139–143. https://doi.org/10.1016/j.juro.2013.01.081.

Vano E, *et al*. 2013. Radiation-associated lens opacities in catheterization personnel: results of a survey and direct assessments. *J. Vasc. Interv. Radiol.* 24(2): 197–204. https://doi.org/10.1016/j.jvir.2012.10.016.

Uwineza A, *et al*. 2019. Cataractogenic load – A concept to study the contribution of ionizing radiation to accelerated aging in the eye lens. *Mutat. Res.* 779: 68–81. https://doi.org/10.1016/j.mrrev.2019.02.004.

Zakeri F, Farshidpour MR, Rajabpour MR. 2017. Occupational radiation exposure and genetic polymorphisms in DNA repair genes. *Radioprotection* 52(4), 241–249.

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