

## Ionizing Radiation-Induced Cataract in Interventional Cardiology Staff

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**Background:** The use of ionizing radiation has led to advances in medical diagnosis and treatment.

**Objectives:** The purpose of this study was to determine the risk of radiation cataractogenesis in the interventionists and staff performing various procedures in different interventional laboratories.

**Patients and Methods:** This cohort study included 81 interventional cardiology staff. According to the working site, they were classified into 5 groups. The control group comprised 14 professional nurses who did not work in the interventional sites. Participants were assigned for lens assessment by two independent trained ophthalmologists blinded to the study.

**Results:** The electrophysiology laboratory staff received higher doses of ionizing radiation ( $17.2 \pm 11.9$  mSv;  $P < 0.001$ ). There was a significant positive correlation between the years of working experience and effective dose in the lens ( $P < 0.001$ ). In general, our findings showed that the incidence of lens opacity was 79% (95% CI, 69.9-88.1) in participants with exposure (the case group) and our findings showed that the incidence of lenses opacity was 7.1% (95% CI:2.3-22.6) with the relative risk (RR) of 11.06 ( $P < 0.001$ ).

**Conclusions:** We believe that the risk of radiation-induced cataract in cardiology interventionists and staff depends on their work site. As the radiation dose increases, the prevalence of posterior eye changes increases.

**Keywords:** Iran; Lens Opacity; Cardiology

### 1. Background

The use of ionizing radiation has led to advances in medical diagnosis and treatment (1). Interventional radiology (IR) is a branch of medicine which focuses on the diagnosis and healing pathologies of some human organs and tissues. Among these procedures, coronary interventions like coronary angiography and coronary angioplasty are the most frequently performed examinations (2, 3). These procedures are generally lengthy and require a large number of images; therefore, patients as well as the medical staff can be exposed to relatively high doses, which could increase the risk of radiation side effects (2, 4). Some of the potential dangers of radiation have become apparent in physicians and staff who overexposed to X-ray radiation (1). A large number of experiments involving animals have evaluated the biological effects of radiation on the human body.

It has been discovered that the severity of certain ef-

fects on human beings will increase with increasing the radiation dose. The severity of these effects depends on the dose, i.e. these undesirable effects will occur when the radiation dose is above the threshold (5, 6). The lens of the eye is recognized as one of the most radiosensitive tissues in the human body (5, 6). Cataract occurs as a result of the accumulation of damaged or dead cells within the lens, the removal of which cannot take place naturally. This occurs after receiving 2 to 10 Gy, but may take years to develop (5, 6). According to the new ICRP recommendations (7), the occupational dose limit for the lens of the eye has been decreased to 20 mSv/y, which shows the importance of considering the radiation dose received by the eye in different radiation practices, especially in interventional radiology.

In recent decades, some studies have been carried out to evaluate the risk of radiation-induced cataract, but there

are some unresolved questions about cataract developing factors under the effects of radiation. There is specifically very little epidemiological data regarding the risk of lens opacity and cataract in the field of interventional radiology. Interventional cardiology procedures are important in cardiac diagnosis and treatment. In these procedures, the interventionists are often unwillingly exposed to X-ray radiation. However, a few small studies have evaluated interventional cardiologists, suggesting an increased prevalence of cataracts in this particular occupation (8). No study has yet evaluated the correlation between lens opacity and radiation in Iranian population.

## 2. Objectives

The purpose of this study was to determine the risk of radiation cataractogenesis in interventionists and staff performing various procedures in different interventional laboratories.

## 3. Patients and Methods

In this historical cohort study, the exposure group comprised individuals with radiation exposure of at least 1 mSv for at least 4 years and the non-exposure group included individuals who had no exposure at all. This historical cohort study included 81 interventional cardiology staff (44 interventionists, and 37 technicians). According to the working site, they were classified into 5 groups: 42 in adult intervention laboratory, 13 in pediatric intervention laboratory, 18 in electrophysiology laboratory, 3 in adult and pediatric intervention laboratory, and 5 in adult and electrophysiology laboratory. The control group consisted of 14 professional nurses not working in the interventional sites with no history of ionizing radiation exposure to the head or neck. In this study, the exclusion criteria in all study groups (interventional physicians, staff, and control group) were having the history of diabetes, hypertension, any eye disease or lens surgery, and non-radiation cataract.

All participants were asked to complete a questionnaire containing demographic information and some information about their occupational and medical history. Written informed consent was obtained from all participants.

### 3.1. Ophthalmic Examination

Participants underwent lens assessment by two independent trained ophthalmologists who were blinded to the study. All participants had visual acuity tests to determine the uncorrected visual acuity. Refraction was first measured using the Topcon KR 8800 Autorefractor (Topcon Corporation, Tokyo, Japan), and the results were used to determine the objective refraction (using the Heine retinoscope) and subjective refraction of the participants. The data were used to determine the distance best corrected visual acuity. To determine lens opacity, slit lamp examination was performed in addition to pho-

tography. Slit lamp photography and lens photography were done using the Topcon photo slit lamp. Moreover, we used the Slit Lamp BM 900 (HAAG STREIT USA) for slit lamp biomicroscopy. An ophthalmologist conducted lens opacity grading with a slit lamp, and graded any nuclear, posterior subcapsular (PSC), and cortical opacity by making comparisons against standard photographs of the Lens Opacities Classification System III (LOCS III). For those with no contraindication, cyclopentolate and epinephrine were instilled twice at an interval of 5 minutes. In this report, slit lamp was used for grading cataract and lens opacity according to LOCS III.

Similar to some other studies, nuclear opalescence and nuclear color of LOCS III grade 4 or more in either eye were defined as nuclear cataract. Cortical cataract and PSC cataract were defined as a LOCS III score of two or more in either eye. Statistical analyses were performed with SPSS software (SPSS 18.0 for Windows, SPSS Inc., Chicago, Illinois). Data is expressed as mean  $\pm$  SD for continuous and as percentage for discrete variables. Independent samples t test or Mann-Whitney U test was used to compare continuous variables between groups. Chi-square was used for statistical analysis of categorical variables. Fisher exact test was used to compare categorical variables, as appropriate. Odds ratios, risk ratio, and 95% confidence intervals (CI) were calculated using Microsoft Excel 2010. P values less than 0.05 were considered statistically significant.

### 3.2. Dosimetry

All interventional cardiology physicians and staff had to wear a thermoluminescence dosimeter (TLD) badge. In addition, in order to detect the levels of scatter doses to the eyes and more accurate measurements, each participant used LiF TLD (consist of a TLD-100 chip and 3 mm tick PMMA stripe ahead of it) as a forehead band to simulate the overlying eye tissue during the procedures. To readout the dosimeters and evaluate the doses, TLDs were sent to a Secondary Standard Dosimetry Laboratory (SSDL) authorized dosimetry laboratory. According to the latest ICRP recommendation (ICRP103, 116, and 118) (NCRP) (7), we determined the equivalent dose received by organ or tissue utilizing the formula provided below:

$$HT, R = \sum DT, RWr$$

Where:

HT, R = equivalent dose by organ or tissue

$\sum DT, R$  = accumulated absorbed dose in different organs

Wr = radiation weighting factor

Since different organs in human body have different radiation sensitivity, it is necessary to determine specific organ radiation exposure. Meanwhile, in order to estimate the occupational exposure to the lens, we assessed the effective dose. The formula for calculating the effective dose is as follows:

$$E = \sum (HT, RWT)$$

Where:

HT, R = equivalent dose received by organ or tissue

WT = tissue weighting factor  
 Absorbed dose in organ or tissue is expressed in Sievert.

#### 4. Results

In this cohort study, we enrolled 105 cardiovascular interventional staff. However, 24 participants were excluded due to the history of diabetes, hypertension, eye diseases, or lens surgery, and non-radiation cataract. We chose professional nurses with no history of ionizing radiation exposure to the head or neck as the control group. Therefore, we finally studied 95 participants (44 interventional cardiologists, 37 technicians, and 14 controls; 44 males and 51 females). Demographic characteristics of the participants by local activity are presented in Table 1. As illustrated in Table 2, staff who worked in the electrophysiology laboratory received more ionizing radiation dose ( $17.2 \pm 11.9$  mSv,  $P < 0.001$ ). The staff of the pediatric and electrophysiology labs were candidates for performing more fluoroscopy-guided procedures ( $P = 0.609$ ). The non-parametric correlation test revealed a significant positive correlation between years of working experience and effective dose in the lens in all subjects ( $P < 0.001$ ). The mean effective dose to the lens of the eye was higher in interventional cardiologists ( $9.1 \pm 9.5$  mSv) in comparison with technicians ( $5.6 \pm 6.8$  mSv), although the difference was not significant ( $P = 0.383$ ). In cardiology interventionists, positive findings in posterior lens opacification were more than technicians (Table 3). Statis-

tical analyses showed that of 81 cardiology interventional staff and physicians, 59 (62.1%) had right eye opacity and 63 (66.3%) had left eye opacity, indicating that most of the participants working in cardiology interventional laboratories (regardless of their working site) had lens opacity either in the left or in right eye ( $P < 0.001$ ).

Figure 1 shows the percentage of lens opacity in the study population. Chi-square showed a significant difference in lens opacity between the study groups with ( $P < 0.001$ ) and without ( $P = 0.016$ ) considering the control group. In general, our findings showed that the incidence of lens opacity was 79% (95% CI, 69.9-88.1%) in participants with exposure (the case group) and 7.1% (95% CI, 2.3-22.6%) in participants without exposure (the control group). Risk analysis showed that the risk difference was 71.9% (95% CI 55.7-88.0%) between the two groups with an attributable risk of 91.0% (95% CI, 40.0-98.6%). Therefore, the relative risk of radiation exposure for lens opacity was calculated at 11.06% (95% CI 1.67-73.37%). This relationship was still observed in a multivariate model after adjusting for age and sex ( $P < 0.001$ ). All subjects with posterior lens changes (either left or right) had more years of working experience ( $10.9 \pm 9.2$  years;  $P = 0.109$ ) and higher numbers of weekly procedures ( $16.5 \pm 7.7$ ;  $P = 0.095$ ) compared with others. All 81 subjects used different protective devices during the procedures: 30.5% of the participants used lead glass, 26.3% used lead glass, apron, and thyroid shield at the same time, and 43.2% used a combination of apron and thyroid band.

**Table 1.** Demographic Characteristics of Participants by Work Location <sup>a</sup>

Work Location	Number	Age, y	Male	Female	BMI, Mass (kg)/Height (m <sup>2</sup> )
Adult intervention laboratory	44	42.9 ± 8.7	24	18	25 ± 2.9
Pediatric intervention laboratory	13	44.3 ± 10.7	11	2	24.5 ± 2.8
Electrophysiology laboratory	18	39.1 ± 8.2	9	9	24.6 ± 2.2
Adult and pediatric intervention laboratory	3	37.6 ± 3.2	1	2	24.6 ± 2.8
Adult and electrophysiology laboratory	5	38.4 ± 12.5	4	1	24.8 ± 3.6
Non-radiation wards (control)	14	41.8 ± 6.9	2	12	25.6 ± 3.7
<b>P value</b>		0.341	0.007	0.007	1.43

<sup>a</sup> Data are presented as Mean ± SD.

**Table 2.** Radiation Characteristics of Participants by Work Location <sup>a, b, c</sup>

Work Location	Radiation History, y	Number of Weekly Procedures	Procedures F, F + C	Lens Equivalent Dose, mSv
Adult intervention laboratory	10 ± 8.5	17.7 ± 9.2	2 (15.4); 11 (84.6)	4.8 ± 4.5
Pediatric intervention laboratory	10.6 ± 9.9	12.4 ± 1.1	0; 13 (100)	4.3 ± 4.5
Electrophysiology laboratory	9.8 ± 7.7	12.2 ± 3	2 (13.3); 13 (86.7)	17.2 ± 11.9
Adult and pediatric intervention laboratory	5.6 ± 2.3	21.6 ± 5.7	0; 2 (100)	4.3 ± 2.9
Adult and pediatric electrophysiology laboratory	10.6 ± 12	20.6 ± 6	0; 2 (100)	5.9 ± 6.6
<b>P-Value</b>	0.933	0.009	0.609	< 0.001

<sup>a</sup> Abbreviations: F, fluoroscopy guided; F + C, cine fluoroscopy guided.

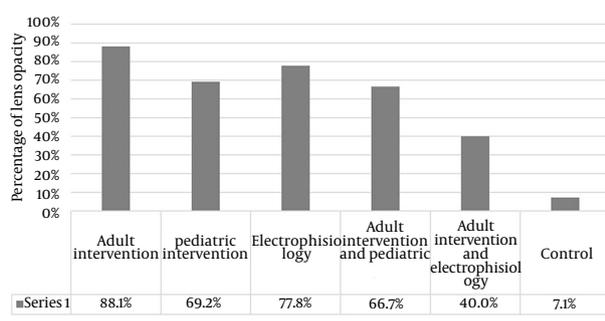
<sup>b</sup> Values are expressed as Mean ± SD or No. (%).

<sup>c</sup> The P value was calculated by ANOVA.

**Table 3.** Posterior Lens Changes of Participants by Type of Activity<sup>a</sup>

Subjects	Positive Right eye Opacity n = 32 (37.9)	Positive Left Eye Opacity n = 59 (62.1)
Interventionists	31 (52.5)	32 (50.8)
Technician	28 (47.5)	31 (49.2)
P-Value	< 0.001	< 0.001

<sup>a</sup> Values are expressed as No. (%).

**Figure 1.** The Percentage of Lens Opacity Between Intervention and Control Groups

## 5. Discussion

There is a great concern about the potential adverse effects of occupational radiation exposure among physicians performing diagnostic radiation procedures. Electrophysiologists and their assisting staff in an electrophysiology room are exposed to high radiation. In our study, the staff were more likely to be exposed to ionizing radiation and were more likely to perform cinefluoroscopy guided procedures. Theocharopoulos et al. (9) reported that the eye lens dose in the electrophysiology laboratory staff depended on the side of the patient the staff was working on. By analogy to the effective dose, eye lens showed peak values of 389  $\mu$ Sv per procedure at the left side of the patient. Although the electrophysiology room staff had the least years of working experience and minimum weekly procedures, they exhibited the highest lens effective dose.

A report of the American Association of Physicists in Medicine (10) revealed that cine fluoroscopy caused a higher risk subsequent ocular exposure to the operator than any other specialty area. One of the main problems concerns the dose of the radiation that would produce opacity (11). According to our statistical analysis, cardiac interventionists were more likely to reveal positive findings of posterior lens opacification in comparison to technicians. In dosimeter readings, the mean ocular dose was higher in interventional cardiologists. On the one hand, the mean years of working experience was higher in them. On the other hand, they were more exposed to radiation because of performing cine-fluoroscopy procedures. Ciraj-Bjelac et al. (12) reported that among

interventional cardiologists, dose-related radiation-associated posterior lens changes were present in 51% of all subjects (interventionists and nurses). It is possibly due to the different physical position of the technicians with respect to the patients and also their various work and physical locations during procedures in interventional laboratories. Although the lenses of the electrophysiology laboratory staff were more likely to be exposed to ionizing radiation since they were more likely to perform cine-fluoroscopy, the prevalence of posterior lens changes was significantly higher in adult cardiology interventional laboratory staff. It is possibly due to the length of the procedures that is longer during adult catheterization. Another possible reason is the room size; the electrophysiology room is much smaller and scatter from the walls could affect the staff involving in interventional procedures. Meanwhile, the dosimetric estimation for pediatric interventionists was the least, despite performing cine-fluoroscopic procedures and the fact that they need to stay closer to the patient compare to adult catheterization. It is possibly related to a good radiation protection.

Our findings are in line with the results of Ciraj-Bjelac et al. study (12). Their findings demonstrated a statistically significant increase in the associated posterior lens opacification. The advantages of our study were that we determined the prevalence of opacity development in the participants on left and right eye and by their working site since the participants performed different procedures and therefore were exposed to different radiation doses. Klein et al. reported that subjects with diagnostic X-ray exposure had higher incidence of posterior sub-scaphular cataracts (13). Experimental studies have confirmed the clinical observations. Merriam and Focht (11) demonstrated that when the rats were exposed to single and fractionated doses of 5, 10, 15, and 20 Gy of 200 kVp X-rays, the resulting opacities were graded 0 to +4, the latter representing a completely opaque lens.

Lens opacification is associated with damage to the lens cell membrane. Another possible mechanism is damage to the lens cell DNA, decreasing the production of protective enzymes, disturbance in sulfur-sulfur bond formation and altering intracellular protein concentrations (14). There are multiple variables like the distance between practitioner and patient, height, weight, and age of the practitioner that can influence the amount of lens exposure (15, 16). We calculated Body Mass Index (BMI) in our participants. In the adult cardiology intervention staff, the mean BMI was insignificantly more than the controls and even more than other participants exposed to radiation. It is documented that increasing the dose of ionizing radiation increases the risk of lens opacification, which appears after a decreasing latency period (14). We observed a positive dose response for the development of opacity. According to NCRP and international council on radiation protection (ICRP), radiation cataract is deterministic and only occurs when a high-dose threshold is exceeded (17). However, sev-

eral studies have shown that radiation-associated opacities occur at much lower (non-threshold) doses (15, 18). Recent findings have demonstrated dose-related significant lens opacification in rats after exposure to as little as 100 mGy (19). Shore et al. noted that medical or environmental radiation exposure to the lens confers the risk of opacity at doses well under 1 Sv (18).

The results indicated that all participants with posterior lens changes in left or right eye had more years of working experience and higher numbers of weekly procedures. It means that interventional cardiologists and staff working in intervention sites are in situations where radiation doses are high enough to cause lens opacity after a few years if protection is not used. Although the amount of reduction in the cataract risk with the use of protective eyewear is not clear (15), it is established that interventional cardiology personnel may be at risk for cataract without use of ocular radiation protection (12). Use of scatter-shielding drapes or leaded glasses decreases the operator lens dose by a factor of 5 to 25, but the use of both barriers together (or use of leaded shields) provides maximal protection to the interventional radiologist's eye (20). In our study, only 30.5% of the participants reported the use of lead glass during procedures. It means that interventional cardiology staff and physicians should use appropriate eye protection. According to Cousin et al. (21), if the interventionist's eyewear does not have protected side shields, the eyes could receive a significant portion of the scatter radiation. One of the important limitations of this study was its small and unmatched control group. We suggest that larger studies be performed in an Iranian population to evaluate the findings of this study. However, power analysis showed that the power of the study regarding the relationship between lens opacity and history of radiation exposure was acceptable.

In conclusion, we believe that the risk of radiation induced cataract in cardiology interventionists and staff depends on their work site. Although the prevalence of lens opacity was higher in both the interventionist and technicians compared to the control group, it was more observed in the interventionist. The prevalence of posterior eye changes increased with the increase in the radiation dose. We believe that good eye protection in the cardiology catheterization laboratory is associated with less occupational eye injury. It is necessary to put more emphasis on observing the principals of radiation protection to reduce the risk of radiation injury to the staff.

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## Authors' Contributions

Dr Ahmad Bitarafan-Rajabi: conducting the project, collecting the data, and imaging; Dr Fereydon Noohi: con-

ducting the project; Dr Hassan Hashemi: project leader; Dr Majid Haghjoo: assisting in preparing the manuscript; Dr Mohammad MirafTAB: managing the patients; Dr Nahid Yaghoobi: data collecting; Dr Fereydon Rastgou: managing the patients; Dr Hadi Malek: data collection; Dr Hoshang Faghihi: managing the patients; Dr Hassan Firouzabadi, Dr Soheila Asgari: managing the patients; Dr Farhad Rezvan, Dr Hamidreza Khosravi : analysis the data; Dr Mehdi Khabazkhoob: data collection.

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