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Original Research Article

Occupational Radiation Exposure and Cataractogenesis–A Hospital-Based Case Control Study in Eastern India

Shrutakirty Parida[1], Snehalata Dash[2], Sangram Keshari Biswal[3]

[1]M.S, Fellow in Pediatric, Squint and Neuro-ophthalmology (LVPEI), Senior Resident, Dept. of Ophthalmology, KIMS, Bhubaneswar

[2]DNB, Assistant Professor, Dept. of Ophthalmology, KIMS, Bhubaneswar

[3]M.D, Senior Consultant Radiology, Spandan Diagnostic Centre, Bhubaneswar

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Corresponding Author: Dr. Shrutakirty Parida

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Abstract:

Introduction: Ocular ionizing radiation exposure produces characteristic dose related, progressive lens changes leading to cataract genesis. Exponential growth in the use of ionizing radiation for diagnosis, treatment and procedure guidance has enhanced our growing concern regarding occupational radiation exposure. Crystalline lens being one of the most radiosensitive tissues is highly vulnerable to this occupational radiation induced adverse effects.

Objectives: This study aims to determine the incidence and type of cataract found in occupationally exposed medical personnel to ionizing radiation and to find out role of protective eye shields in exposed group by comparing it with unexposed age, sex matched controls (medical personnel).

Methods: This was a hospital-based case-control study. All selected participants completed a questionnaire regarding detail occupational history. Complete ophthalmological evaluation was done. Lens opacity grading was done with slit- lamp biomoicroscopy (Haag streit) and as per the Lens Opacities Classification System III. Dilated fundus examination was done in all patients. Patients with very hazy media and no or minimal fundus view B-scan was done.

Results: Incidence of cataract was 24.8% in case group whereas it was 10% in the control group (p-value <0.0001). There was a male preponderance (Male: Female=1.48:1), with an earlier onset of cataract in case (40 - 50 years) versus control (50 - 60 years) group. The most common type of cataract in radiation exposed group was posterior subcapsular cataract (19%) as compared to nuclear cataract (6.3%) in the unexposed group. Effectiveness of protective eye wears on incidence of cataract was well evidenced with a relative risk (R.R) of 0.387.

Conclusion: Radiation induced cataractogenesis occurs at lower doses than expected. Frequent failure of use of protective eye wears explains the crucial need for radiation monitoring and risk assessment for medical staff. Long-term follow-up studies are needed to analyse the risk of cataract formation over extended time periods following exposure to low-dose ionizing radiation.

Key words: Posterior subcapsular cataract, Ionizing radiation, Crystalline lens.

Introduction

Crystalline lens is one of the most radiosensitive tissues. [1] Ocular ionizing radiation exposure produces characteristic dose related, progressive lens changes leading to cataractogenesis. [2] Cataractogenesis associated with ionizing radiation is well known from experimental studies and has been demonstrated in humans by studies among survivors of the Hiroshima and Nagasaki atomic bombs. [3, 4] Use of ionizing radiation has led to advances in medical diagnosis and treatment. Exponential growth in the use of fluoroscopy for diagnosis and procedure guidance has enhanced our growing concern regarding occupational radiation exposure among medical personnel. [5] Coronary interventions like coronary angiography, coronary angioplasty and cardiac catheterisation are the most common fluoroscopy guided procedures performedby the interventional cardiologists which makes them most highly exposed of all medical personnel because of their exposure to scattered X-rays. [6,7] Failure to use protective eye wears is the major contributory factor for radiation induced cataract formation.

Over the past four decades, the International Commission on Radiological Protection (ICRP) has classified radiation effects into tissue reactions (previouslycalled non-stochastic or deterministic effects) and stochastic effects. [8] Tissue reactions result from injury to populations of cells, and are characterized by a threshold below which no effect would occur. [9] Typical examples are cataracts and

non-cancer skin changes, the severity of which increases with dose. [10,11] Deterministic effects occur with a dose threshold depending on the rate of dose delivery (acute, fractionated/protracted, or chronic). [12,13] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation)2008 Report considers radiation induced cataractogenesisas a stochastic effect (non-threshold effect). [13] The latest revision took place in 2012 when the ICRP Seoul Statement on tissue reactions lowered the chronic threshold for VIC (Vision Impairing Cataract) from >8 Gray to 0.5 Gray and the occupational equivalent dose limit for the lens from 150 mSv/year to 20 mSv/year (100 mSv in defined 5 years with no single year exceeding 50 mSv). [14,15]

Ionizing radiation is associated with posterior subcapsular and sometimes cortical lens opacities. [15] The damage begins at the anterior surface, where dividing cells normally form a clear crystalline protein fibre that migrates towards posterior pole of the lens in posterior subcapsular region. [16] This differentiation is altered by exposure to ionizing radiations. [16,17] The fibre cells elongate and align with each other prematurely causing loss of lens fibres` transparency. On a molecular level, the cyclin-dependent kinase inhibitor (CDKN1A) gene, that regulates the cell cycles and DNA synthesis are vulnerable to radiation crystalline (lens proteins). [17,18] Ionizing radiation causes double strand breaks (DSBs) in DNA. Damage to central zone and dividing cells of lens epithelium and impaired DNA damage repair mechanisms in addition to dysregulation of lens cell morphology contribute to the pathogenetic process. [19, 20]

In view of public health importance, this study has been done to provide information on the magnitude and pattern of occupational radiation exposure cataractogenesis, at a tertiary care hospital in Eastern India and to serve as the basis for designing and implementing preventive measures thereof. As the fluoroscopy guided procedures are peaking day by day, it is essential to have a detail study on the incidence, clinical aspects and etiopathogenesis of this entity so that early diagnosis and timely management can be sought at the earliest and visual prognosis can be improved. The present study is just a small paving stone that will encompass the above objectives and will throw some light onto the importance of using protective eye shields, which can go a long way in preventing cataractogenesis in this subset of medical personels, exposed to ionising radiations.

Aims and Objectives: This study aims to determine the incidence and type of cataract found in occupationally exposed medical personnel to ionizing radiation and to find out role of protective eye shields in exposed group by comparing it with unexposed age, sex matched controls (medical personnel).

Materials and Methods:

Place of the Study: The present study was conducted in the in Regional Institute of Ophthalmology (RIO), eastern India.

Study Design: This was a hospital-based case - control study. Total 223 subjects were selected for the study, out of which 155 were included in the study based on inclusion and exclusion criteria. This includes 78 cases and 77 controls.

Inclusion Criteria: Medical personnel age 20-60 years having duration of occupational exposure with dose monitoring > 5years and cumulative recorded radiation dose >10msv/year) were included in the study. Cases included interventional cardiologists, interventional cardiology staff, radiologists, orthopaedicians, electrophysiology lab technicians and nurses, while the controls included the same number of unexposed medical personnel of the same age and sex cohort.

Exclusion Criteria: Those with history of any cataractor prior cataract surgery, ocular trauma, radiation therapy for any head and neck malignancy, any ocular disease, congenital or developmental cataract, metabolic diseases that may produce cataract or prolonged use of systemic and topical steroids were excluded.

Procedure: All the selected participants completed a questionnaire regarding detail occupational history after giving written informed consent. The questionnaire enquired about start and duration of radiation exposure, dose per exposure, average number of weekly procedures, cumulative radiation dose exposure, history of associated risk factors for cataract development, including smoking, use of steroids, diabetes mellitus, and alcohol consumption.

The recorded doses were based on film dosimeter worn outside the lead apron. No separate dose estimates were done for ocular structures, including lens. The participants were enquired about regular use of protective eye shields. A complete ophthalmological evaluation was done including best corrected visual acuity (BCVA), intraocular pressure measurement (IOP), anterior segment evaluation with slit-lamp, and lacrimal punctal irrigation. Lens opacity grading was done with slit lamp biomoicroscopy (Haag streit), and graded as nuclear, posterior subcapsular (PSC), and cortical opacity by the Lens Opacities Classification System III. Dilated fundus examination was done in all patients. Biometry was done to calculate (intraocular lens) IOL Power in patients planned for cataract surgery. In all patients with very hazy media and no or minimal fundus view, an ultrasonographic examination (B-scan) was done.

Statistical Analysis: Statistical analyses were performed with SPSS software. P values less than 0.05 were considered statistically significant. Data is expressed as mean +/- SD for continuous and as percentage for discrete variables. Chi-square test was used for statistical analysis of categorical variables. Risk ratio (relative risk) was calculated.

Results

Total 223 subjects were selected for the study, out of which 155 were included in the study based on inclusion and exclusion criteria. This includes 78 cases and 77 controls. Incidence of cataract was 24.8% in test group whereas it was 10% in the control group (p-value < 0.0001). There was an overall as well as group wise male preponderance (Male: Female=1.48:1) noted in the cases group.We observed an earlier onset of cataract in case (40 - 50 years) versus control (50 - 60 years) group. Most common age group affected in the cases group was that of 40-50 years, in which a total of 49 eyes(10.9%) developed cataract in, while, most common age group affected in the control group was the 50-60 years age group, in which a total of 27 eyes(8.7%) developed cataract (Table-1).

Table 1: Demographic Data in Case vs. Control Group

Age group	No of eyes with cataract in males (case group)	No of eyes with cataract in females (case group)	Total no of eyes with cataract (case group)	No of eyes with cataract in males (control group)	No of eyes with cataract in females (control group)	Total no eyes with cataract (control group)
30-40	6	4	10 (3.2%)	0	0	0
40-50	29	20	49 (10.9%)	3	1	4 (1.3%)
50-60	11	7	18 (5.8%)	15	12	27(8.7%)
Total	46(14.8%)	31(10%)	77 (24.8%)	18	13	31(10%)

Interventional cardiologists followed by nurses, other staff working in the department of interventional cardiology and radiologists were the three most common occupations affected with cataract caused by exposure to ionizing radiations. Interventional cardiologists had an earlier onset of cataractogenesis (mean age of onset was 45 ± 3 years), whereas nurses had the later age of onset (mean age of onset was 52 ± 5 years) of cataractogenesis (Table-2).

Table 2: Occupational Variability of Cataract among Study Subjects

Occupation	Mean age of onset of cataract (years)	Number of eyes with cataract (males)	Number of eyes with cataract (females)
Interventional cardiologist	45±3	17	02
Interventional cardiology staff	48 ±5	10	01
Nurse	52±5	00	09
Radiologist	47± 4	07	00
Orthopaedician	51± 5	05	00
Electrophysiolgy lab technician	48± 2	03	01

Interventional cardiologists had the highest radiation exposure (in terms of number of years of exposure, average number of weekly procedures, average number of fluoroscopy guided procedures per week and lens equivalent dose in millisieverts), followed by the radiologists and the other staff of the department of interventional cardiology (Table-3).

Table 3: Radiation characteristics among case group

Occupation	Radiation exposure (in years)	Average no of weekly procedures	Average no of fluoroscopy guided procedure/week	Lens equivalent dose(in Msv)
Interventional Cardiologist	11±4.5	7±3	5±2	13±8.5
Interventional Cardiology Staff	9±2.5	5±2	2±1	8.6±4.8
Nurse	8±2.7	3±1	2±1	4.5±2.7
Radiologist	11±2.5	7±2	3±2	8±5.5
Orthopaedician	9±2.5	3±2	2±1	5.4±2.2
Electrophysiology Lab Technician	9±3.2	5±3	3±2	9±5.4

The most common type of cataract in radiation exposed group was posterior subcapsular (19%), followed by cortical (5.2%) as compared to nuclear (6.3%) in the unexposed group 9 (Table-4). As per the LOCS classification of cataract, 77 eyes of test group in different occupations showed varied cataract morphology (Table - 5). Nuclear opacities were seen in only 2 eyes (1 nurse and 1 electrophysiology laboratory technician) . Posterior subcapsular cataract was seen 30 eyes among case group which includes doctors and staffs of interventional cardiology, followed by 9 eyes in nurses, 8 eyes in radiologists, 7 eyes in electrophysiology laboratory technicians and 5 eyes in orthopaedicians. Cortical opacities were seen in 16 eyes -3 eyes from interventional cardiologist, 4 eyes from interventional cardiology staff, 3 eyes from nurses, 3 eyes from radiologists, and 2 from electrophysiology laboratory technicians and one from orthopaedician.

Table 4: LOCS grading of cataract in case vs. control

LOCS cataract type	No of eyes (case group)	No of eyes (control group)
Nuclear	2 (0.64%)	19 (6.3%)
Cortical	16 (5.16%)	10 (3.2%)
Posterior Subcapsular	53 (19%)	3 (0.97%)
Total	77 (24.8%)	31 (10%)

Table 5: LOCS classification of cataract in 77 eyes of case group subjects in different occupations

Occupation	Nuclear cataract (no of eyes)	Cortical cataract (no of eyes)	Posterior subcapsular cataract (no of eyes)
Interventional cardiologists	0	3	19
Interventional cardiology staff	0	4	11
Nurse	1	3	9
Radiologist	0	3	8
Orthopaedician	0	1	5
Electrophysiology lab Technician	1	2	7
Total	2(0.64%)	16 (5.2%)	59 (19%)

Out of 155 subjects in our study, 85 persons (170 eyes) gave a history of regular use of protective eye wears for the entire working period. 29 of the 170 eyes (0.17%) of these 85 subjects developed cataract whereas 31 subjects with irregular use of protective eye wears, of which12 eyes (3.9%) developed cataract. Rest 39 subjects did not use protective eye shields, of which 63 eyes (20.3%) developed cataract. Relative risk calculated was 0.387, which was suggestive of a protective effect of the eye shields on cataractogenesis.

Discussion

Cataracts refer to the opacification of the crystalline lens, which alters their transparency by changing their refractive indices, leading to varying degrees of visual impairments. Causes of cataract can be multifactorial. Radiation-induced cataracts havebeen initially proposed to take place only following an exposure to high-dose of radiation. [20] However, various studies have demonstrated a higher risk of cataracts even with low-dose radiation exposure. [19]

In the present study incidence of cataract among case group more than double that of control group with male preponderance. Male doctors, staffs and medical personnel are more exposed to radiation fluoroscopy guided procedures which could be the possible reason behind male preponderance. Earlier onset of cataract in case group was observed as compared to control group. More prevalence and earlier onset of cataract in case group suggests the risk of cataract following radiation exposure.

Interventional cardiologists had an earlier onset of cataractogenesis whereas nurses had the later age of onset of cataractogenesis. Interventional cardiologists had the highest radiation exposure which could be the possible explanation for these findings. Our study is in accordance with French Society of Cardiology O'CLOC study (Occupational Cataracts and Lens Opacities in Interventional Cardiology) which shows increased risk of cataracts among exposed interventional cardiologists compared with a control group. [12] Posterior subcapsular cataract, typical of ionizing radiation exposure were found in 91.5% of interventional cardiologists, 77% of technicians and 100% of nurses, according to the Merriam–Focht scale in the RELID (Retrospective Evaluation of Lens Injuries and Dose) study. The estimated retrospective cumulative lens dose was estimated to be 6.42 ± 8.42 Gray for the cardiologists with lens opacities and 3.17 ± 7.32 Gray for those without any lens opacities. [21]

In the present study posterior subcapsular cataracts are the most commonly reported lens opacities in the radiation exposure group. A Study by Junk A.et al showed higher frequency of posterior subcapsular cataracts in 22 (37.3%) out of 59 participants. [22] O'CLOC study conducted by Jacob et al

investigated the risk of cataract in French interventional cardiologists and electrophysiologists and found that a mean exposure of 423 mSv was found for a mean working time of 22 years, with an OR of 3.8 (95% confidence interval, 1.3–11.4) for the development of PSC in exposed medical personnel compared with non-exposed controls. [12] A pilot study conducted on interventional radiologists reported the prevalence and severity of posterior subcapsular cataract to be associated with age and years of practice. The annual eye lens dose ranged from 0.45 to 0.90 sieverts in their study. [22] Beaver DamEye Study showed that exposure to CT scans is significantly associated with PSC. [23]

Multiple factors can also influence the amount of lens exposure, like the distance of the practitioner from the patient, height of the practitioner, patient size and weight, age, as well as the use of collimation techniques (by altering the amount of scatter radiation emanating from the patient). [24]

Incidence of cataract among regular user of protective eye wear was least; however the incidence increased among irregular user of protective eye wear in present study. Incidence of cataract was very high among subjects those did not use protective eye shields which shows importance of protective eye shields. Effectiveness of protective eye wears on incidence of cataract was well evidenced with a relative risk (R.R) of 0.387. Higher radiation doses have a greater cataract incidence, but the shape of the dose response curve, especially at low doses is not clear from the available data. Long term follow up studies with large sample size are needed to analyse the risk of cataractogenesis over extended time periods following low-dose ionizing radiation.

Conclusion

Radiation induced cataractogenesis occurs at lower doses than expected. Several epidemiological studies strongly suggest a non-threshold effect. It has an earlier onset than senile cataracts. Frequent failure of use of protective leaded eye wear explains the crucial need for radiation monitoring and risk assessment for medical staff. This study will provide some evidence about the risk of radiation-induced cataract and will help to improve the awareness among medical personnel about the importance of radiation protection.

The present study also highlights the importance of proper implementation and strengthening of the training programs for all the medical staff, so as to focus on the need to use the protective elements and raise awareness about the risks of working with ionizing radiation, as recommended by the ICRP and the European Commission. Long-term follow-up studies are needed to analyse the risk of cataract formation over extended time periods following low-dose ionizing radiation.

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