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Occupational eye lens dose among nuclear medicine workers in a tertiary hospital in Saudi Arabia

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Abstract – Background: Exposure to ionizing radiation remains a major concern in nuclear medicine, especially given the possible health risks posed to medical personnel. Additionally, since the occupational eye dose limit was lowered in 2011 to an equivalent dose of 20 mSv/yr, new implications have extended to roles within nuclear medicine units. The goal of this investigation was to determine the current occupational radiation eye doses for nuclear medicine employees. Methods: A 5 yr retrospective assessment was performed on staff members involved in all nuclear medicine imaging from different categories. Optically Stimulated Luminescence (OSL) badges were used to measure occupational dose. The H-lens values were calculated for each staff member during this period. Results: Significant differences were observed between individual staff members in terms of H-lens values. They were significantly higher among hot lab technicians than among NIC ($p < 0.001$) and NM ($p < 0.0001$) technicians. Conclusions: Although none of the participants exceeded the eye dose limit for ionizing radiation exposure, there was significant variation in exposure across various roles and expertise. The annual average eye dose ranged from 0.2 mSv to 2.9 mSv, which is within the advised dose limit.

Keywords: eye lens dose / nuclear medicine / radiation protection / occupational doses

1 Introduction

The field of nuclear medicine, an integral aspect of modern healthcare, has witnessed an unprecedented surge in recent years. While this growth has brought remarkable diagnostic and therapeutic benefits to patients, it also poses potential risks owing to prolonged exposure to ionizing radiation, particularly in sensitive areas, such as the eyes (Bernier, 2018).

The International Commission on Radiological Protection (ICRP) acknowledged these risks, changed the threshold to the eye lens to 0.5 Gy, and revised its guidelines in 2011, lowering the occupational eye dose limit to an equivalent dose of 20 mSv/yr averaged over defined 5 yr periods, with no single year exceeding 50 mSv (ICRP, 2012). This significant reduction from the previous standard of 150 mSv/yr has implications extending to the broader nuclear industry. This impacts the daily workload of the staff involved in radiation-emitting devices and procedures, including nurses, surgeons, medical technologists, radiologists, and other personnel.

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These updated guidelines highlight the importance of assessing and minimizing occupational eye dose exposure, establishing rigorous eye protection protocols, and improving eye lens estimation methods for effective compliance (ICRP, 2012). The need for improved methods is underscored by the lack of robust mathematical models and phantoms dedicated to this field.

The precise occupational eye dose experienced by nuclear staff remains largely undefined despite growing concerns over occupational exposure. Research on the deterministic effects of radiation has shown that radiation exposure can lead to lens opacity, even at doses as low as 0.2 Gy (Covens, 2007). However, the stochastic effects of radiation exposure on the eyes remain unknown.

According to a study conducted in Colorado, technicians' occupational exposure from handling radioactive materials accounted for 60% of their yearly dose and with patient interactions accounting for 40% (Seierstad, 2007). Wearing personal protective equipment (PPE) is essential but was not enough due to large energy of annihilation radiation. They concluded that it is possible to maintain moderate doses for technicians by rotating the personnel and duties (Seierstad, 2007).

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Numerous epidemiological studies from Hiroshima, Nagasaki, and Chernobyl child survivors have shown that low-dose radiation exposure and induced cataracts are correlated, and that posterior subscapular cataracts are more common in those who have had x-ray exposure from diagnostic imaging modalities (Fish, 2011).

These have all highlighted the need for better measurement and more accurate personal dosimeters specific for the eye lens. A 3 mm depth has been recommended by the ICRP for measuring the dosage to the eye lens, Hp(3), but generally personal dosimetry to monitor skin doses Hp(0.07), the personal dose equivalent at a depth of 0.07 mm, is also used for this purpose. A dosemeter specifically designed for measuring HP(3) has been created by the Optimizations of Radiation Protection for Medical Staff Project (Bilski, 2011). These were used at Mount Vernon Hospital and compared to the regular Hp (0.7) (Summers, 2012). They have also compared their exposure and workload from a survey conducted in 2002 to 2011. Staff wore separate pairs of TLDs on their foreheads when distributing, releasing, injecting, and giving I-131 capsules to patients. They reported eye lens doses from 0.18 to 4.51 mSv but also anticipated that the average annual occupational exposure to the eyes of staff members will continue to increase to levels higher than 6 mSv (Summers, 2012).

In a nationwide study conducted in the United States, a group of radiology technicians assessed radiation-induced cataracts. More than 42,000 technicians were included in this study, and an elevated risk of cataracts was discovered. Compared with technicians who did not perform any nuclear medicine procedures, higher risks were observed in those who performed both diagnostic and therapeutic nuclear medicine scans (Bernier, 2018).

Our study aimed to determine the current occupational radiation doses to the eyes of nuclear medicine staff. We used personal dose-equivalent Hp3 values from the annual Optically Stimulated Luminescence (OSL) dose reports spanning 2014 to 2022. We also aimed to identify the staff categories subjected to high estimated eye doses. Additionally, we experimentally evaluated the effectiveness of the current protective measures in safeguarding the eyes of nuclear medicine staff.

2 Methods

King Abdulaziz University Hospital (KAUH) in Jeddah, Saudi Arabia, utilizes optically stimulated luminescent (OSL) badges with aluminum oxide chips for long-term radiation tracking. The OSL is a technology which now finds medical dosimetry applications in radiation dose measurement. The type of OSL dosemeter used is the 'nanodot' that consists of a small disk (4 mm in diameter and ~ 0.3 mm thick) covered, when closed, in a 10 × 10 × 2 mm light-tight plastic casing meant to prevent light exposure of the sensitive element. This format is suitable to measure point doses with high spatial resolution. The screened nanodots have individual sensitivity factors provided by the manufacturer with 2% of uncertainty. To check the sensitivity factor, a sample of 20 nanodots with 1.76 mGy from an 81 kV p 3.37-mm Al of HVL X-ray beam were irradiated. The readings corrected by sensitivity were then compared. Readouts of OSLDs were performed with a MicroStar reader (Landauer, Inc.) using a laser diode working in the continuous wave mode (CW). With the CW mode, stimulating laser beam and fluorescent emission coexist and OSL fluorescence has then to be discriminated using a set of filters coupled with a photomultiplier tube. The reading process is fast (~ 1 s) portion of the traps is released (0.1-1%).

Each staff member was provided with an OSL badge to be worn at collar level outside the lead apron. The OSL badges were read every quarter, and the minimum detectable dose (Md) was set at 0.1 mSv. Readings of 0.1 mSv are recorded as Md.

A 5 yr retrospective analysis was performed all staff involved in nuclear medicine procedures representing 100% of the staff members from different categories (nuclear medicine technicians, non-nuclear medicine (cardiac stress) technicians, hot lab technicians, and doctors).

The H-lens values (computed equivalent dose for the eye lens, Hp3) were extracted from the OSL system for each staff member. The H-lens variable was checked for normality, which indicated a non-normally distributed variable (Shapiro-Wilk test, $p < 0.0001$).

3 Results

The mean eye lens dose among nuclear medicine workers was reported to range from 4 to 24 quarters in occupational dose records during the study period. The lowest mean dose was 0.26 ± 0.11 while the highest reported was 1.43 ± 0.88.

Significant differences were observed between individual staff members in terms of H-lens values (Tab. 1). In general, the differences in H-lens values between different occupations were significant (Kruskal-Wallis rank sum test, $p < 0.0001$; Tab. 2). Pairwise differences revealed that H-lens values were significantly higher among hot lab technicians than among non-nuclear medicine technologists ($p < 0.001$) and nuclear medicine technologists ($p < 0.0001$). Other pairwise comparisons did not reveal any significant differences between the groups. The highest annual dose was received in 2015 and was reported to be for the radiologists as shown in Table 3, it's under the department investigation level

4 Discussion

Exposure to ionizing radiation is a fundamental concern in nuclear medicine because of the risk it poses to the health and safety of medical staff. Monitoring and controlling this exposure within acceptable limits is paramount. These limits are defined by international regulatory bodies such as the ICRP (ICRP, 2012).

This study aimed to investigate the annual average eye dose of ionizing radiation received by nuclear medicine staff and compare the findings with those of other studies in the field. The goal was to understand whether the established safety protocols were effective, and whether staff exposure remained within the recommended dose limits.

In our study, none of the participants surpassed the eye dose limit for ionizing radiation exposure. The annual average eye dose ranged from 0.2 mSv to 2.9 mSv, which is within the advised dose limit stipulated by the ICRP. This is in higher than

Table 1. Average eye lens dose (H-lens) in millisievert among different subjects.

Name	N of Quarters	Mean ± SD	p
Doctor			< 0.0001
Physican 1	9	0.82 ± 0.57	
NM Tech			
Tech 1	6	0.60 ± 0.33	
Tech 2	9	0.38 ± 0.27	
Tech 3	10	0.26 ± 0.11	
NIC Tech.			
Tech 1	8	0.40 ± 0.03	
Tech 2	4	0.72 ± 0.00	
Tech 3	4	0.43 ± 0.00	
Tech 4	12	0.51 ± 0.20	
Tech 5	4	0.26 ± 0.00	
Tech 6	4	1.08 ± 0.00	
Tech 7	4	0.11 ± 0.00	
Tech 8	4	0.46 ± 0.00	
Tech 9	7	0.35 ± 0.08	
Hot Lab Tech.			
Tech 1	20	1.29 ± 0.53	
Tech 2	23	0.91 ± 0.44	
Tech 3	11	0.76 ± 0.58	
Tech 4	24	1.43 ± 0.88	
Tech 5	16	0.78 ± 0.60	

* SD: Standard Deviation.
* N: Number.
NM Tech: Nuclear Medicine technologist.
NIC Tech: Noninvasive Cardiac technologist.

Table 2. Average eye lens dose (H lens) in millisievert by occupation

Occupation	Mean ± SD	p
NIC Tech.	0.47 ± 0.25	< 0.0001
Hot Lab Tech.	1.09 ± 0.68	
Doctor	0.82 ± 0.57	
NM Tech.	0.38 ± 0.27	

*SD: Standard Deviation.
NM Tech: Nuclear Medicine technologist.
NIC Tech: Non-Invasive Cardiac technologist.

what was observed in a similar study conducted in the UK, which found that nuclear medicine staff receive an average annual eye dose of 4.5 mSv. The marked difference in these findings could potentially be attributed to variations in workload or the inconsistent use of OSL dosimeters during procedures. However, a UK study reported that their participants did not exceed the average dose limit (Thome, 2018).

Additionally, we identified notable variations in eye dose exposure across different roles in the nuclear medicine department. The lens dose, represented by the H-lens value, was significantly elevated in hot lab technicians compared to both non-nuclear medicine technicians involved in cardiac stress tests ($p < 0.001$) and other nuclear medicine technicians ($p < 0.0001$). This discrepancy in exposure levels can be chiefly attributed to the different duties of the staff. In particular, hot lab technicians face higher ambient dose rate values owing to the handling and preparation of radiopharmaceuticals and the specific techniques used in their procedures. This aligns with previous studies suggesting that technicians involved in radionuclide therapy or PET scans typically experience higher radiation exposure than other staff members (Seierstad, 2007; Summers, 2012; Antic, 2014; Adliene, 2020).

While most studies examining radiation dose exposure among nuclear medicine staff have found that exposure levels typically do not exceed recommended limits, the same cannot be said for other radiology specialties (Mettler, 2008; Antic, 2014; Thome, 2018). In a nuclear medicine practice serving high volume of patients, a study reported eye lens doses for 19 staff members (Demeter, 2019). They work with high loads of cardiac PET imaging and run the cyclotron center. Their reported maximum eye lens doses did not exceed 3.68 mSv for the 3-month period of the study.

Meanwhile, a Spanish study assessed eye lens dose for staff in Interventional Cardiology (IC) and demonstrated that doses exceeded ICRP limits in 4 out of 9 IC physicians while nurses received 2 to 4 mSv (Principi, 2015). The number of procedures for each of the 9 physicians had ranged from 77 to 385 per year. In addition, physician's measured eye lens doses ranged from 8 to 61 mSv due to the variability in radiation protection tools used by each of them.

These findings emphasize the need for further research and evaluation of interventional facilities to identify staff members most vulnerable to high radiation dose exposure and to implement rigorous protective measures.

Moreover, a study conducted in the field of interventional radiology compared the radiation doses measured by dosimeters worn close to the eyes with those worn around the neck (Al-Haj, 2015). The results indicated that neck-worn dosimeters tended to overestimate the radiation dose compared to eye dosimeters, which is a potential limitation of our study. Therefore, further evaluation using dosimeters positioned near the eyes is recommended, and dosimeters should be worn as close to the eye as possible for the most accurate monitoring of the eye lens dose (Al-Haj, 2015).

In summary, while our study confirms that radiation exposure among nuclear medicine staff generally remains within the recommended limits, it also sheds light on the differences in exposure across different roles and specialties. This highlights the need for continued vigilance, ongoing research, and implementation of role-specific protective measures to maintain highest level of radiation protection all staff members working in environments where ionizing radiation is present. This study also recommends reconsidering the positioning of dosimeters for more accurate dose monitoring.

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Table 3. Annual average eye lens dose (H lens) in millisievert.

Occupation	2014	2015	2016	2017	2018	2019	2020	2021	2022
Doctor	0.48	1.56	Md	Md	Md	Md	Md	Md	0.03
NM Tech.	Md	0.15	0.16	0.61	0.46	0.16	Md	Md	0.13
Hot Lab Tech.	1.196	0.97	2.43	0.9	1.11	0.46	0.29	0.19	0.2
NIC Tech.	Md	0.48	0.5933	0.58	Md	Md	Md	Md	Md

Md: dose equivalent for a wear period below the minimal threshold of the dosimeter, 0.10 mSv.
NM Tech: Nuclear Medicine technologist.
NIC Tech: Non-Invasive Cardiac technologist.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The datasets generated and/or analyzed during the current study are not publicly available due to [restrictions *e.g.* their containing information that could compromise the privacy of research participants] but are available from the corresponding author [R.Y. Nasr] on reasonable request.

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