International Journal of Biomedicine 14(3) (2024) 386-391
http://dx.doi.org/10.21103/Article14(3)_RA3

REVIEW ARTICLE

INTERNATIONAL JOURNAL OF BIOMEDICINE

Occupational Eye Lens Dose in Medical Imaging in Saudi Arabia: A Systematic Review

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Abstract

This review examines and summarizes all published work on occupational eye lens doses among medical imaging and interventional staff in Saudi Arabia to ensure their safety. Multiple databases were used, such as PubMed/MEDLINE, SCOPUS, and Google Scholar. Articles between 2013 and 2023 that met the inclusion criteria were analyzed. Sixty-two publications were initially identified for screening, of which 5 articles met the inclusion criteria and were included in this review. After extensive review, it was concluded that although none of the studies reported doses to the eye lens that exceeded the annual limit set by the regulations, there is room for optimization. This review also reveals a dearth of research on this topic in Saudi Arabia. **(International Journal of Biomedicine. 2024;14(3):386-391.)**

Keywords: eye lens dose • occupational doses • radiation exposure • imaging modalities

For citation: Albahiti M, Aboalsamh A. Occupational Eye Lens Dose in Medical Imaging in Saudi Arabia: A Systematic Review. International Journal of Biomedicine. 2024;14(3):386-391. doi:10.21103/Article14(3)_RA3

Introduction

In recent years, the eye lens dose-response relationship has become a topic of intense interest. Multiple studies have highlighted the adverse side effects and diseases that may develop at much lower radiation doses than previously expected.[1] The eye lens is one of the most radiosensitive and radio-vulnerable tissues of the human body.[2] Due to the cumulative nature of radiation, it is important to understand that the constant exposure of the eye, even to low doses of radiation, could lead to the development of a plethora of ocular issues as but not limited to glaucoma, cataracts, optic neuropathy, retinopathy, and angiopathy.[2,3] Due to the high risk of developing such diseases, evaluation of eye lens dose is considered extremely important when protecting healthcare workers. Hence, in 2011, the International Commission on Radiation Protection (ICRP) recommended lowering the annual eye lens dose limit from 150 mSv/year to 20 mSv/year to reduce the risk of X-ray-induced lens opacity in medical staff.[4]

Occupational exposure to ionizing radiation has always been a major concern in nuclear medicine, specifically diagnostic imaging and interventional procedures. During interventional procedures, medical staff are continuously exposed to patient-scattered radiation, which can reach extremely high levels at the eye.[1] At present, no dosimeter is specifically designed for routine eye lens monitoring, although the crucial issue is the actual radiation dose to the lens.[1] To ensure staff safety, strict protocols, and rigorous guidelines have been implemented to monitor and manage radiation exposure. These implemented measures are crucial in minimizing occupational exposure. These measures include but are not limited to personal protective equipment, adherence to established safety procedures, and ongoing training to promote awareness and proper handling of radioactive materials.[3] Additionally, routine medical surveillance and dose monitoring are essential for detecting and addressing any potential concerns related to radiation exposure as required by national and international regulatory bodies such as the Nuclear and Radiological Regulatory Commission and the Saudi Food and Drug Authority.[5,6]

This systematic review aims to analyze the literature on occupational eye lens exposure in medical imaging practices, specifically for healthcare staff. It included all papers published

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between 2013 and 2023 in Saudi Arabia. The authors screened the retrieved publications based on predefined inclusion criteria to identify relevant studies, extracted key information, and summarized the data in this article. A total of 8 potentially relevant articles were identified. Among these, only 5 articles were complete and reported the eye lens dose of actual staff. Based on the findings, we wanted to assess the risk of radiation-associated eye lens opacities and cataracts among all healthcare workers occupationally exposed to radiation.

Methodology

Search strategy

Multiple databases were searched: PubMed/MEDLINE, Google Scholar, and Scopus. The following keywords were used with the Boolean operator 'AND': occupational exposure, staff in diagnostic radiology, and "eye lens dose" AND Saudi Arabia, searching in titles, abstracts, and full texts. The reference lists of eligible papers were also examined to uncover studies we may have overlooked by searching phrases in the titles and abstracts. Articles published in English between 2013 and 2023 that reported findings on the eye lens dose of occupational radiation exposure were included. Studies were omitted if they only described the radiation protection system or reported occupational exposure from ionizing radiation for the whole body.

Inclusion criteria for this review were (i) articles that were fully available in English, (ii) articles that reported occupational eye lens dose, and (iii) studies conducted in Saudi Arabia.

The identification and selection process findings are shown in a flow diagram (Figure 1), as specified in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[7] The PRISMA was used as a guideline.

Data extraction

Data on sample size, methodology, source population, reported eye lens dose, and time frame were collected from the articles. In addition, each study was analyzed for limitations. Two reviewers (MA, AA) separately conducted data extraction and cross-validated their reports to ensure accuracy and establish a consensus on data synthesis from the source articles.

Results

Sixty-two publications were initially identified for screening, out of which only 7 abstracts were considered possibly eligible for inclusion and obtained for full-text evaluation. In total, five articles met the inclusion criteria and were included in this review.

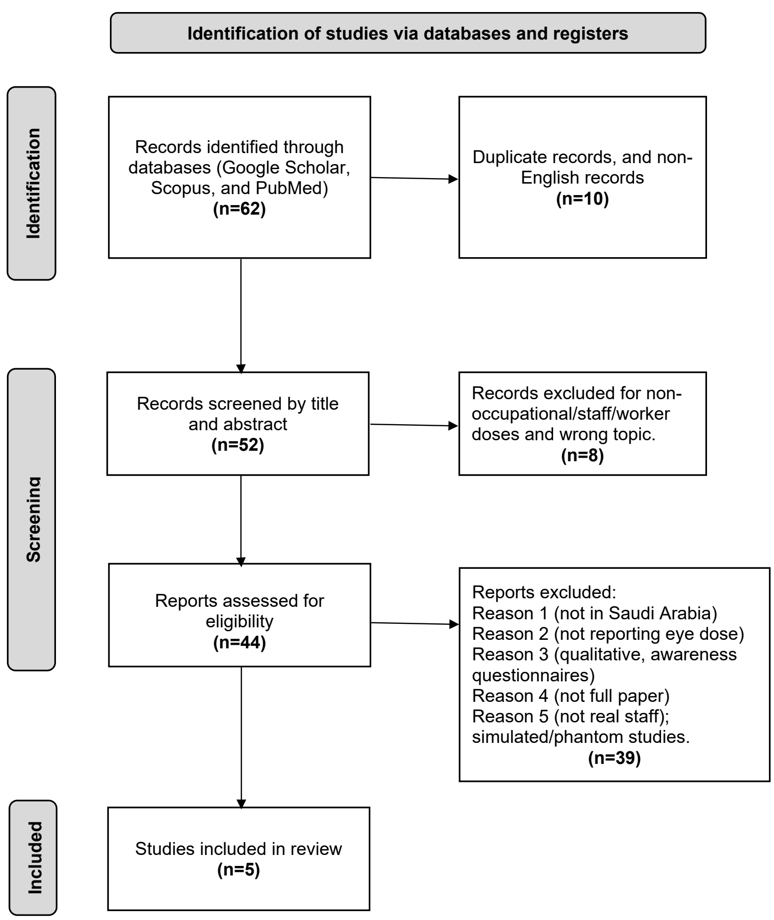

Fig. 1. *PRISMA 2020 flow diagram for new systematic reviews.*

A study by Khafaji et al.[8] aimed to measure and compare the occupational doses to the eye lens and thyroid of pediatric interventional cardiologists during 93 different procedures in the catheterization laboratory conducted in one month using dosimeters. Dosimeters were attached to bandanas to measure absorbed doses to the eyes and thyroid gland, and data on procedure types, fluoroscopy time, and tube voltage were collected. The type of dosimeters used were NanoDots© optically stimulated luminescence (OSL) by Landauer, Glenwood, Illinois, United States.[8] Four pediatric cardiologists wore lead aprons and thyroid collars during the procedures, and ceiling-mounted lead shields were used. Dosimeters were provided to each participant, with two dosimeters worn above each eye to measure eye doses and another two dosimeters attached to a bandana placed at neck level under the thyroid collars to assess thyroid doses. The dosimeters were used during the entire procedure and were removed immediately after completion to ensure accurate dose readings. Data on procedure demographics and procedure type were collected. Procedures were classified according to age groups. Several parameters were recorded to obtain procedure, eye, and thyroid dose-related data. The mean absorbed doses for all procedures in both eyes and thyroid were 0.09 mGy and 0.08 mGy, respectively. A significant difference was found between the left and right eye measurements, with higher doses administered to the left eye.[8] No significant difference was observed between the right and left thyroid doses. Significant correlations were found between the eye and thyroid doses and the procedure type. The study emphasizes the need for radiation safety measures in pediatric interventional cardiology due to the proximity of cardiologists to radiation beams during procedures. The study did not investigate the long-term effects of radiation exposure on the eye lens and thyroid, such as the development of cataracts or thyroid cancer. The article did not provide detailed information about the specific types of procedures performed, which could have influenced the radiation doses received by the cardiologists. The study did not compare the radiation doses received by pediatric interventional cardiologists with those of other healthcare workers in the same setting, which could have provided additional insights into the relative risks faced by different professionals.[8]

The study by Matter et al.[9] aimed to retrospectively estimate operator eye lenses among interventional cardiologists during two different procedures. The first was a dose for diagnostic coronary angiography (DCA) and percutaneous coronary interventions (PCI) using literature-derived conversion coefficients. This was done to address concerns among interventional cardiologists due to the threshold decrease by the ICRP. Dose measurements from eight cardiologists were reported for three months (January 1, 2014, to March 31, 2014), during which they performed an average of 20-37 procedures.[9] Data from Digital Imaging and Communications in Medicine (DICOM) headers of 250 patients who underwent DCA and PCI procedures were used for this retrospective analysis based on air kerma-area product (PKA) values and conversion coefficients. In the three-month period, the estimated average operator eye lens dose per procedure was 54.4 to 73.0 μSv during DCA and 92.9 to 207.8 μSv in PCI procedures. The cumulative operation eye lens doses ranged from 7.20 to 19.6 mSv. The authors reported that the use of exposure control tools such as ceiling screens, radiation protection cabins, biplane X-ray fluoroscopy, and proper X-ray tube configuration, as well as two cardiologists always using lead glasses, resulted in an intermediate dose reduction factor of 0.2.

The study was based on a retrospective estimation of operator eye lens doses, which may introduce potential biases and limitations in data collection and accuracy. The sample size of 250 patients may not be representative of the entire population undergoing DCA and PCI procedures, limiting the generalizability of the findings. The authors rely on literature-derived conversion coefficients, which may vary across different studies and settings, potentially affecting the accuracy of estimated eye lens doses. The study does not provide information on the specific radiation protection tools used by each operator, which could impact the effectiveness of dose reduction measures. Other potential factors that could influence operator eye lens doses, such as the duration of procedures, patient characteristics, and operator technique, were not considered.[9]

A study by Sulieman et al.[10] aimed to measure occupational exposure in nuclear medicine while estimating the eye lens equivalent dose and radionuclide exposure risks. The study examined three nuclear medicine procedures: bone, renal, and thyroid scans. While the focus was on eye lens doses due to the new ICRP dose limit adjustments for opacity formation at low doses, they also reported patient doses for the three protocols. The study was conducted over 10 weeks and included procedures for 350 patients. Personnel radiation exposure was measured at different times after radiopharmaceutical administration. Co-doped lithium fluoride (LiF: Mg, Cu, P) thermoluminescence dosimeters (TLD-GR200A) in the form of circular chips were used to measure staff occupational exposure. To measure eye lens dose, a software was developed that utilized tissue weighting factors. Ambient dose evaluations were also carried out by assessing different locations using a survey meter (monitor 4, S.E. International, Inc., Summertown, USA). Nuclear Medicine technologists were the largest group exposed in the department, with annual effective doses ranging between 0.1 and 18.6 mSv. Nurses received doses ranging between 0.4 and 13.4 mSv. The annual eye lens dose equivalent was projected to be 2.2 mSv, which is less than the annual occupational dose; however, it is still close to it and presents space for optimization.

One limitation is that it was conducted for only 350 patients, which means they measured the occupational exposure to staff during handling of those patients undergoing only 3 types of nuclear medicine procedures for 10 weeks only, then annual dose estimates were made. The data shown does not represent their workload, as the number of patients scanned may vary in some months. The study also did not mention any preventive measures taken by staff to protect from radiation exposure.[10]

Saeed et al.[11] aimed to estimate the effective dose during radiologic and nuclear medicine examinations of both patients and staff. Eye lens doses were only measured for personnel working with technetium 99 (^{99}Tc) for four protocols: bone, renal, thyroid, and liver-spleen scans. Therefore, only the results from nuclear medicine scans will be reported for comparison in this systematic review. The study was conducted over a period of 9 weeks, and the staff were grouped according to the following tasks: preparation and operation groups. Annual and monthly eye dose exposure was calculated for the operator group as 5.0 ± 0.1 mSv and 0.42 mSv, respectively, while for the preparation group, 12.8 ± 0.2 mSv and 1.07 mSv, respectively. These were all within the limits set by the ICRP.

A major limitation of the present report is that it included only technicians who work in nuclear medicine; not all technicians nor other staff members are represented in the data. Similar to Sulieman et al.,[10] they estimated the entire year's patient load and, subsequently, the yearly dose of eye lenses based on workload from a brief period.[11]

Lastly, Al-Haj et al.[12] aimed to assess staff eye lens doses and determine the category of staff with high eye lens doses. Furthermore, the study investigated reasons for high doses received and recommended dose-reduction techniques. The investigation was a retrospective 5-year analysis conducted on 34 staff members (11 cardiologists, 13 technologists, and 10 nurses). Eye lens occupational doses were measured using TLD badges worn at the collar level or on lead badges. The mean eye doses ranged from 0.17 to 4.21 mSv for all staff members. Workload variation, tube angulation, fluoroscopy time, and implementation of radiation protection programs were variables considered in this study. Their results showed that the highest annual eye lens dose was 15.45 mSv obtained from a cardiologist. All measured eye lens doses, including the highest dose, did not exceed the new ICRP dose limit. When looking at exact numbers, eight staff members received a dose of <5 mSv while 12 exceeded 5mSv, and this increase was due to the use of new procedures.

In summary, the reported occupational eye doses from each of the 5 studies above are presented in Table 1.

Discussion

Diagnostic Imaging is a newly regulated area of medicine in Saudi Arabia. The governing bodies are the Saudi Food and Drug Authority and the Nuclear and Radiological Regulatory Commission (NRRC).[13,14] They both have policies and licensing requirements that have been in place for less than a decade. In addition, occupational dose monitoring is compulsory, but eye lens dose is not enforced nor reported individually for nuclear medicine or interventional workers.

The systematic review search yielded a few studies, suggesting that more research is necessary. The increasing number of procedures being out in Saudi Arabia coincides with a rise in the use of ionizing radiation equipment, indicating that the need for more publications should be a top priority.

A study by Khafaji et al.[8] aimed to measure and compare the occupational doses to the eye lens and thyroid of pediatric interventional cardiologists during different procedures in the catheterization laboratory and its significance. The authors reported that the mean absorbed eye and thyroid doses were 0.09 mGy and 0.08 mGy, respectively. A significant difference between the right and left eye was reported, with the left eye having more exposure. Significant

Table 1.

Comparison of the eye lens doses reported in 5 studies

Study	Reported eye dose	Modality/Procedure
Khafaji et al. [8]	Mean per month: 0.09 ± 0.05 mSv Maximum dose: 0.28 mSv Mean per procedure: 0.132 mSv	Pediatric interventional cardiology procedures conducted in one month.
Mattar et al. [9]	Mean: 54.4 to 73.0 µSv (per procedure) Mean: 92.9 to 207.8 µv (per procedure) Cumulative operation eye lens doses ranged from 7.20 to 19.6 mSv	Interventional cardiology during diagnostic coronary angiography (DCA). Interventional cardiology during percutaneous coronary interventions (PCI)
Sulieman et al. [10]	Mean: 2.2 mSv	Nuclear medicine (bone, renal & thyroid scans)
Saeed et al. [11]	Mean range: 4.9 mSv to 12.8 mSv Max mean per month: 1.07 mSv	Nuclear medicine (bone, renal, thyroid & liver-spleen scans)
Al-Haj et al. [12]	Mean range: 0.17 mSv to 4.21 mSv Max reported dose: 15.45 mSv Mean: 0.02 mSv to 0.1 mSv (per procedure)	Interventional cardiology

correlations were also reported with different procedures; however, the study did not specify procedure details. Any long-term effects caused by the radiation exposure were also not reported. While Matter et al.[9] conducted their work over 10 weeks on interventional cardiologists conducting two different procedures, the eye lens dose per procedure was 54.4 to 73.0 uSv during DCA procedures and 92.9 to 207.8 uSv in PCI procedures with a cumulative dose ranging from 7.20 to 19.6 mSv. The operator eye lens dose was calculated via a retrospective estimation. A study by Sulieman et al.,[10] which was conducted over the span of 10 weeks, measured occupational exposure in nuclear medicine while estimating the eye lens equivalent dose. The study mainly focused on operators conducting three procedures: bone, renal, and thyroid scans. With annual doses ranging from 0.1 to 18.6 mSv for technicians. 0.4 and 13.4 mSv for nurses, which fall under the annual requirements. Saeed et al.[11] measured the eye lens doses for personnel working with technetium 99 (^{99}Tc) over 9 weeks. The eye lens dose was calculated for technologists, ranging from 4.9 to 12.8 mSv. These limits are below the annual limit. Finally, Al-Haj et al.[12] measured staff eye lens doses and categorized staff depending on exposure levels. The investigation was a retrospective study conducted over 5 years. All obtained eye lens doses do not exceed the new ICRP dose limit, including the highest dose with 8 staff members <5 mSv and 15 exceeding 5 mSv.

Although the documented studies do not exceed the annual ICRP limit, a large variation in reported eye lens doses requires further guidelines. Even though all the reported studies did not exceed the annual limit, they came very close to it, indicating a need for more optimization. The literature has shown that technique optimization and positioning significantly affect occupational eye dose.[15] Reaching the ICRP dose threshold for eye lenses is achievable when facilities do not enforce wearing protective tools, do not commit to technique optimization, or promote radiation safety education. Contrary to our results in Saudi Arabia, some studies reported eye lens doses exceeding the recommended dosage.[15] A study conducted in Japan[16] showed alarming high eye lens doses for radiography technicians. Researchers explained that with the possibility of being directly exposed to X-rays while assisting patients. Their reported eye lens doses ranged from 8.95 to 54.75 mSv per year, significantly exceeding the ICRP limit.[16]

Endoscopic procedures that utilize imaging modalities lack guidelines and references for best practices regarding possible radiation-induced eye lens damage. A study on staff involved in endoscopic retrograde cholangiopancreatography (ERCP) showed that the estimated equivalent dose to the eye of a gastroenterologist working with an overcouch X-ray tube is 11.7 mSv per annum (based on a typical workload of 130 cases per gastroenterologist per year). For the same workload, using a ceiling-mounted shield and with an under-couch tube X-ray, the estimated equivalent dose to the eye of a GE is 1.3 mSv per annum. Although this figure was below the ICRP limit, the researchers warned that it could be exceeded in facilities that perform more than 130 cases per year. The operator's skills, technique, protocol, and X-ray tube position (under or over table configurations) are critical in delivering doses.[17]

A publication in the British Journal of Radiology reviewed dosimetry studies for interventional radiologists and cardiologists that provided dose assessments to various parts of the body.[18] It was highlighted that the workload where interventionists could reach dosage constraints or limits for the eye lens could range from a minimum of six procedures per month to 150. The manuscript emphasizes the importance of providing radiation protection and carefully controlling eye lens doses to ensure the safety of diagnostic and interventional imaging personnel. Ciraj-Bjelac et al.[19] also emphasized that properly fitting lead glasses is essential for protection.

Declaration

The authors declare that they have no conflict of interest that could have appeared to influence the work reported in this review paper.

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