QUANTIFICATION OF RADIATION DOSE TO THE RADIOLOGIST'S EYES ASSOCIATED WITH VARIOUS INTERVENTION PROCEDURES

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Abstract— **This study aimed to measure equivalent doses to the eyes of intervention radiologists during various procedures using an organ TLD dosimeter and compare them with the threshold radiation dose to the eyes. The study was conducted at the Interventional Radiology Department of the Sanjay Gandhi Post Graduate Institute of Medical Sciences in Lucknow, Uttar Pradesh. A TLD eye dosimeter (Head badge) comprising three CaSO4: Dy Teflon TL discs (0.4 mm thickness, 5.0 mm diameter) was used to measure radiation dose to the eyes. Doses were evaluated using the standard dose evaluation algorithm employed in TLD personal monitoring services, with a PC-based Nucleonic TL Research Reader (Type TL 1009I). Additional data collected included procedure type, fluoroscopy duration, primary doctor, secondary doctor (assisting physician), and machine model. The dose received in mSv/hr by an interventional radiologist was converted to mSv/yr based on the specified working hour limits by the International Commission on Radiological Protection (ICRP).The study revealed the highest ocular radiation dose during gastroenterological procedures at 2.9 mSv/h, followed by vascular and neurological procedures at 0.69 and 0.41 mSv/h, respectively. The primary operators received higher doses compared to the secondary auxiliary physicians. On average, the radiation exposure to the eyes of doctors (205 mSv/yr) exceeded the acceptable equivalent annual dose limit for the eye, which is 20 mSv/year, as recommended by ICRP 103 (2007).The study highlights that interventional radiologists at our center are exposed to significantly higher doses to the eyes than the recommended levels, which may lead to long-term adverse side effects. Alongside strict radiation dose monitoring, implementing measures such as an increase in the frequency of rotating intervention radiology postings and providing appropriate radiation protection (Ceiling shield for Eye) could help prevent high radiation exposure to the eyes.**

Keywords— **TLD, Eye dose, Interventional radiologist.**

I. INTRODUCTION

Interventional radiology procedures play a crucial role in medical diagnosis and treatment but come with the challenge of exposing both interventional radiology staff and patients to significant doses of radiation. The extent of radiation exposure can vary depending on several factors, including the complexity and duration of the procedure, the experience of the radiologist, and the distance between the staff and the radiation source.

Of particular concern is the potential radiation exposure to the eyes, which can increase the risk of developing cataracts. Research conducted by Haskal and Worgul[2] identified cataracts in five out of 59 (8%) interventional radiology physicians screened, with an additional 22 subjects (37%) exhibiting small paracentral dotlike opacities an early sign of cataract development. Furthermore, studies, such as the one by Ainsbury et al.[3] in 2009, have suggested that the threshold for radiation-induced cataract formation might be lower than previously estimated. As a result, ensuring radiation protection and accurate dose evaluation are critical aspects of safeguarding interventional radiology staff.

Typically, the radiation dose received by interventional radiologists is measured using personal radiation monitoring devices, which assess the effective dose received by the whole body. However, there is limited research focusing on organ-specific equivalent dosages for the eyes. Thus, the objective of this study was to measure the equivalent dose to the eyes of interventional radiologists during various procedures, utilizing an organ TLD dosimeter. Subsequently, the findings were compared with the threshold radiation dosage considered safe for the eyes.

In light of the potential long-term health implications associated with radiation exposure, this study aims to contribute valuable insights that can help refine safety measures and establish best practices for protecting interventional radiology staff from the hazards of excessive radiation exposure to the eyes. By providing essential data on organ-specific equivalent dosages, we aim to underscore the significance of radiation protection and promote the well-being of those dedicated to advancing medical care through interventional radiology procedures.

II. MATERIALS AND METHODS

The research was conducted in the interventional radiology department's gastroenterology, neurology, and vascular units, which are integral parts of the medical facility. To measure the eye lens dose, an eye lens dosimeter (head badge) was used, which was worn on the forehead between the eyes. The dosimeter comprised three CaSO4: Dy Teflon TL discs, each with a thickness of 0.4 mm and a diameter of 5.0 mm (as depicted in Fig. 1). The doses were evaluated using a standard dose evaluation algorithm, which is part of the TLD (Thermoluminescent Dosimeter) personal monitoring service. The readings were analyzed on a PC-based Nucleonic TL Research Reader (Type TL 1009I), as shown in Fig. 2.

During the evaluation process, a reporting dose of 0.5 mSv was used, and any evaluated dose below this threshold was recorded as 0.00 mSv. The equivalent dose was measured in terms of the operational quantity Hp (0.07), which represents the dose absorbed in the eye lens.

A total of 164 readings were collected from seven specifically designated eye lens dosimeters (ELDs), assigned to the neurology (ELD1, ELD2), gastroenterology (ELD3, ELD4, ELD6), and vascular (ELD5, ELD7) interventional radiology units. However, it is important to note that data from ELD5 was not included in the study due to a missing disc.

For each procedure, the x-ray parameters (Kv, mA, mAs) and the total fluoroscopy time in mGy were meticulously recorded. Additionally, detailed information was gathered concerning the duration of each procedure, the specific type of procedure performed, the experience level of the interventional radiologist conducting the procedure, and the utilization of various radiation protection equipment. These protective measures included the use of table curtains, ceiling shields, floor shields, eyeglasses, thyroid collar shields, whole-body lead aprons, and other relevant safety gear.

The comprehensive data collection and analysis in this study aim to provide a thorough understanding of the eye lens doses received by interventional radiology staff during various procedures. By examining the x-ray parameters, fluoroscopy times, and protective measures utilized, we seek to identify potential factors influencing radiation exposure to the eyes. The outcomes of this research are vital in establishing guidelines and best practices to ensure the safety and well-being of interventional radiology personnel, reducing the risk of cataract development and other adverse effects associated with excessive eye lens radiation exposure.

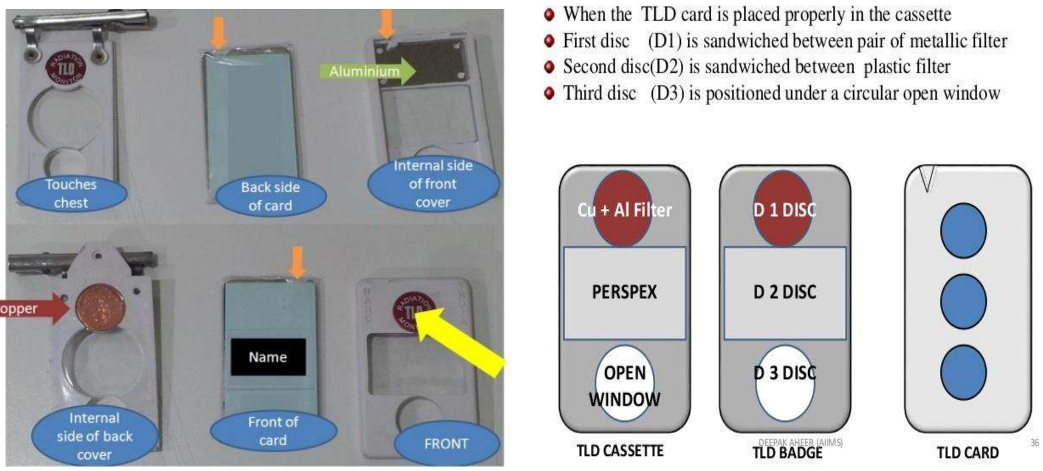

Figure 1: Cross section of TLD Badge description

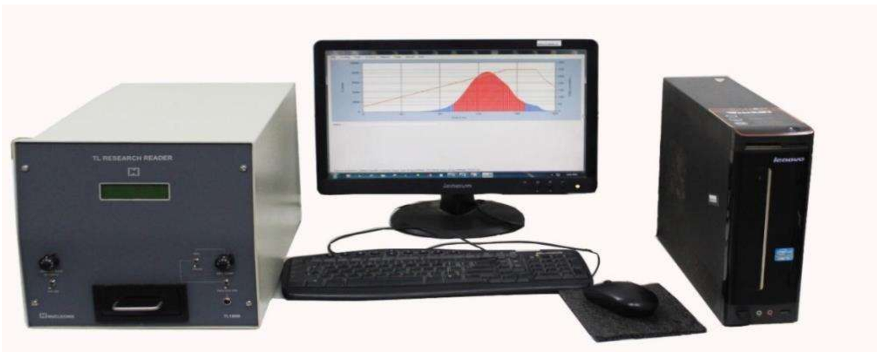

Figure-2: TLD Chest Badge Reader

III. RESULTS

In our study, we employed Thermoluminescent Dosimeters (TLDs) to assess the integrated dose, also referred to as the cumulative dose, received by medical personnel during various interventional radiology procedures. The integrated dose represents the total radiation dose accumulated over a specific exposure period. However, for our analysis and reporting in the results section, we focused on the dose rate, which denotes the rate at which radiation is received per unit of time, measured in millisieverts per hour (mSv/hr). To calculate the dose rate from the integrated dose readings, we divided the total integrated dose by the corresponding exposure hours for each doctor involved in the procedures. This division provided us with the average dose rate per hour for each specific procedure, allowing us to comprehend the intensity of radiation exposure during various moments throughout the medical interventions.

For example, in the case of the Gastro procedure, TLD measurements provided the integrated dose for both the primary and secondary doctors. By dividing these integrated doses by the respective exposure hours for each doctor, we obtained the dose rate values:

Integrated dose (TLD reading): 34.60 mSv
Exposure time: 11.94 hours
Dose rate (mSv/hr) for the primary doctor: 34.60 mSv / 11.94 hours ≈ 2.89 mSv/hr
Dose rate (mSv/hr) for the secondary doctor: 11.03 mSv / 15.78 hours ≈ 0.70 mSv/hr
Total dose rate (mSv/hr) for Gastro doctors: 2.89 mSv/hr + 0.70 mSv/hr = 3.59 mSv/hr

Similarly, we followed the same process for the Neuro and Vascular procedures, resulting in dose rate values of 0.56 mSv/hr and 0.54 mSv/hr, respectively.

Neuro Procedure:
Integrated dose (TLD reading): 6.80 mSv
Exposure time: 16.72 hours
Dose rate (mSv/hr) for the primary doctor: 6.80 mSv / 16.72 hours ≈ 0.41 mSv/hr
Dose rate (mSv/hr) for the secondary doctor: 3 mSv / 20.48 hours ≈ 0.15 mSv/hr
Total dose rate (mSv/hr) for Neuro doctors: 0.41 mSv/hr + 0.15 mSv/hr = 0.56 mSv/hr

Vascular Procedure:
Integrated dose (TLD reading) for the primary doctor: Data not received (due to no disc in the ring)
Integrated dose (TLD reading) for the secondary doctor: 4.5 mSv
Exposure time for the secondary doctor: 8.32 hours
Dose rate (mSv/hr) for the secondary doctor: 4.5 mSv / 8.32 hours ≈ 0.54 mSv/hr
Total dose rate (mSv/hr) for Vascular doctor: 0.54 mSv/hr

The results from the vascular unit may not be fully representative due to the mechanical defect in one of the ELDs.

Regarding the eye lens dose, the average radiation dose to the eyes of the doctors was measured at 0.79 mSv/hr, which is equivalent to 205 mSv/yr (the dose received in mSv/hr was converted to mSv/yr according to the ICRP specified working hours limit for the year). This calculated dose is 10 times higher than the equivalent annual dose limit of 20 mSv/yr for the eyes, as recommended by the ICRP 103 (2007) guidelines.

To elucidate the cumulative dose in a year to the eye, the following calculation was performed:
Total Eye (mSV/hr) calculated in DSA procedure for Gastrology, Neurology & Vascular departments was 0.79 mSv/hr as per TLD reading. It was converted to 205 mSv/yr.

The calculation process:
52 weeks / year * 5 Working hours * 1 Hour (fluoroscopy time <X-ray pressed by Doctors>) = 260 Hours.

260 Hours X 0.79 mSv/hr = 205 mSv/yr

It is essential to note that approximately per week, one doctor can be exposed to X-rays for about 60 minutes during fluoroscopy time (X-ray pressed by the Doctor), even though each procedure may take 3 to 4 hours, fluoroscopy time typically lasts for 15-20 minutes only.

Our study reveals concerning findings regarding the high radiation dose rates experienced by interventional radiologists during various procedures, especially in the eyes. These results underscore the critical importance of implementing strict radiation protection protocols and safety measures to safeguard the well-being of medical personnel exposed to ionizing radiation regularly. By addressing and mitigating the risk of excessive radiation exposure, we can better protect the health and safety of interventional radiology staff, reducing the potential long-term adverse effects associated with such exposure.

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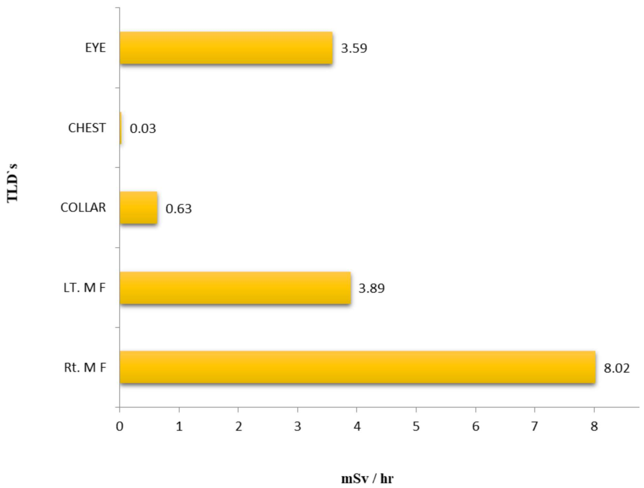

Figure 3: Distribution with regards to radiation exposure (mSv/hr) to the eye (ELD-eye lens dosimetry), chest (whole body), collar, left hand middle finger and right-hand middle finger (ERB-extremities ring badge) to the doctors in Gastrology unit while working on DSA radiology

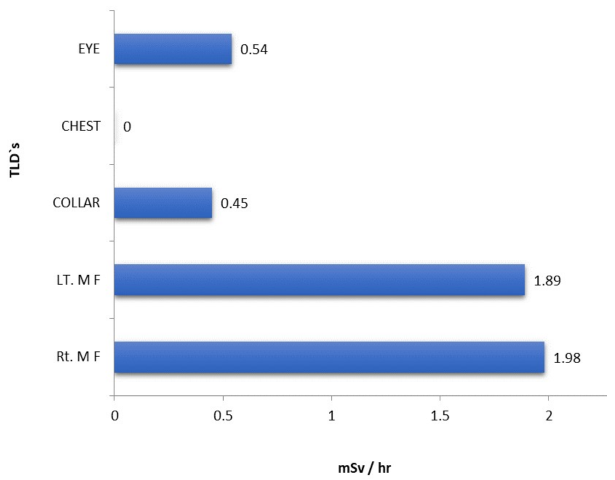

Figure 4: Distribution with regards to radiation exposure (mSv/hr) to the eye (ELD-eye lens dosimetry), chest (whole body), collar, left hand middle finger and right hand middle finger (ERB-extremities ring badge) to the doctors in vascular unit while working in DSA radiology

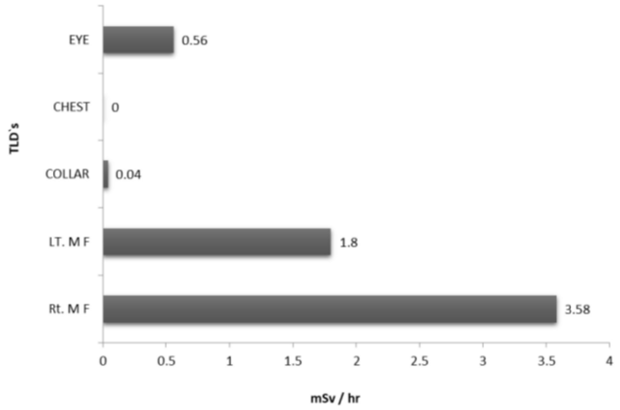

Figure 5: Distribution with regards to radiation exposure (mSv/hr) to the eye (ELD-eye lens dosimetry), chest (whole body), collar, left hand middle finger and right-hand middle finger (ERB-extremities ring badge) to the doctors in neurology unit while working in DSA radiology

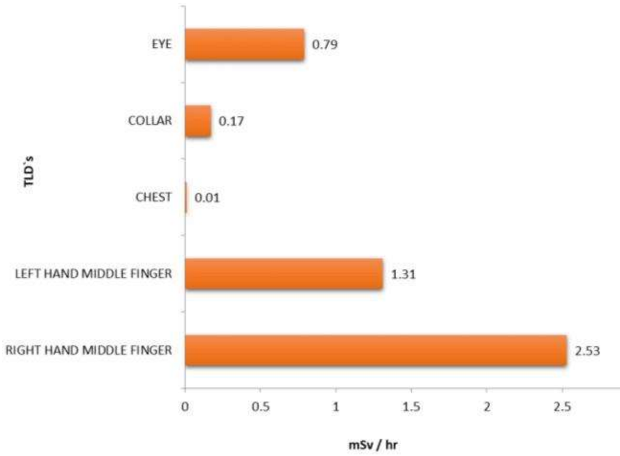

Fig-6:- Distribution with regards to radiation exposure (mSv/hr) to the Eye, Collar, Chest and Finger to the doctors working in Neuro, Gastro & Vascular units, in the DSA Radiology department

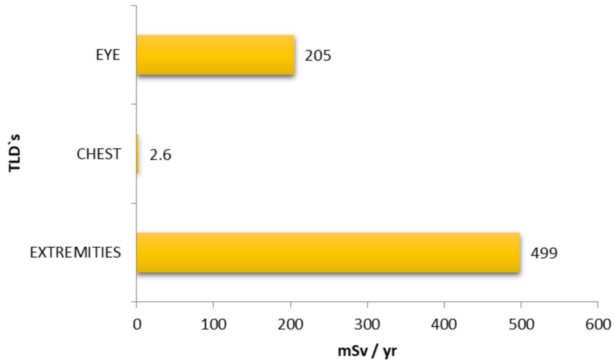

Figure 7: Conversion graph with regards to radiation exposure mSv per hour to mSv per year to the Eye, Chest (WB) and Extremities to the doctors working in Neuro, Gastro & Vascular units, in the DSA Radiology department

IV. DISCUSSION

The findings from our study raise significant concerns regarding the high radiation doses received by interventional radiologists to their eyes, potentially leading to an increased risk of cataract development. The lack of specific local studies addressing this issue further emphasizes the urgency of investigating and objectively measuring the impact of radiation dose on the eyes of medical personnel working in interventional radiology.

The annual reference equivalent dose limit for ocular lenses set at 20 mSv/year, as per ICRP 203 (2007) guidelines, serves as a crucial benchmark for radiation safety. However, in routine practice, the radiation dose to the eyes is not routinely measured, making it vital to incorporate additional Eye TLDs (head badges) alongside conventional TLDs for accurate and precise evaluation of the cumulative radiation dose to the radiologists' eyes.

Our study revealed notable variations in the cumulative radiation dose to the eyes among different interventional radiology units. Specifically, the gastroenterology procedures demonstrated the highest dose, followed by vascular and neurology procedures. This discrepancy could be attributed to the increased number and duration of procedures performed in the gastroenterology units compared to the other units. Nevertheless, we must acknowledge that the radiation dose measured in vascular procedures may have been underestimated due to the absence of data from one of the TLDs, indicating the need for further investigations to address this limitation.

The strikingly high average equivalent dose to the eyes, approximately 10 times higher than the equivalent annual dose limit recommended by IRCP 103 (2007), is a significant cause for concern. While some of the observed discrepancies may be attributed to the small sample size and unusual radiation dose in specific instances (ELD 3), it nonetheless highlights the critical importance of diligently monitoring radiation dose and ensuring strict adherence to radiation safety guidelines.

To effectively mitigate the potential adverse effects of excessive radiation exposure, proactive measures are necessary. Ensuring the availability and proper use of radiation protective gear, including lead aprons, thyroid collars, and eyeglasses, can significantly minimize radiation exposure to sensitive organs like the eyes.

Furthermore, implementing appropriate rotation in the duty roster is crucial to limit the frequency and duration of radiation exposure for individual radiologists. An organized and well-managed scheduling system can provide adequate recovery time between procedures, minimizing the cumulative impact of radiation exposure on the eyes and overall health of the medical personnel.

Continuing education and training programs play a pivotal role in raising awareness among interventional radiology staff regarding radiation safety guidelines and best practices. By staying informed and updated on the latest advancements in radiation protection, medical professionals can take proactive steps to safeguard their health while providing optimal patient care.

To comprehensively address this issue, larger-scale studies and collaborative efforts within the medical community are essential. Gathering comprehensive data from multiple institutions and countries will enable the establishment of evidence-based guidelines for radiation dose limits specific to interventional radiologists, thereby improving radiation safety protocols and practices.

Our study serves as a critical call-to-action to prioritize the monitoring and control of radiation dose in the eyes of interventional radiologists. By recognizing and addressing potential risks, and implementing stringent safety measures, we can ensure the well-being and long-term health of medical professionals working in this field. Protecting the health of interventional radiologists is not only crucial for their own sake but also paramount for providing high-quality patient care and advancing the field of interventional radiology as a whole. Additional research and concerted efforts within the medical community are necessary to fully comprehend the extent of radiation exposure and devise effective strategies to mitigate potential adverse effects on the health of interventional radiologists.

V. CONCLUSIONS

The findings of our study have shed light on a critical concern for interventional radiologists—the high radiation doses they receive to their eyes, which significantly increases the risk of developing cataracts. The implications of this revelation are profound, as cataracts can have debilitating effects on an individual's vision and overall quality of life.

Although the alarmingly high equivalent dose to the interventional radiologist's eyes, as demonstrated in our study, should be interpreted with caution due to the small sample size and the asymmetry of the data, it nonetheless serves as a wake-up call for the medical community. It underscores the urgent need for strict monitoring of radiation dose and the implementation of effective radiation safety protocols.

The health and well-being of interventional radiologists are at stake, and measures must be taken to reduce the harmful effects of excessive radiation exposure. Frequent exposure to high radiation doses can have cumulative and long-term adverse effects on the eyes, potentially leading to severe health issues for medical professionals who dedicate their careers to helping patients through interventional radiology procedures.

To address this issue, there must be a collective effort to prioritize radiation protection and safety in interventional radiology departments. This includes ensuring the availability and proper use of radiation protective gear, such as lead aprons, thyroid collars, and eyeglasses, to minimize radiation exposure to critical organs like the eyes.

Furthermore, appropriate rotation in the duty roster should be implemented to limit the frequency and duration of radiation exposure for individual radiologists. A careful and thoughtful scheduling system can help ensure that no one is exposed to excessive levels of radiation and allow for adequate recovery time between procedures.

Additionally, continuing education and training programs should be provided to interventional radiology staff to raise awareness of radiation safety guidelines and best practices. By staying informed and up-to-date on the latest advancements in radiation protection, medical personnel can take proactive steps to safeguard their health while providing the best care possible to their patients.

Furthermore, larger-scale studies and collaborative efforts within the medical community are needed to gather comprehensive data and establish evidence-based guidelines for radiation dose limits specific to interventional radiologists. This will enable the development of more tailored and effective radiation safety protocols that suit the unique demands of interventional radiology procedures.

In conclusion, the findings of our study serve as a crucial reminder of the potential risks faced by interventional radiologists due to high radiation doses to their eyes. While more extensive research is necessary to fully understand the extent of this issue, immediate action is warranted to protect the health and well-being of medical professionals who play a crucial role in patient care. By emphasizing radiation safety and implementing stringent monitoring measures, we can ensure that interventional radiologists can continue their invaluable work while safeguarding their own health. The health of medical professionals is paramount, and it is our collective responsibility to prioritize their well-being in the pursuit of advancing medical knowledge and improving patient outcomes through interventional radiology.

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