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Research Article

Determination of Radiation Dose Levels Incurred by Lenses During Scopy Imaging

Feyzanur Abuş[1*], Aleyna Gürçalar[2], Osman Günay[*3], Duygu Tunçman[4], Fahrettin Fatih Kesmezacar[5], Mustafa Demir[6]

[1]Yildiz Technical University, Electrics and Electronics Faculty, Biomedical Engineering Dep., Istanbul-Turkiye
Corresponding Author Email: feyzanur.abus@std.yildiz.edu.tr – **ORCID:** 0009-0008-1416-4010

[2]Yildiz Technical University, Electrics and Electronics Faculty, Biomedical Engineering Dep., Istanbul-Turkiye
Email: aleyna.gurcalar@std.yildiz.edu.tr – **ORCID:** 0009-0003-8343-1411

[3]Yildiz Technical University, Electrics and Electronics Faculty, Biomedical Engineering Dep., Istanbul-Turkiye
Email: ogunay@yildiz.edu.tr - 0000-0003-0760-554X

[4]Istanbul University, Science Faculty, Physics Department, 34134, Istanbul-Turkey
Email: duygutuncman@gmail.com - ORCID: 0000-0002-0929-0441

[5]Istanbul University – Cerrahpasa, Vocational School of Health Services, Medical Imag. Tech. Program, Istanbul-Turkey
Email: okesmezacar@hotmail.com - ORCID: 0000-0001-5110-1184

[6]Department of Nuclear Medicine, Cerrahpasa Faculty of Medicine, Istanbul University-Cerrahpasa, Istanbul, Turkey
Email: demirm@istanbul.edu.tr - ORCID: 0000-0002-9813-1628

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Abstract: The radiation dosage that a patient's lenses get during C-arm scopy for cranial angiography applications is examined in this study. The Alderson Rando Phantom (ART) and TLD-100 thermoluminescent dosimeters are used in the study to mimic and quantify radiation exposure. To evaluate the effect on the lenses, several exposure durations (0.5-1-2-4-8 minutes) are used in the experiment. The outer tissue of the right lens was exposed to larger radiation doses over time, according to the data. The significance of regulated radiation application in medical processes is emphasized by mathematical models that show a high link between dosage and time. The study advances medical practices and procedures by offering insightful information on how to optimize radiation exposure for patient safety during scopy imaging.

1. Introduction

The smallest building block of all matter in the universe is the atom. Atom consists of protons, neutrons and electrons, but if there is not a balanced number of protons and neutrons in the atomic nucleus, the atom is radioactive. The radioactive atom has energy that is released in the form of electromagnetic waves and particles. This energy is called radiation. Radiation is divided into two types: ionizing and non-ionizing. Ionizing radiation is widely used in the medical world for medical diagnosis and treatment purposes. Ionizing radiation can pass into the tissues within the body and therefore, in case of long exposure, it can cause cell damage, skin damage, genetic disorders and many diseases such as cancer [1, 2].

Today, with the development of nuclear technology, ionizing radiation plays a very important role in the diagnosis and treatment of many diseases . In the medical world, the most commonly used type of ionizing radiation in imaging devices is X-rays. X-rays were discovered by Wilhelm Röntgen on November 8, 1895, and soon X-rays began to be used in medicine. In the first years of its use, its effect was not fully known, but in the following years, harmful biological effects were observed in many doctors and other healthcare workers exposed to X-rays. The devices in which X-rays are most commonly used in the field of radiology are X-ray, computed tomography (CT), mammography and scopy. Scope is an imaging device that takes simultaneous images of organs. C-arm scopy is used in cranial angiography applications. With the use of scope in medical fields, scope provides valuable information by simultaneously guiding the doctor during a surgical intervention and provides an advantage in terms of time. However, in addition to this advantage, exposure to X-rays may cause certain negative effects such as cancer in the patient. Various protective equipment (lead apron, lead live glasses, etc.) are used to prevent this radiation exposure.

Doctors send X-rays to the target organ for a specified period of time. This is achieved by operating the X-ray tube even though they require imaging throughout the operation period. X-rays are produced continuously as each imaging is taken. During this application, the patient is exposed to continuous radiation at certain intervals. As a result of the radiation to which lenses are exposed, negative biological effects such as cataract formation, lens damage and retinal vision problems may occur. These effects may vary depending on radiation dose, duration and type. Dose optimization and modern radiation protection methods are used to reduce the effects of radiation on the lens. However, it is possible for permanent eye damage to occur as a result of long-term exposure to high doses. According to the International Commission on Radiological Protection (ICRP) reports, the permissible radiation dose for the whole body and lenses is 20 mSv/year for radiation personnel, as seen in Table 1. For the public, this figure is 15 mSv.

Table 1: *Table of maximum radiation dose values.*

	Radiation Personnel (mSv)	Public (mSv)
Whole Body (Yearly)	50	1
Hands, Feet and Skin (Yearly)	500	50
Eye Lens (Yearly)	Average of 5 Years -> 20 Maximum Value in Any Year -> 50	15

Determining the levels of radiation dose obtained through natural and artificial means is of great importance. There are various methods for determining the levels of natural and artificial radiation doses, and there are numerous studies related to this matter [3-19].

This study is aimed at investigating the amount of radiation dose to which the patient's lenses are exposed during imaging with C-arm scope in cranial angiography applications. In the study conducted by Günay, O. and others in 2019, it was seen that the amount of radiation to which the patient was exposed was determined in computerized tomography (CT) [20]. However, this study will be a first in determining the radiation dose to which lenses are exposed during scopy imaging. The purpose of this study is to calculate the radiation dose to which the lenses are exposed by shooting the patient for certain periods of time (0.5-1-2-4-8 minutes) in fluoroscopy applications. In this context, it is aimed to determine the radiation dose to which the patient's eye lens is exposed. Thermoluminescence Dosimetry (TLD) will be used to calculate the radiation dose level. TLDs are small detectors that measure the radiation dose from a radioactive source. Thanks to these detectors, the radiation dose to which the eye lens is exposed will be calculated.

2. Materials and Methods

Alderson Rando Phantom (ART) was used in this study to determine the radiation level to which lenses are exposed during scopy imaging (Figure 1). The ART phantom is a common phantom used for simulated human dosimetric measurements. Approximately 10,000 ART phantoms have been used for various studies for 30 years and these phantoms follow ICRU-44 standards [20]. ART phantoms are prepared from tissue-equivalent material, molded in accordance with human anatomy. Fatom is cut horizontally into 2.5 cm thick slices, and each slice has holes that are closed with tissue equivalent pins, which can be replaced with TLD retaining pins. The material it is made of has a density of 0.985 gcm^{-3} and the phantom has the dimensions of a woman who is 155 cm tall and weighs 50 kg [1].

Figure 1. *Alderson Rando Phantom (ART)*

TLD-100 (Figure 2) thermoluminescent dosimeters are now widely used in radiation treatments, diagnostic radiology, and similar different dosimetry fields. These dosimeters have LiF, Mg, and Ti content. The dosimeters used in this study have 3.2 mm width, 3.2 mm length and 0.89 mm thickness [21]. For the calibration of the dosimeters, the dosimeters were first annealed at 400°C for 1 hour and then at 100°C for 2 hours. It was studied with those whose relative standard deviation was below 3% [22]. The calibration and post-C-arm Scope imaging evaluation of the TLD-100 dosimeters to be used in the study were carried out in the secondary standard dosimetry (SSDL) laboratory located in Cekmece Nuclear Research Center, and the reading of these dosimeters was carried out on the Harshaw 4500 computer connected to the computer with the WinREMS software in the same laboratory. Cs-137 source and Yxlon International MGC 41 model X-ray system were used in the calibration process of the Harshaw 4500 model reader. A dosimeter, which is the reference standard for radiation dose measurements, was used [1].

Figure 2. *TLD-100 Dosimeters*

C-arm fluoroscopy imaging was performed in automatic mode. In the study, Alderson Rando Phantom, which was located at Istanbul University-Cerrahpaşa Cerrahpaşa Faculty of Medicine, Radiation Oncology and was previously used by the project consultant, was used. Irradiation of the phantom was performed with a C-arm scope at Cerrahpaşa Medical Faculty. A total of 10 TLD-100 dosimeters were used in this study. Before starting the studies, TLDs were reset and calibration procedures were carried out at Çekmece Nuclear Research Center (TENMAK). In the experimental study, first of all, 2 dosimeters were placed in the lens area of the phantom (3rd section of the phantom) and images were taken with the fluoroscopy device for 0.5 minutes. Later on, these two TLD-100 dosimeters were removed from the lens part of the phantom and two new, unused dosimeters were placed in their place.

This time, images were taken with the scopy device for 1 minute. Again these two dosimeters. Again, these two dosimeters were removed from their places and two new dosimeters were placed on the lenses of the phantom and images were taken with a scopy for 2 minute. These two dosimeters were removed from the phantom and two new dosimeters were placed in the phantom and images were taken for 4 minutes this time. Lastly, these two dosimeters were removed from the phantom again and two new dosimeters were placed in the phantom and images were taken for 8 minutes this time. The remaining 2 TLD-100 dosimeters were used to determine the background radiation level in the environment. The irradiated TLDs were read and evaluated and a mathematical model was established. The graph of the data obtained against time was drawn and the scopic exposure time to reach the maximum allowable radiation dose was determined with the mathematical model.
Thus, the aim was achieved and the radiation dose to which the lenses were exposed during fluoroscopy was calculated. Thus, the aim was achieved and the radiation dose to which the lenses were exposed during fluoroscopy was calculated.

3. Results and Discussions

In the experiment, the maximum and minimum radiation values received by the inside of the right lens and the outside of the right lens were determined. The maximum radiation dose affecting the inner tissue of the right lens was determined as 1198 mSv for half a minute, 2617 mSv for 1 minute, 4893 mSv for 2 minutes, 10274 mSv for 4 minutes, and 18327 mSv for 8 minutes. The minimum radiation exposure received from TLDs placed in the right lens center is as follows; 996 mSv for half a minute, 2453 mSv for 1 minute, 4579 mSv for 2 minutes, 9183 mSv for 4 minutes and 17342 mSv for 8 minutes (table 2). The maximum radiation dose affecting the outer tissue of the right lens was determined as 1326 mSv for half a minute, 2831 mSv for 1 minute, 5214 mSv for 2 minutes, 11285 mSv for 4 minutes, and 21436 mSv for 8 minutes. The minimum radiation dose affecting the outer tissue of the right lens was determined as 1128 mSv for half a minute, 2675 mSv for 1 minute, 4921 mSv for 2 minutes, 9934 mSv for 4 minutes, and 20134 mSv for 8 minutes (table 3).

Table 2: *Values of the radiation dose that affects of the inside right lens.*

Time (minute)	**Maximum Radiation Dose (mSv)**	**Minimum Radiation Dose (mSv)**	**Average Radiation Dose (mSv)**
0.5	1198	996	1097
1	2617	2453	2535
2	4893	4579	4736
4	10274	9183	9728,5
8	18327	17342	17834.5

Table 3: *Values of the radiation dose that affects of the right lens.*

Time (minute)	**Maximum Radiation Dose (mSv)**	**Minimum Radiation Dose (mSv)**	**Average Radiation Dose (mSv)**
0.5	1326	1128	1227
1	2831	2675	2753
2	5214	4921	5067.5
4	11285	9934	10609.5
8	21436	20134	20785

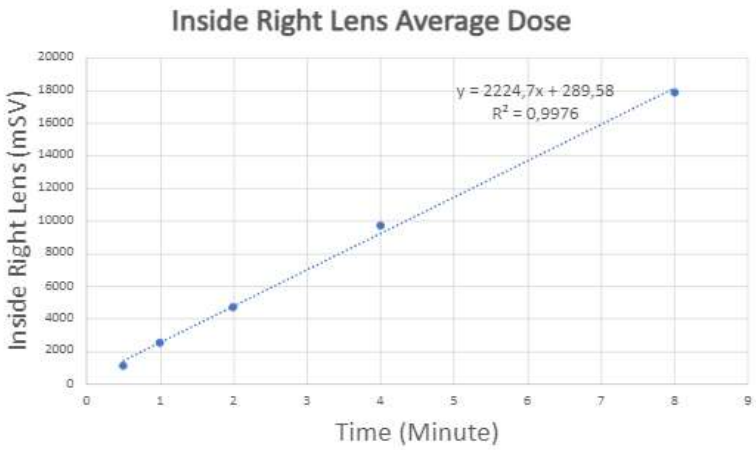

Figure 3. *Average of Inside Right Lens with R-squared value*

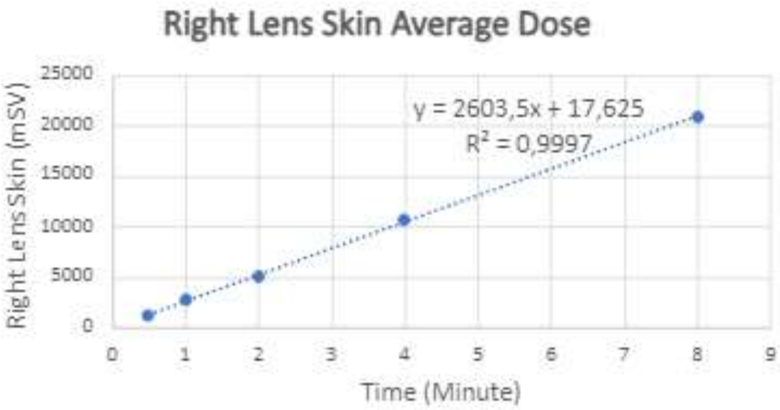

Figure 4. *Average of Right Lens Skin with R-squared value*

The averages of these radiation values obtained were calculated and the graphical results regarding the average dose values changing over time were shown (Figure 3-Figure 4). In the graph, it was determined that there was a directly proportional increase in the amount of radiation dose over time. In this case, it is concluded that the radiation dose will increase at a certain rate as time increases. Additionally, when the mSv values of the right lens interior and the right lens outer layer were compared, it was seen that the right lens outer tissue was more exposed to radiation.

R^2 values were found by calculating the equations obtained in the graph. The R^2 value of the right lens inner tissue between dose and time is 0.9976, and the R^2 value of the right lens outer tissue is 0.9997. R^2 value approaching 1 is an indication of the accuracy of the correlation in the equation. A strong correlation provides important information in the context of research or analysis. The results reveal that both the inside of the right lens and the outer layer of the right lens have a strong correlation.

Significant health benefits are likely to be achieved by increasing the dose of radiation obtained from this experiment over time. It may help to ensure that this medicinal product is applied in a controlled manner, particularly during certain treatment or examination procedures and that the radiation exposure of an individual has been carefully monitored.

Radiation emits energy into the environment in the form of electromagnetic waves or particles. It's got two types of radiation: Ionising Radiation and Notionizing Radiation. Ionising radiation was the basis for this research. This type of radiation is high-energy electromagnetic waves such as X-rays and gamma rays [23]. There are also examples of ionizing radiation from nuclear substances, such as alpha, beta and gamma. Today, medical devices such as Computed Tomography (CT), X-ray, ultrasound, and mammography used in the field of medical imaging are the devices in which this type of radiation is widely used [24]. Although radiation is a frequent source of energy for medical purposes, the mean annual exposure around the world amounts to 0.3 mSv [25]. These exposures can be caused by nuclear power generation, medical scans, and many other fields. Within the framework of ALARA principles (As Low As Reasonably Achievable), radiation levels are considered to be at a minimum that is practicable in terms of economics and social considerations [4][9].The aim is to minimize radiation doses as far as possible. The results of this study provide valuable information about the radiation dose to which the patient's lenses are exposed during C-arm imaging. The research focused on various exposure times (0.5-1-2-4-8 minutes) and radiation doses affecting both the inner and outer tissues of the right lens were carefully measured using TLD-100 dosimeters. The study contributes to the understanding of the potential risks associated with long-term exposure to ionizing radiation in medical imaging procedures. The results show that, with a longer exposure period, increases in the dose of radiation are proportional. This finding is consistent with the basic principle of ionizing radiation, in which the cumulative effects on tissues tend to increase over time. The suggestion that minimizing exposure time is essential for reducing potential adverse effects on the optical sight has been supported by a direct correlation observed in an historical graphic representation of radiation dose. Significant observations were made that the outer tissue of the right lens was exposed to a higher level of radiation than its inner tissue. This difference highlights how important it is to take into account individual tissue layers in assessing the effects of radiation. Different absorption and scattering of radiation due to variation in tissue thickness and composition may occur resulting in various doses received by each anatomical structure. Stronger correlation coefficients (R-2 values) for both internal and external tissues further confirm the reliability of the study's findings.

4. Conclusion

In conclusion, the research revealed that in medical imaging procedures eye lenses are exposed to extremely high radiation levels. The findings indicate that in order to minimize the exposure of patients, especially during long procedures, it is necessary to optimize imaging protocols. In order to provide efficient health care, while focusing attention on the protection of patients and minimizing potential risks related to ionizing radiation, it is important to continue research and further developing technological and safety protocols.

Author Statements

- **Ethical Approval:** The research conducted does not involve human or animal subjects.
- **Conflict of Interest:** The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.
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