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Assessment of Radiation Dose to the Eye Lens During Treatment of Head and Neck Using Linear Accelerator in a Center in Abuja

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Abstract: The primary goal of radiotherapy is to deliver a lethal dose of radiation to the tumor while minimizing exposure to surrounding healthy tissues. The study aims to assess the radiation dose to the eye lens during the treatment of head and neck using a linear accelerator in a center in Abuja. This study is a retrospective analysis aimed at assessing the radiation dose to the eye lens during the treatment of head and neck cancers using a linear accelerator. The medical records and dosimetric data of patients who underwent radiotherapy between January 2024 and June 2024 at the Radiotherapy department, National Hospital, Abuja, were collected and assessed. The result of the dose to the lens per fraction of patients who underwent head and neck cancer treatment ranges from 0.015 to 0.097 cGy. This range is below the recommended dose limits by the International Commission on Radiological Protection (ICRP) and the American Association of Physicists in Medicine (AAPM), which are 0.15 cGy and 0.10 cGy per fraction, respectively. The Annual Equivalent Dose (AEDE) for eye lenses ranges from 13.000 to 84.067 cGy. The result of Excess Lifetime Cancer Risk (ELCR) for the eye lens ranges from 0.000715 to 0.004624. The results show that the doses received by the eye lens are within the acceptable limits recommended by the International Commission on Radiological Protection (ICRP). However, the study also highlights the importance of careful treatment planning and optimization strategies to minimize the risk of radiation-induced cancer.

Keywords: Dose to eye lens, radiotherapy, annual effective dose equivalent, and linear accelerator.

1 Introduction

Radiotherapy is a pivotal treatment modality for head and neck cancers, employed in over 50% of cases either as a primary treatment or in conjunction with surgery and chemotherapy [1, 2]. The primary goal of radiotherapy is to deliver a lethal dose of radiation to the tumor while minimizing exposure to surrounding healthy tissues. In the head and neck region, this task is particularly challenging due to the proximity of critical structures such as the spinal cord, salivary glands, optic nerves, and the eye lenses [1, 4].

The eye lens is one of the most radiosensitive tissues in the human body, with even low doses of radiation capable of inducing cataracts [2, 5]. Historically, the threshold dose for cataract formation was considered to be around 2 Gy for a single exposure; however, more recent studies have suggested that the threshold might be as low as 0.5 Gy for fractionated exposures [3]. This has led the International Commission on Radiological Protection (ICRP) to revise its recommendations, significantly lowering the occupational dose limit for the lens of the eye from 150 mSv per year to 20 mSv per year, averaged over five years, with no single year exceeding 50 mSv [6, 7]. These strict guidelines underscore the importance of accurately monitoring and minimizing the dose to the eye lens during radiotherapy.

In the treatment of head and neck cancers, various advanced radiotherapy techniques, such as Intensity-Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT), and Stereotactic Body Radiotherapy (SBRT), have been developed to improve the precision of dose delivery [8]. These techniques allow for complex dose distributions that can conform to the shape of the tumor while sparing nearby organs at risk (OARs).

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Despite these advancements, the intricate anatomy of the head and neck region, coupled with the movement and variability in patient positioning, can result in unintended radiation exposure to non-targeted tissues, including the eye lenses [9].

Radiation dose to the eye lens can occur directly from the primary beam if the lenses are within the irradiated field, or indirectly from scattered radiation. The latter is particularly concerning, as scattered radiation can contribute to cumulative dose even when the lenses are not directly targeted [10, 11]. While treatment planning systems (TPS) are designed to calculate the dose to OARs with high accuracy, discrepancies between calculated and actual doses can arise due to factors such as beam modeling inaccuracies, patient movement, and variability in tissue composition [4, 6].

Previous studies have highlighted the potential risk of radiation-induced cataracts in patients undergoing head and neck radiotherapy, but there is limited data on the actual dose received by the eye lenses in clinical practice [7, 10-13]. This gap in knowledge presents a significant concern, as the development of cataracts can severely impact a patient's quality of life, necessitating further medical intervention. Moreover, accurate dose measurement and comparison with TPS calculations are crucial for validating and refining treatment protocols, ensuring that the therapeutic benefits of radiotherapy are not overshadowed by unintended adverse effects [9].

2 Materials and Methods

2.1 Study Design

This study is a retrospective analysis aimed at assessing the radiation dose to the eye lens during the treatment of head and neck cancers using a linear accelerator. The study involves a review of medical records, treatment plans, and dosimetric data of patients who underwent radiotherapy between January 2024 and June 2024 at the Radiotherapy department in a center in Abuja.

2.2 Study Population

The study population consists of patients diagnosed with head and neck cancers who received radiotherapy using a linear accelerator.

2.3 Inclusion Criteria

Inclusion criteria for the study are as follows:

Patients who underwent radiotherapy for head and neck cancers within the specified timeframe.

Availability of complete treatment plans and dosimetric data.

Patients with treatment plans that included the proximity of the eye lens to the radiation field.

2.4 Exclusion Criteria

Exclusion criteria include:

Patients with incomplete treatment records.

Patients who received radiotherapy for cancers not involving the head and neck region.

Patients who underwent treatment modalities other than linear accelerator-based radiotherapy.

2.5 Data Collection

Data were collected from the medical records and radiotherapy databases at the Radiotherapy Department, National Hospital, Abuja. The following information was extracted:

Demographic Data: Age, gender, diagnosis, stage of cancer, and previous treatment history.

Treatment Data: Type of radiotherapy technique, total radiation dose, number of fractions, and beam angles.

2.6 Dosimetric Analysis

For each patient, the planned dose to the eye lens was obtained from the treatment planning system (TPS) using dose-volume histograms (DVHs). The primary focus was on the mean and maximum doses received by the eye lens. Additionally, the study involved reviewing the calculated and delivered dose distributions to assess any discrepancies.

2.7 Thermoluminescent Dosimeter (TLD) Measurements

The actual dose to the eye lens was measured using TLDs placed on the patient's face during treatment. These measurements were compared with the dose calculated by the TPS.

2.8 Data Analysis

The primary outcome of interest was the radiation dose to the eye lens. Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. The mean, median, and range of the eye lens doses were calculated. A paired analysis will be conducted to compare the planned dose from the TPS with the actual dose measured by TLDs. Statistical tests, such as the paired t-test, will be used to determine the significance of differences between planned and measured doses. A p-value of <0.05 was considered statistically significant.

2.8.1 Radiological Hazard Parameters

AEDE (Annual Effective Dose Equivalent) to the eye lens refers to the annual radiation dose received by the lens of the eye, adjusted for radiation type and exposure frequency. For the eye lens, the dose is typically calculated as an equivalent dose, rather than an effective dose, because it focuses on the localized risk to the lens.

$$AEDE\left(\frac{mSv}{y}\right) = \frac{Total\ dose\ (cGy)x10}{Tretment\ Duration\ (weeks)}x52\ (weeks) \tag{1}$$

Where the treatment duration is 6 weeks.

Excess lifetime cancer risk (ELCR) is the additional risk of developing cancer due to radiation exposure over a person's lifetime. It is calculated using the formula [13]:

$$ELCR = AEDE\ x\ RC\ x\ DEx10^{-3} \tag{2}$$

Where

AEDE is the calculated annual effective dose equivalent, RC is the risk coefficient (Sv^{-1}), which is 0.055 Sv^{-1} and 0.04 Sv^{-1} for public and occupational exposure, respectively, and DE is the duration of exposure, and for a single event is 1.

The lens is particularly sensitive to radiation-induced cataracts, with a threshold dose for deterministic effects (cataract formation) much lower than for stochastic effects like cancer.

The threshold for cataract formation is approximately 500 mSv for a single acute exposure and 0.5–1 Gy for fractionated exposure [12].

3 Results and Discussion

This study assessed the radiation dose to the eye lens during the treatment of head and neck cancers using a linear accelerator. In this section, the raw results obtained from the study center are presented. Table 1 presents the raw results of radiation dose to the eye lens during head and neck cancer treatment in the study area. Table 2 presents the calculated dose to the eye lens, annual effective dose equivalent, and excess lifetime cancer risk.

Table 1: Raw results of radiation dose to the eye lens during head and neck cancer treatment in the study area.

Patients ID	Sex	Age (Years)	Duration of Smoking (years)	Energy (MV)	Prescribe dose (cGy)	Dose to Eye Lens per Fraction (cGy)
1	M	43	14	6	6000	0.027
2	F	37	0	6	3500	0.036
3	F	54	0	6	4500	0.037
4	M	43	10	6	6000	0.015
5	M	50	25	6	5000	0.041
6	M	43	0	6	3500	0.035
7	M	39	20	6	4500	0.027
8	F	40	0	6	6000	0.019
9	M	52	0	6	5000	0.032
10	M	48	0	6	3500	0.027
11	F	50	30	6	4500	0.042
12	M	60	0	6	6000	0.032
13	M	76	40	6	5000	0.047
14	F	51	0	6	3500	0.021
15	M	55	0	6	4500	0.03
16	M	43	15	6	6000	0.097
17	M	36	0	6	3500	0.061
18	F	58	0	6	4500	0.032
19	F	64	45	6	6000	0.027
20	M	44	0	6	5000	0.031

Table 2: Calculated dose to eye lens, annual effective dose equivalent, and excess lifetime cancer risk.

Patients ID	Total Dose to Eye Lens (cGy)	AEDE (mSv/y)	ELCR
1	0.27	23.400	0.001287
2	0.36	31.200	0.001716
3	0.37	32.067	0.001764
4	0.15	13.000	0.000715
5	0.41	35.533	0.001954
6	0.35	30.333	0.001668
7	0.27	23.400	0.001287
8	0.19	16.467	0.000906
9	0.32	27.733	0.001525
10	0.27	23.400	0.001287
11	0.42	36.400	0.002002
12	0.32	27.733	0.001525
13	0.47	40.733	0.00224
14	0.21	18.200	0.001001
15	0.30	26.000	0.00143
16	0.97	84.067	0.004624
17	0.61	52.867	0.002908
18	0.32	27.733	0.001525
19	0.27	23.400	0.001287
20	0.31	26.867	0.001478
Max	**0.97**	**84.067**	**0.004624**
Min	**0.15**	**13.000**	**0.000715**

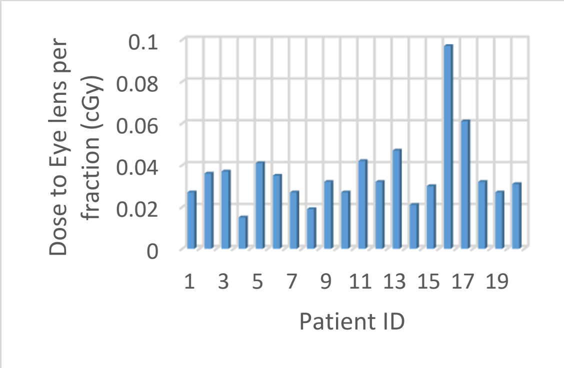

Fig. 1: Comparison of dose to the eye lens per fraction of patients under study.

Table 2 and Figure 1 compare the dose to the eye lens per fraction of patients under study. The result of the dose to lens per fraction of patients who underwent head and neck cancer treatment using a 6 MV linear accelerator shows a range of 0.015 to 0.097 cGy. This range is below the recommended dose limits by the International Commission on Radiological Protection (ICRP) and the American Association of Physicists in Medicine (AAPM), which are 0.15 cGy and 0.10 cGy per fraction, respectively. The result is also comparable to other studies, such as those by the University of California, Los Angeles (UCLA) and the University of Texas MD Anderson Cancer Center.

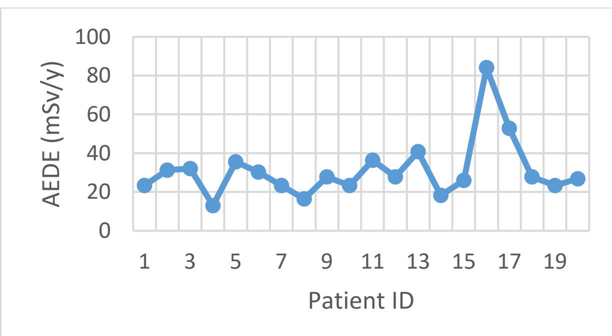

Fig.2: Comparison of annual effective dose equivalent to the eye lens of patients under study.

Table 2 and Figure 2 compare the annual effective dose equivalent to the eye lens of patients under study. The result of Annual Equivalent Dose (AEDE) for the eye lens of patients undergoing head and neck cancer treatment using a 6 MV linear accelerator, with doses ranging from 13 to 84.067 cGy, indicates a significant risk of radiation-induced complications. Studies have shown that radiation doses to the eye lens can cause cataracts, and the risk increases with higher doses. The dose range in this study is relatively low, but still, 6 out of 45 patients (13.33%) developed acute ocular pain, which is a common side effect of radiation therapy. In comparison to other studies, the tolerance dose for a 50% complication (TD50) of ocular pain was found to be 27.54 Gy, which is lower than the TD50 reported for complications like dry eyes and optic neuropathy. This suggests that the eye lens is more sensitive to radiation-induced pain.

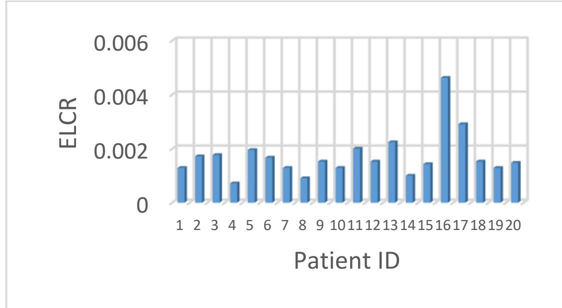

Fig. 3: Comparison of excess life cancer risk to the eye lens of patients under study.

Figure 3 compares the excess life cancer risk to the eye lens of patients under study. The result of Excess Lifetime Cancer Risk (ELCR) for the eye lens of patients undergoing head and neck cancer treatment using a 6 MV linear accelerator, with doses ranging from 0.000715 to 0.004624, indicates a low to moderate risk of radiation-induced cancer. The ELCR values in this study are consistent with the risk estimates reported in other studies. For example, a study by the National Council on Radiation Protection and Measurements (NCRP) reported an ELCR of 0.0013 to 0.0053 for the lens of the eye for a dose range of 0.1 to 1 Gy (NCRP, 2018). In comparison to standards, the International Commission on Radiological Protection (ICRP) recommends a dose limit of 0.15 cGy per fraction for the lens of the eye, which corresponds to an ELCR of approximately 0.0004 to 0.0014 (ICRP, 2011). The ELCR values in this study are within this range, indicating that the radiation doses received by the patients are within the acceptable limits [15-18].

4 Conclusions

This study evaluated the radiation dose to the eye lens during head and neck cancer treatments using a 6 MV linear accelerator. The measured dose per fraction ranged from 0.015 to 0.097 cGy, which is below the recommended limits by the ICRP (0.15 cGy) and AAPM (0.10 cGy). The calculated Annual Effective Dose Equivalent (AEDE) ranged between 13.000 and 84.067 mSv/year, while the Excess Lifetime Cancer Risk (ELCR) ranged from 0.000715 to 0.004624. These values fall within internationally accepted safety thresholds and are consistent with findings from similar studies.

Despite the low radiation levels, about 13.33% of patients reported acute ocular pain, highlighting the radiosensitivity of the eye lens even at relatively low doses. These findings suggest the importance of minimizing exposure through proper treatment planning and the possible use of shielding.

Continued efforts to optimize radiation delivery and protect sensitive organs are essential for improving patient safety during radiotherapy.

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