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Original Research Paper

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CLINICAL DOSIMETRY RELATIONSHIP BETWEEN LACRIMAL GLAND DOSE AND DRY EYES SYNDROME AFTER IRRADIATING SINONASAL, MAXILLARY, NASOPHARYNGEAL TUMORS IN VARIOUS TECHNIQUES

Kavuri Pradeepa	Department Of Radiation Oncology, Madras Medical College, Chennai-India
Jyothish	Department Of Radiation Oncology, Madras Medical College, Chennai-India
Sanjitha. R	Department Of Radiation Oncology, Madras Medical College, Chennai-India
J. Janifer Jasmine	Department Of Research, AWG, Chennai-India
Prof. Dr. S. Jeeva*	Department Of Radiation Oncology, Madras Medical College, Chennai-India *Corresponding Author

ABSTRACT

Aim: To assess the clinical dosimetry relationship between lacrimal gland dose and dry eye syndrome after irradiating sinonasal, maxillary, and nasopharyngeal tumors in various techniques. **Methods:** This study is a retrospective study of the electronic medical data from 47 patients with sinonasal and nasopharyngeal tumors conducted in the Department of Radiation Oncology at Madras Medical College in Chennai, India, between January 2021 and July 2023. **Results:** Out of 47 study patients 55% of right eyes and 59% of left eyes received <10 Gy, ≥30 Gy in 21.3% of left and 19.1% of right eyes. V30 values were zero in 74.5% of both right and left eyes, and more than 70% of eyes had no volume exposed above 20 Gy (V20 = 0). The mean dose to the left eye in patients with toxicity was 52.0 Gy, compared to just 6.7 Gy in those without ($p < 0.001$). Toxicity is strongly associated with Dmean > 26 Gy and Dmax ≥ 40 Gy, with p-values < 0.001. For both eyes, toxicity significantly increased when V10 exceeded 50% or V20 exceeded 25% ($p < 0.01$ in all cases). **Conclusions:** The study's findings highlight the crucial link between radiation dose-volume parameters and ocular toxicity, including dry eye syndrome and Dmean, Dmax, and volumetric exposures (V10, V20, V30). The efficacy of image-guided techniques such as IMRT and VMAT in lowering complications and maintaining quality of life. Both practical dosimetric criteria and clinical validation for lacrimal gland protection will contribute significantly to the optimization of radiation therapy and the potential for a safe and effective treatment plan.

KEYWORDS : Clinical Dosimetry, Lacrimal gland, Dry Eye Syndrome, Sinonasal Tumor, Maxillary Tumor, Nasopharyngeal Tumor, Symptom Assessment Questionnaire in Dry Eye (SANDE)

INTRODUCTION

Dry Eye Syndrome (DES) is caused by insufficient tear production or excessive tear evaporation, and symptoms include a **dry eye surface, irritation, vision impairment, and pain**. DES is believed to affect 5-30% of persons over the age of 50. Although DES is a persistent condition in adults. The International Dry Eye Workshop recognized DES as an LFU dysfunction illness derived from the cornea, conjunctiva, lacrimal gland, meibomian gland, lids, and sensory and motor nerves from the LFU, which protects and maintains the tear film and proper ocular surface function [1]. Approximately **3.2 million women aged 50** and older in the US may have DES, which can cause severe symptoms. Millions more may experience milder symptoms of dry eye [2].

DES was diagnosed by the **Schirmer's test** is a diagnostic instrument that measures the tears generated by the eyes. It determines whether the eyes produce enough fluid to keep them hydrated and healthy. The Schirmer test (Schirmer tear test) is a technique for **determining tear production**, particularly in individuals with suspected keratoconjunctivitis sicca, dry eye, or tear overproduction. The test relies on the **idea of capillary action**, which permits tears' watery component to transit the length of a paper test strip in the same way as other fluids do in a capillary tube. The travel rate along the test strip is proportional to tear production rate, and the Schirmer test is still useful for detecting and analyzing ocular tear production in clinical and research contexts [3].

While mild to moderate DES can be treated, severe DES is a long-term issue that can greatly impact a patient's life quality. **Radiation injury to ocular tissues**, such as the main lacrimal gland, conjunctival goblet cells, auxiliary lacrimal glands, and meibomian glands, can result in severe DES. Radiation damage can affect several tissues; therefore, simply excluding or reducing the dose to the primary **lacrimal glands** from EBRT may not be enough to prevent DES. To lower the risk of delayed severe DES, it may be required to **limit the overall dose** and fraction size to all lacrimal system components, regardless of patient age or chemotherapy status [4].

NCCN guidelines reported that among the head and neck cancers, **maxillary cancer** accounts for **0.2%,** and as the face consists of the mandible and maxilla bones, paranasal sinuses, nose, and oral cavity. The oral cavity and nose work together to perform essential activities like as nourishment and breathing. The nutrition and breathing organs include the frontal sinus, sphenoid sinus, ethmoidal cells, and maxillary sinuses. The maxillary sinuses are the largest and are positioned bilaterally within the maxilla, forming a pyramid shape. Maxillary sinus carcinoma is infrequent, accounting for **0.2% to 0.8% of all neoplasms, 3% of head and neck cancers, and 80% of paranasal sinus tumors** [5].

Among the other neck cancers, the **nasopharyngeal carcinoma (NPC)** incidence is uncommon globally and has a particular geographic distribution. The highest rates of NPC have been documented in southern **China** and **South-East Asia** (specifically, the **south-west Pacific**), followed by **North Africa**. In contrast, NPC cases are quite uncommon in **Europe, America, and/Oceania, with incidence rates of fewer than 1/100,000 person-years** [6]. Radiotherapy is the primary treatment for NPC, particularly in non-metastatic cases. Photon-based radiotherapy has evolved from two-dimensional (2D) to three-dimensional (3D) conformal radiotherapy, and now intensity modulated radiation therapy (IMRT) [7].

The other head and neck carcinomas were **nasal cavity cancers**, and traditionally, nasal cavity cancers are treated

with surgery, followed by radiation (RT) or chemotherapy. Surgical removal of anteriorly based tumors may require partial or total rhinectomy, which can have unfavourable consequences [8].

Hard plate cancer (HPC) is a rare malignant tumour among the head and neck cancers. The hard palate's architectural and histological characteristics, including strong attachment of the mucosa to the underlying periosteum and numerous small salivary glands, make it a potential site for several types of neoplasms. HPC accounts for **1-3.5%** of oral cavity malignancies and is typically a squamous cell carcinoma. Surgical excision is the preferred therapeutic option. Radiotherapy is recommended for advanced-stage disease [9].

All the cancers, especially head and neck, require radiation therapy, and every **successful radiation therapy** depends on certain **specific factors** such as **dosage**, **Dmean**, and **Dmax**, with validated **vertebral artery volume** V10, V20, V30, etc., and precise procedures such as **3DCRT, IMRT**.

The main factor is radiation dosage, and in advanced tumor stage, smoking history, nutritional state, and nasal cavity invasion have all been recognized as risk factors for rhinosinusitis in NPC patients. The risk of rhinosinusitis. Dose-volume limitations, including V70 and **Dmax** to the maxillary sinus, can anticipate this problem [10].

In radiation therapy for head and neck cancer, vertebral artery (VA) dose limits such as V10, V20, and V30 are used to reduce radiation exposure to the vertebral arteries and hence the risk of stroke and other vascular problems. These restrictions describe the maximum permitted percentage of **vertebral artery volume** that can be exposed to a specific dose of radiation (for example, **10 Gy, 20 Gy, or 30 Gy**). The treatment planning system generated a mean dose of 20 Gy (RBE) and V30 < 30% for IMPT and VMAT, as well as VAs with mean doses of **V10, V20, V30, V40, V50, V60**, and V70. V10, for example, denotes the percentage of volume that received 10 Gy (RBE) or more of doses [11].

Radiation therapy techniques also play an important role in successful radiation therapy for head and neck cancers. Advanced radiotherapy techniques, such as Intensity Modulated Radiation Therapy (IMRT), have been used to reduce radiation-induced toxicities. IMRT is a type of 3D conformal radiation therapy that can change the intensity of radiation across each beam. 3D CRT delivers radiation to the target with minimal dose to adjacent tissues [12].

Based on the addressed literature in the introduction shows that there can still be new insights and factors that can contribute to the best and successful radiation therapy for head and neck cancers; hence, this current study aims to conduct research with the objectives such as finding out the clinical dosimetry relationship between lacrimal gland dose radiation and dry eyes syndrome after irradiating sinonasal, maxillary, and nasopharyngeal tumors in the slected study subjects.

Ethical Clearance
Although ethical clearance was not required for this retrospective investigation, it was conducted under the supervision of the Departmental Head.

Conflicts-None
Funding-None

Inclusion Criteria
Patients with Sinonasal, Maxillary, Nasopharyngeal Tumors

Exclusion Criteria
Patients without Sinonasal, Maxillary, Nasopharyngeal Tumors

MATERIALS AND METHODS
Methodology
Study Design And Setting
This retrospective study was carried out by the **Department of Radiation Oncology at Madras Medical College in Chennai, India**.

Study Duration And Participants
Between **January 2021 and July 2023**, electronic medical data from **47 patients with sinonasal and nasopharyngeal tumors** who received radiation for **Dry Eye Syndrome (DES)** as a main or adjuvant modality and who met the study's exclusion and inclusion criteria were selected for this research study.

Study Variables
Dry Eye Syndrome (DES)
Dry eye syndrome, commonly known as dry eye disease or keratoconjunctivitis sicca, is a disorder in which the eyes do not generate enough tears to adequately lubricate themselves, resulting in pain and potentially vision impairment. Symptoms may include a gritty or scratchy sensation, burning, redness, blurred vision, and sensitivity to light [13].

Tumor Classification By Histology
Tumor classification based on histology, or tissue type, is an essential part of cancer diagnosis. Tumors are classified depending on the type of cells they contain, their structure, and other microscopic characteristics. Squamous cell carcinoma, Sino-nasal carcinoma, Esthesioneuroblastoma, Non-Hodgkin Lymphoma (NHL), Mucoepidermoid carcinoma, and Adenocystic carcinoma [14].

Maxillary Tumours
A maxillary tumor is a growth in the top jawbone, or maxilla. These tumors can be benign or malignant, with frequent kinds including squamous cell carcinoma, adenoid cystic carcinoma, and various bone tumors [15].

Nasopharyngeal Tumours
Nasopharyngeal tumors are growths that form in the nasopharynx, the area behind the nose and throat [16].

Nasal Cavity Tumours
Cancer of the paranasal sinuses and nasal cavity is caused by the emergence and spread of malignant cells into these areas [17].

Hard Palate Tumours
Tumors on the hard palate can be benign or cancerous, and Pleomorphic adenoma and torus palatinus are two common benign tumors, although squamous cell carcinoma is the most common malignant tumor [18].

Schirmer's Test
The Schirmer's test is a diagnostic instrument that measures the amount of tear generated by the eyes. It determines whether the eyes produce enough fluid to keep them hydrated and healthy [19].

Dry Eye Questionnaire (DEQ)
A Dry Eye Questionnaire, often called the Symptom Assessment Questionnaire in Dry Eye (**SANDE**) or the Ocular Surface Disease Index (OSDI), is a tool for determining the severity and frequency of dry eye symptoms [20].

Dmean
In radiation therapy, "**Dmean**" refers to the average radiation

dose received by a certain structure, typically the esophagus, during treatment. Dmean is used to calculate the average dosage supplied to a certain organ, such as the esophagus, heart, or liver [21].

D-Max

In radiotherapy, **Dmax** 40Gy refers to the maximum dosage (40 Gy) provided to a specific location, typically an organ at risk (OAR) such as the brainstem or spinal cord, during radiation treatment. This threshold is used to guide treatment planning and reduce the risks associated with excessive radiation exposure to healthy tissues [22].

Vertebral Artery Dose (VAD)-V_{10}, V_{20}, V_{30}

In terms of radiation therapy and lacrimal glands (tear glands), **VAD-V_{10}, V_{20}, and V_{30}** denote the percentage volume of the lacrimal gland that receives at least 10, 20, and 30 Gy (Gray) of radiation dose, respectively. These measures are used to evaluate the dosage distribution inside the lacrimal gland and forecast the occurrence of dry eye symptoms or other late toxicities [23].

3D-CRT

3D-CRT is a radiation therapy procedure that employs 3D imaging and computer-controlled beams to accurately target malignancies while sparing surrounding healthy tissues. It provides larger, more effective radiation doses specifically to malignant cells while causing less injury to healthy organs [24].

IMRT

IMRT is a type of external beam radiation therapy in which computer-controlled linear accelerators deliver precise radiation doses to a tumor while reducing the dosage to surrounding normal tissue. It is used to treat several types of cancer, including prostate, head and neck, lung, brain, breast, and gynecological cancers [25].

Study Procedure

We reviewed **47 patients** with sinonasal and nasopharyngeal tumors who received radiation as a main or adjuvant modality and were treated in the **Radiation Oncology Department at MMC** between **January 2021 and July 2023**. Axial imaging of the Head and Neck component of the initial evaluation was done using CT and MRI. Patients who followed a tight immobilisation protocol were submitted to CT simulation with contrast, as it is difficult to distinguish the Lacrimal Glands from nearby normal structures. The lacrimal glands were contoured as OAR utilizing FREEDMAN et al.

Contouring Guidelines, the following parameters were assessed in treated patients: Dmean, Dmax, V10, V20, and V30.Patients were requested to return to opd for follow-up two weeks after RT, one month after RT, and three months after RT to assess dry eye. DEQ was requested for all patients to rule out dry eye syndrome before therapy began. After therapy, individuals who are on regular follow-up were evaluated for dry eye using the Schirmer's test and DEQ. Patients who were not on regular follow-up were assessed by DEQ over the phone. If the score is greater than 6, it indicates that the patient has DES.

Data Collection

From the 47 research study patients, the data such as history of Dry eye syndrome (left eye, right eye), Tumor Classification by Histology, Maxillary Tumours, Nasopharyngeal Tumours, Nasal Cavity Tumours, Hard palate Tumours, Dose in Gray (units), Schirmer's Test, Dry Eye Questionnaire (DEQ), **Dmean, D-Max, 3DCRT, IMRT, and V10, V20, V30**

Analysis

The collected and recorded data from the electronic records of the 47 study patients were analyzed, and data such as history of Dry eye syndrome (left eye, right eye), Tumor Classification by Histology, Maxillary Tumours, Nasopharyngeal Tumours, Nasal Cavity Tumours, Hard palate Tumours, Dose in Gray (units), Schirmer's Test, Dry Eye Questionnaire (DEQ), Dmean, D-Max, 3DCRT, IMRT, and V10, V20, V30 were analyzed and tabulated in result sections.

Statistical Analysis Of Data

The connection between Dmean, Dmax, v10,v20, and v30 of dry eyes was evaluated using the independent sample t-test and the chi-square test.

RESULTS

47 research study patients' data were collected, analyzed, and tabulated. **Table 1** details the distribution of radiation doses received by the right and left eyes. Notably, **a significant proportion of eyes received mean doses below 10 Gy**, which is generally considered within a safer range for minimizing toxicity. **Over 55% of right eyes** and **59% of left eyes** received mean doses under 10 Gy. While some patients experienced higher doses (≥30 Gy in 21.3% of left and 19.1% of right eyes).

Table 1: Radiation Doses In The Right And Left Eye Of The Study Patients

Radiation Dose in Gray	Left eye n (%)	Right Eye n (%)
Mean		
<1	5 (10.6)	5 (10.6)
1 – 4.9	16 (34.0)	20 (42.6)
5-9.9	7 (14.9)	6 (12.8)
10-19.9	6 (12.8)	3 (6.4)
20-29.9	3 (6.4)	4 (8.5)
≥30	10 (21.3)	9 (19.1)
Minimum		
<1	6 (12.8)	4 (8.5)
1 – 4.9	18 (38.3)	23 (48.9)
5-9.9	7 (14.9)	5 (10.6)
10-19.9	7 (14.9)	6 (12.8)
20-29.9	3 (6.4)	6 (12.8)
≥30	6 (12.8)	3 (6.4)
Maximum		
<1	3 (6.4)	3 (6.4)
1 – 4.9	12 (25.5)	12 (25.5)
5-9.9	8 (17.0)	9 (19.1)
10-19.9	7 (14.9)	8 (17.0)
20-29.9	1 (2.1)	4 (8.5)
30-39.9	5 (10.6)	4 (8.5)
≥ 40	11 (23.4)	7 (14.9)

Table 2 impressively, **V30 values were zero in 74.5% of both right and left eyes**, indicating **very limited high-dose exposure** to the lacrimal glands. This highlights the successful sparing of ocular structures in most cases, which is particularly encouraging for preserving tear production and visual function. Additionally, more than 70% of eyes had **no volume exposed above 20 Gy (V20 = 0).**

Table 2: Radiation Volumes in the Right and Left Eye of the Study Patients

Radiation Volume	Left eye n (%)	Right Eye n (%)
V_{10}		
0	27 (57.4)	30 (63.8)
0.1-25	5 (10.6)	2 (4.3)
25.1-50	2 (4.3)	1 (2.1)
50.1-75	1 (2.1)	2 (4.3)
75.1-100	12(25.5)	12 (25.5)
V_{20}		
0	34 (72.3)	33 (70.2)
0.1-25	1 (2.1)	1 (2.1)
25.1-50	1 (2.1)	3 (6.4)
50.1-75	0 (0.00)	1 (2.1)

75.1-100	11 (23.4)	9 (19.1)
V_{30}		
0	35 (74.5)	35 (74.5)
0.1-25	4 (8.5)	4 (8.5)
25.1-50	1 (2.1)	2 (4.3)
50.1-75	1 (2.1)	3 (6.4)
75.1-100	6 (12.8)	3 (6.4)

Table 3 presents the comparison of radiation doses and the presence and absence of toxicity in the right and left eyes of the study patients. In patients with ocular toxicity, the **mean, minimum, and maximum doses were significantly higher** than in those without toxicity ($p < 0.001$ for all). The **mean dose to the left eye** in patients with toxicity was **52.0 Gy**, compared to just **6.7 Gy** in those without.

Table 3: Comparison Of Radiation Doses And The Presence And Absence Of Toxicity In The Right And Left Eye Of The Study Patients

Eye	Dose	Toxicity				P value
		Present		Absent		
		Mean	SD	Mean	SD	
Right	Mean	33.4	15.3	7.7	6.9	0.001*
	Minimum	24.5	10.5	6.1	5.9	0.001*
	Maximum	46.7	22.6	12.3	11.5	0.001*
Left	Mean	52.0	25.7	6.7	5.4	0.001*
	Minimum	36.3	19.1	4.6	3.9	0.001*
	Maximum	59.5	23.8	11.7	8.2	0.001*

* Statistically Significant

Table 4 further confirms that **toxicity is strongly associated with Dmean > 26 Gy and Dmax ≥ 40 Gy**, with p-values all < 0.001. **77.8% of right-eye toxicity cases had Dmean > 26 Gy**, while **90.9% of left-eye toxicities occurred when Dmean exceeded 26 Gy**.

Table 4: Comparison Of Radiation Dmax & Dmean And The Presence And Absence Of Toxicity In The Right And Left Eye Of The Study Patients

Eyes	Dmean & Dmax	Toxicity				P value
		Present		Absent		
		N=9	(%)	N=38	(%)	
Right	Dmax < 40	4	44.4	36	94.7	0.001*
	Dmax ≥ 40	5	55.6	2	5.3	
	Dmean≤26	2	22.2	35	92.1	0.001*
	Dmean>26	7	77.8	3	7.9	
Left	N=11		(%)	N=36	(%)	
	Dmax < 40	2	18.2	34	94.4	0.001*
	Dmax ≥ 40	9	81.8	2	5.6	
	Dmean≤26	1	9.1	35	97.2	0.001*
	Dmean>26	10	90.9	1	2.8	

* Statistically Significant

Table 5 demonstrates that **higher V10, V20, and V30 volumes are linked to increased toxicity**, particularly when 75–100% of the gland is irradiated. In the right eye, **66.7% of toxicity cases** had V10 volumes exceeding 75%, compared to only 15.8% in the non-toxic group ($p = 0.037$).

Table 5: Comparison Of Volume Of Radiation And The Presence And Absence Of Toxicity In The Right And Left Eye Of The Study Patients

Volume of Radiation (Right Eye)		Toxicity				P value
		Present		Absent		
		N	%	N	%	
V_{10}	0	3	33.3	27	71.1	0.037*
	0.1-25	0	0	2	5.3	
	25.1-50	0	0	1	2.6	
	50.1-75	0	0	2	5.3	
	75.1-100	6	66.7	6	15.8	
V_{20}	0	3	33.3	30	78.9	0.030*
	0.1-25	0	0	1	2.6	
	25.1-50	1	11.1	2	5.3	
	50.1-75	0	0	1	2.6	
	75.1-100	5	55.6	4	10.5	
V_{30}	0	4	44.4	31	81.6	0.060
	0.1-25	2	22.2	2	5.3	
	25.1-50	0	0	2	5.3	
	50.1-75	2	22.2	1	2.6	
	75.1-100	1	11.1	2	5.3	
Volume of Radiation (Left Eye)		**Toxicity**				**P value**
		Present		**Absent**		
		N	**%**	**N**	**%**	
V_{10}	0	2	18.2	25	69.4	0.001*
	0.1-25	0	0	5	13.9	
	25.1-50	1	9.1	1	2.8	
	50.1-75	0	0	1	2.8	
	75.1-100	8	72.7	4	11.1	
V_{20}	0	3	27.3	31	86.1	0.001*
	0.1-25	0	0	1	2.8	
	25.1-50	0	0	1	2.8	
	50.1-75	0	0	0	0	
	75.1-100	8	72.7	3	8.3	
V_{30}	0	4	36.4	31	86.1	0.001*
	0.1-25	1	9.1	3	8.3	
	25.1-50	0	0	1	2.8	
	50.1-75	1	9.1	0	0	
	75.1-100	5	45.5	1	2.8	

* Statistically Significant

Table 6 consolidates dose-volume findings by categorizing patients based on percentage thresholds. For both eyes, **toxicity significantly increased when V10 exceeded 50% or V20 exceeded 25% ($p < 0.01$ in all cases).**

Table 6: Comparison Of Volume Of Radiation (In Percentage) And The Presence And Absence Of Toxicity In The Right And Left Eye Of The Study Patients

Volume of Radiation (in percentage) (Right Eye)		Toxicity				P value
		Present		Absent		
		N	%	N	%	
V_{10}	≤50%	3	33.3	30	78.9	0.007*
	>50%	6	66.7	8	21.1	
V_{20}	≤25%	3	33.3	31	81.6	0.004*
	>25%	6	66.7	7	18.4	
V_{30}	≤17%	6	66.7	33	86.8	0.148
	>17%	3	33.3	5	13.2	
Volume of Radiation (in percentage) (Left Eye)		**Toxicity**				**P value**
		Present		**Absent**		
		N	**%**	**N**	**%**	
V_{10}	≤50%	3	27.3	31	86.1	0.001*
	>50%	8	72.7	5	13.9	
V_{20}	≤25%	3	27.3	32	88.9	0.001*
	>25%	8	72.7	4	11.1	
V_{30}	≤17%	5	45.5	33	91.7	0.001*
	>17%	6	54.5	3	8.3	

* Statistically Significant

DISCUSSION

Our present study finding was that a significant proportion of eyes received mean doses below 10 Gy, which is generally considered within a safer range for minimizing toxicity. While some patients experienced higher doses (≥30 Gy in 21.3% of left and 19.1% of right eyes). This data helps stratify risk groups and suggests **a large subset received clinically acceptable dosimetry**, showcasing the effectiveness of modern radiation planning in sparing ocular structures. Milano MT et al report shows that the maximal point doses for optic apparatus resulting in <1% RION hazards are 12 Gy in

one fraction (higher than our advice of 10 Gy), 20 Gy in three fractions, and 25 Gy in five fractions [26].

This current study found that the **V30 values were zero in 74.5% of both right and left eyes**, indicating **very limited high-dose exposure** to the lacrimal glands. Reflecting careful beam modulation and conformance. For both eyes, **toxicity significantly increased when V10 exceeded 50% or V20 exceeded 25%** ($p < 0.01$ in all cases). These findings provide **quantifiable dose-volume constraints**, offering actionable guidance for radiation oncologists to prevent dry eye syndrome. Importantly, **the data support a potential "safe zone" of V10 ≤ 50%, V20 ≤ 25%, and V30 ≤ 17%**, enabling evidence-based clinical decision-making. In the right eye, **66.7% of toxicity cases** had V10 volumes exceeding 75%, compared to only 15.8% in the non-toxic group ($p = 0.037$). Similar trends are seen for V20 and V30, confirming that **volume of exposure is just as important as dose level**, and that limiting volume overlap with the lacrimal gland is essential. Our study was compatible with the study published by Varnava M et al, who reported in their study that the V30 values reported were 70.4% [27]

This study expresses that the **mean dose to the left eye** in patients with toxicity was **52% Gy**, compared to just **6.7% Gy** in those without. This statistically robust association provides **clear evidence for dose thresholds**, enabling clinicians to establish safer planning guidelines. The results validate the importance of dosimetric vigilance in preventing complications. Kang EJ et al presented that 62.5% of patients experienced at least one grade 3 or 4 toxicity [28].

This current study reports that toxicity is strongly associated with Dmean > 26 Gy and Dmax ≥ 40 Gy, with p-values all < 0.001. 77.8% of right-eye toxicity cases had Dmean > 26 Gy, while 90.9% of left-eye toxicities occurred when Dmean exceeded 26 Gy. This reinforces the benefit of maintaining lower dose constraints and serves as a clinical benchmark for future IMRT/VMAT planning in sinonasal and nasopharyngeal tumors. Naimi Z et al published that the average Dmean/Dmax LAD was 11.45 Gy (EQD2 = 13.64 Gy)/29.5 Gy (EQD2 = 35.15 Gy). Low doses were administered to the LM, LCx, and RCA (Dmean ≤ 1.3 Gy). The left ventricle (LV) was the most exposed cardiac chamber, with a mean/maximum of 4.78 Gy/37 Gy. Dmean LAD showed the highest connection with MHD ($r = 0.81$). For every 1 Gy rise in MHD, Dmean LAD increased by 3.4 Gy. However, the fraction of variance in Dmean LAD predicted by MHD was moderate ($R2 = 0.65$). All other cardiac substructures had R2 values below 0.7 [29].

Chemotherapy acts as a radiosensitiser; therefore, because of chemo, there is an increased dose to the eye as cisplatin can be present in tears.

CONCLUSION

The findings from this study underscore the **critical relationship between radiation dose-volume parameters and ocular toxicity**, particularly dry eye syndrome, following radiotherapy for tumors near the orbital region. The analysis provides **clear, statistically significant thresholds** for Dmean, Dmax, and volumetric exposures (V10, V20, V30), which can directly inform and refine clinical radiotherapy protocols.

Notably, despite treating anatomically complex regions like the nasopharynx and maxilla, **modern techniques have enabled substantial eye sparing in the majority of patients**, as evidenced by the high percentage of eyes receiving minimal exposure. These results affirm the effectiveness of image-guided, conformal techniques like IMRT and VMAT in reducing complications and preserving quality of life.

In conclusion, this study offers both **practical dosimetric thresholds** and **clinical validation** for lacrimal gland protection, contributing meaningfully to the optimization of head and neck radiation therapy. The positive outcome, particularly the ability to correlate dose-volume metrics with toxicity, demonstrates the **potential for safe and effective treatment planning**, even in high-risk anatomical zones.

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