

## Evaluation of the Lens-absorbed Dose of the Scattered Radiation Generated During Tomotherapy IMRT to the H&N Cancer Patient

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This paper uses a glass dosimeter to evaluate the lens-absorbed dose of scattered radiation generated in tomotherapy intensity modulated radiation therapy (IMRT). The head and neck portion of the rando phantom was subjected to a CT scan. The tomotherapy plan was designed to ensure delivery of the prescribed total 70 Gy day 2.2 Gy. With the lens portion of the glass dosimeter, a 5mm bolus was subjected to the scattered radiation treatment, and the dose was measured in each of the three megavoltage CT (MVCT) modes. The result is multiplied by 30 times and was determined once as the mean value. The measurement at the MVCT Coarse mode is RT mode 10.797 mGy, that for the Normal mode is 13.360 mGy, for the Fine mode is a maximum of 22.872 mGy, and for the treatment mode is 895.830 mGy. A small amount of scattered radiation in the MVCT is measured in the lens scattered radiation, but scattered radiation during treatment was measured to be near 1 Gy on the lens. Compared to a one-time radiation treatment of 2.2 Gy, the survey showed something unexpected in that it was half the value of that research to the patient. Therefore, will be aware of how much of an influence there will be on sensitive organs, such as the lens by scattered radiation generated during intensity modulated radiation therapy.

**Keywords :** scattered radiation, IMRT (intensity modulated radiation therapy), absorbed dose, tomotherapy, MVCT (megavoltage CT)

### 1. Introduction

Treatment for head and neck cancer (H & N Cancer) involves a combination of radiotherapy and chemotherapy. Radiation therapy has been developed into intensity modulated radiation therapy (IMRT), which is performed through conventional 2D radiotherapy and 3D stereotactic radiotherapy [1]. The head and neck are complicated, with various organs, and a pencil beam can be designed to control the intensity of the radiation therapy in various organs and to achieve local control of the initial head and

neck cancers (T1, T2) (T3, T4). 44-73 % of patients with advanced head and neck cancer (87-100 %) showed better response to other types of site radiotherapy, and the patient was easily fixed using an aquaplast mask (WFR-Aquaplast/Qfix System, Avondale, pennsylvania) that makes treatment possible [2]. However, the scattering line generated during the megavoltage CT (MVCT) scan and the radiotherapy process are anticipated to expose radiation-sensitive organs. When an absorbed dose other than the computerized treatment plan is given to a patient, critical organs including the spinal cord, brainstem, optic nerve, optic disc, parotid gland, and lens can be included, depending on the size and location of the tumor. Among various organs, the lens is an important structure that is located in the anterior part of the eye, and it is transparent

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to the iris behind it and collects light. The lens is 4 mm in thickness, 9 mm in diameter, and is convex on both sides. It is sensitive to radiation, so a careful observation of absorbed doses should minimize the risk of secondary radiation injury, such as cataract or lens opacity, to ensure maximum quality of life after treatment [3]. Recent studies have shown that the lens located near the surface of the body is at risk of cataracts at 4 Gy and that lens opacity that may occur at 0.5-2 Gy, with a reduction in the threshold dose as radiation therapy proceeds [4]. In addition, caution should be exercised when acquiring images for imaging-guided radiation therapy because 5 % of 5-year-long adverse effects may occur when 10 Gy is exceeded for the lens during radiotherapy [5].

## 2. Subjects and Method

### 2.1. CT simulation

The aquaplast mask was prepared using a phantom (Anderson rando phantom, USA), and a 2.5 mm slice thickness CT scan was performed to cover the neck to the head (LightSpeed RT 16, General Electric, USA).

### 2.2. Treatment RT Planning

Contouring the patient's tumor location and size from the acquired image was planned in Phantom, so that no dose was absorbed by the lens in the treatment plan. The Clinical Target Volume (CTV) has a margin of 3 mm for the gross tumor volume (GTV), and the target volume for planning (PTV) is 95 % for 70 Gy in CTV + 3 mm (Tomotherapy, Inc, USA) (Fig. 1, Radiation therapy). The daily doses and total number of doses may vary depending on the patient's progression stage and size. However, the baseline attempt was made at 18 Gy per day at 2.2

Gy, and 12 doses added to 2.4 Gy. However, since this study focuses on scattering lines that can occur in intensity modulated radiotherapy, treatment is assumed to be performed at 2.2 Gy for the same 10 times.

### 2.3. Measurement method of absorbed dose of cataract

To accurately measure the radiation, the glass dosimeter was calibrated by irradiating 6 mGy to the glass element using standard source 137Cs. To remove the background value of the glass dosimeter (GD-352M, CHIYODA TECHNOL CORPORATION), the glass dosimeter was annealed at 400 °C for 2 hours. The measured device was measured by preheating at 80 °C for 1 hour before the reading the dose value. FDG-1000 (CHIYODA TECHNOL CORPORATION) was used as the reading instrument for the glass dosimeter.



Fig. 2. (Color online) Mega Voltage Computed Tomography.

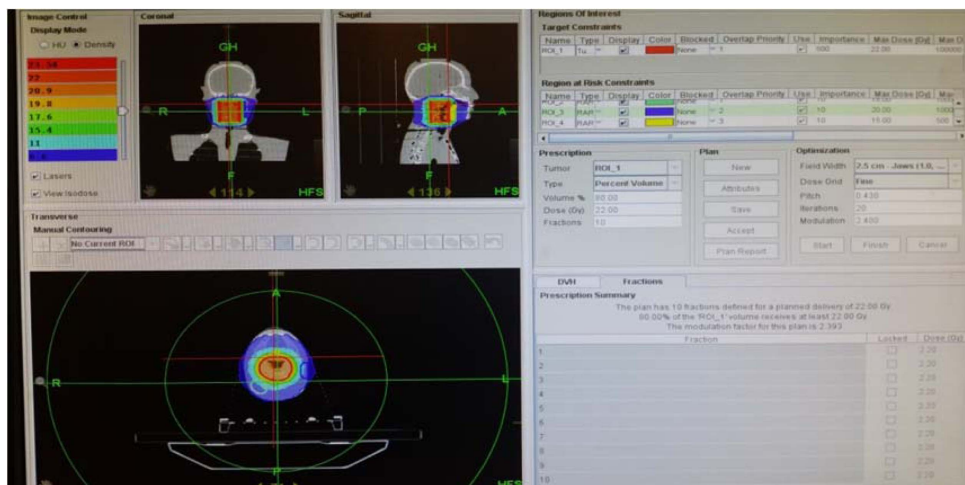
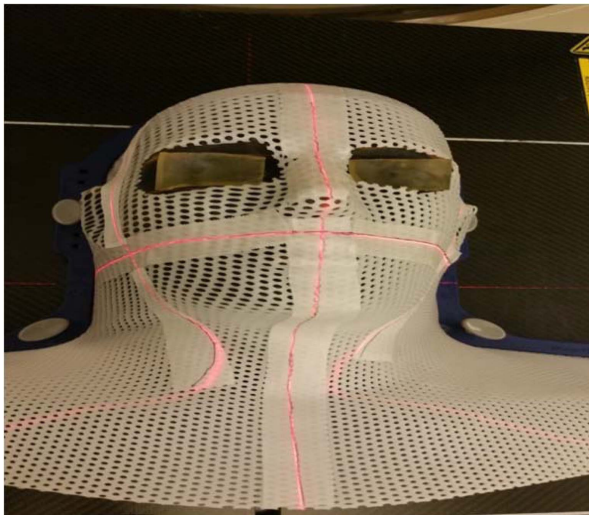


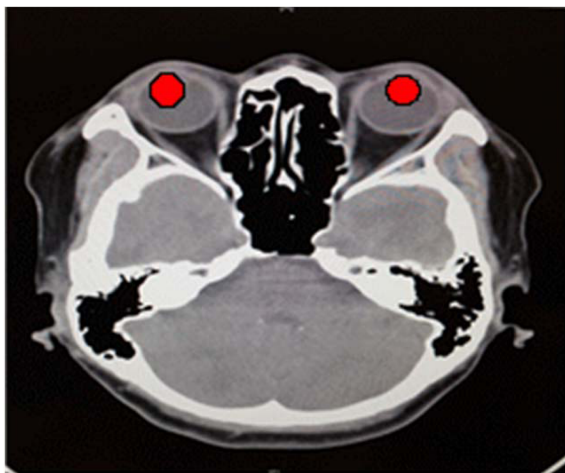
Fig. 1. (Color online) Treatment RT Planning.

**Table 1.** Megavoltage CT Irradiation condition.

Exposure conditions	Exposure thickness (mm)	Exposure time (sec)	Energy	Jaw size (mm)
Fine	2	206	3.5 MV	4
Normal	4	116	3.5 MV	4
Coarse	6	81	3.5 MV	4



**Fig. 3.** (Color online) 5 mm Bolus apply.



**Fig. 4.** (Color online) Location of glass dosimeter.

**2.4. Method of measuring dose**

Tomotherapy HD generally uses 6 MV of single energy for treatment and 3.5 MV for the MVCT scan. The MVCT Scan has three modes – coarse, normal, and fine – which capture images as the couch moves during one rotation of the Gantry, and these usually consisting of 6 mm (coarse), 4 mm (normal), and 2 mm (fine) (Fig. 2) (Table 1). A 5-mm bolus was placed on the left side of the phantom's

eye and the anatomical structure of the lens. The measurement was repeated ten times in three modes with MVCT, 10 times, and the average value was calculated by summing all results (Figs. 3, 4).

**3. Result**

In the case of Tomotherapy MVCT, the measured value of the absorbed dose of the lens is 0.360 mGy for coarse, 0.336 mGy for LT, 0.446 mGy for normal, 0.412 mGy for RT, 0.762 mGy for RT, and LT 729 mGy for fine (Tables 2-4). The measured value is the average value measured ten times, and the difference between the average value of coarse and fine measurements is about two times at maximum. Since the total treatment plan is established more than 30 times to treat head and neck cancer, the

**Table 2.** Coarse megavoltage CT Crystal scattering ray absorption dose. (Unit: mGy)

Number of measurements	Coarse	
	Rt lens	Lt lens
1st	0.394	0.335
2nd	0.399	0.335
3rd	0.367	0.323
4th	0.368	0.324
5th	0.333	0.327
6th	0.329	0.328
7th	0.356	0.350
8th	0.359	0.350
9th	0.345	0.345
10th	0.349	0.346
Mean	0.360	0.336
30 frac.	10.797	10.089

**Table 3.** Normal megavoltage CT lens scattered radiation absorbed dose. (Unit: mGy)

Number of measurements	Normal	
	Rt lens	Lt lens
1st	0.492	0.438
2nd	0.487	0.433
3rd	0.431	0.434
4th	0.429	0.435
5th	0.446	0.427
6th	0.445	0.424
7th	0.401	0.368
8th	0.402	0.370
9th	0.462	0.395
10th	0.461	0.396
Mean	0.446	0.412
30 frac.	13.368	12.360

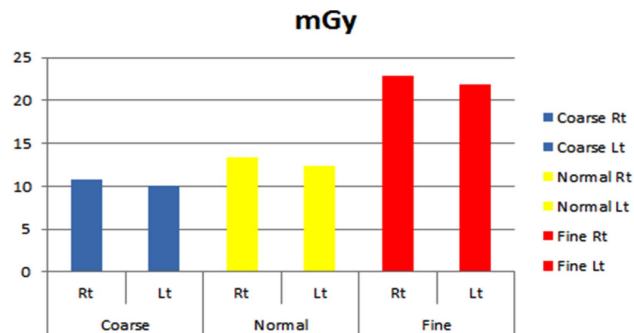
**Table 4.** Fine megavoltage CT lens scattered radiation absorbed dose. (Unit: mGy)

Number of measurements	Fine	
	Rt lens	Lt lens
1st	0.786	0.728
2nd	0.778	0.734
3rd	0.765	0.740
4th	0.677	0.702
5th	0.680	0.699
6th	0.833	0.764
7th	0.829	0.767
8th	0.748	0.718
9th	0.749	0.721
10th	0.779	0.723
Mean	0.762.4	0.730
30 frac.	22.872	21.888

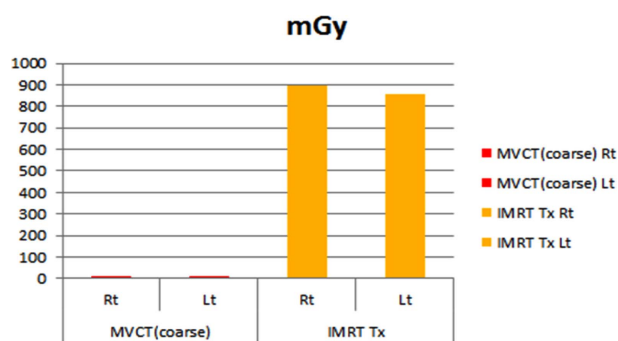
**Table 5.** Tomotherapy Lens scattered radiation absorbed dose. (Unit: mGy)

Number of measurements	IMRT Tx	
	Rt lens	Lt lens
1st	30.710	28.620
2nd	30.780	28.600
3rd	27.910	29.550
4th	30.940	31.960
5th	30.900	31.940
6th	30.160	26.390
7th	31.550	26.370
8th	27.490	26.400
9th	27.440	26.380
10th	30.730	28.580
Mean	29.861	28.479
30 frac.	895.830	854.370

absorbed dose generated by acquiring the pre-treatment image is 30 times the average measurement value, and the maximum is RT 22.872 mGy, LT 21.888 mGy, and the minimum is RT 10.797 mGy, LT 10.089 mGy (Table 2) (Fig. 5). Intensity modulated radiotherapy was used to measure the amount of absorbed dose of the lens at RT 29.296 mGy, and LT 28.479 mGy, respectively. This measurement is the average value measured ten times. In addition, since the total treatment was applied more than 30 times, the amount of absorbed dose of the lens produced during treatment is 308 times the average value, resulting in RT 895.83 mGy and LT 854.37 mGy. Assuming 30 times of MVCT and tomotherapy radiation treatment, the maximum dose of the lens was about 40 times higher than that of 22.872 mGy at 895.830 mGy (Table 5) (Fig. 5).



**Fig. 5.** (Color online) Compared to the amount of absorbed dose of lens by MVCT irradiation condition.



**Fig. 6.** (Color online) Comparison of MVCT and Intensity Modulated Radiation Therapy Lens Scattering Absorption Dose.

### 4. Discussion

In the case of head and neck cancer, if the tumor is located close to the lens or there is overlap in the MVCT or radiotherapy, the data in this paper show a measured value that cannot be ignored if the lens's constant is set near the limit dose. In the radiation therapy oncology group (RTOG) 0539, a total of 60 Gy or more was applied to the planning target volume (PTV) in the IMRT treatment and a total of 30 Gy [6-10]. We recommend that the maximum limit of the absorbed dose of the lens be 7 Gy. In a clinical setting, the limited dose of the lens is often set to 5-6 Gy. If an unexpected dose of 1-2 Gy is absorbed by the lens in such a situation, the scattering line should be carefully considered because it exceeds the recommended 7 Gy and may interfere with the lens. The reason to perform tomotherapy in the treatment of cervical cancer intensity-modulated radiotherapy is that the dose homogeneity, dose conformity, and dose distribution of planned target volume (PTV) [11-15]. The mean peak dose of the phacoemulsification beam generated during the acquisition of the MVCT image of tomotherapy was 0.336 mGy in the coarse mode and 0.73 mGy in the fine

mode at 1 time. The mean dose was 10.089 mGy and up to 22.872 mGy. The mean value of the intensity-controlled radiotherapy using tomotherapy was 895.83 mGy. This result implies that the maximum radiation dose that the patient receives during the entire treatment process is 0.91 Gy when combined with MVCT, which is an image-guiding process, and intensity-modulated radiation therapy. This means that an approximate dose of 1 Gy can reach the patient and damage the lens. As mentioned in the introduction, the lens can exhibit lens opacity with a threshold dose of 0.5-2 Gy for radiation, as well as cataracts at 4 Gy. In conclusion, it is necessary to design a computerized treatment plan that considers radiation-sensitive organs, such as the lens, in the treatment of head and neck cancer with intensity-modulated radiation therapy. It is necessary to carefully recognize doses other than the treatment dose and reduce secondary side effects.

## 5. Conclusion

In the image induction process, the minimum dose should be given considering the location and size of the tumor and adjacent organs. There are various sites and sizes of nasopharynx, oropharynx, and oral cavity in the head and neck of patients with head and neck cancer. We hope that further studies will be conducted on salivary glands, which are important when treating head and neck cancer, as well as the lens and the basic data.

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