International Journal of Multidisciplinary and Current Educational Research (IJMCER)
ISSN: 2581-7027 ||Volume|| 4 ||Issue|| 5 ||Pages 160-163 ||2022||

Evaluation of the probability of secondary cancer during radiotherapy for prostate cancer

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ABSTRACT : The purpose of this study was to study the incidence of secondary cancer due to photoneutron exposure dose to the colon and thyroid gland, which are normal organs, in VMAT and IMRT 9 portals, which are radiotherapy methods for prostate cancer. The total prescribed dose for prostate cancer was 6600 cGy, 220 cGy per dose, and the total number of divisions was 30. After setting the Rando phantom the couch of the medical linear accelerator, the optically stimulated luminescence dosimeter was placed on the corresponding area of the colon and thyroid gland for measurement. The VMAT treatment resulted in a cancer probability of 3.5 per 1,000 people and the IMRT 9 portals 1.2 per 1,000 people. Based on this study, it is thought that it will be used as useful data in relation to the stochastic effect of radiation in the future.

KEYWORDS – Intensity modulated radiation therapy, Optically stimulated luminescence dosimeter, Prostate cancer, Secondary cancer, Volumetric modulated arc therapy

I. INTRODUCTION

The purpose of radiation therapy is to irradiate the appropriate prescribed dose to the tumor and to reduce the absorbed dose to the surrounding normal organs as much as possible [1]. It is reported that prostate cancer is particularly common with side effects of the colon and rectal urinary system [2]. In the case of radiation therapy for prostate cancer, when the daily prescribed dose is changed from 1.8 Gy to 2.0 Gy 5 times a week, a total of 70 Gy is received. The side effects that occur during this process greatly affect the quality of life of the patient [3]. In radiation therapy for prostate cancer, the normal organs, the rectum and part of the abdomen, are exposed to radiation dose. In order to reduce the side effects, it is important to reduce the exposure dose to normal organs [4]. In particular, exposure of normal tissues by neutrons is important during radiation therapy using high energy using 10 MV or more. Since the biological effect is greater than that of X-rays, the risk of secondary cancer is being considered [5]. Therefore, this study intends to study the probability of secondary cancer by each treatment method during radiotherapy of prostate cancer.

II. MATERIAL AND METHODS

For each of the two radiation treatment methods, VMAT (Volumetric modulated arc therapy) and IMRT (Intensity modulated radiation therapy) 9 portals were established for each treatment plan. The medical linear accelerator used in the experiment was Varian's True Beam STx (Varian, USA). To measure the dose of photoneutrons, 15 MV energy was used in the Planning Target Volume. The radiation treatment plan used Eclipse System (Varian Ver 10.0, USA), and VMAT established 2 ARCs. IMRT was performed with a total of 9 portals (0°, 40°, 80°, 120°, 160°, 200°, 240°, 280°, 320°). Rando phantom was set on the couch of a medical linear accelerator. Then, the optically stimulated luminescence dosimeter was placed in the corresponding area of the phantom's colon and thyroid gland to measure the photoneutron dose. OSLD annealing was performed using microStar Dosimetry Reader, USA equipment, followed by irradiation for 3 hours. In addition, the doses irradiated 5 times each were averaged and read using a dedicated reader (microStar Dosimetry Reader, USA).Nominal risk factor was used to calculate the probability of secondary carcinogenesis due to the photoneutron dose of IMRT and VMAT.

III. RESULT

As shown in Table 1, as a result of measurement of photoneutron dose in IMRT and VMAT, which are radiotherapy methods, IMRT was measured higher than VMAT in both positions of the colon and thyroid gland. The Nominal risk factor used to calculate the cancer probability using the measured photoneutron dose is 5.7 % per Sv for the entire population. According to ICRP 103 [6], the colon tissue weighting factor was 0.12 and the thyroid tissue weighting factor was 0.04, which calculated the cancer probability. According to ICRP 103 [6], the probability of secondary cancer occurrence due to photoneutron dose to the colon and thyroid gland during IMRT 9 portals and VMAT radiation therapy for prostate cancer is as follows.

(Secondary exposure dose) × (Total fraction) × (Tissue weighting factor) × (Neutron radiation weighting factor) × 0.057 / Sv (nominal risk coefficient) (1)The radiation weighting factor of a neutron is a continuous function. Therefore, the average energy of neutrons, 10 MeV, was obtained with a radiation weight of 8.8 based on the following equation presented in ICRP 103 [6].

$$W_R = 5.0 + 17.0\, e^{-[\ln (2En)]2/6} \qquad (2)$$

As a result, it can be seen that the cancer incidence rate due to radiation exposure of the colon and thyroid gland, which are normal organs, was 10.6 cases per 1,000 people, and there was a chance of developing cancer in 3.5 cases in VMAT when IMRT 9 portals were treated with radiation for prostate cancer.

IV. FIGURES AND TABLES

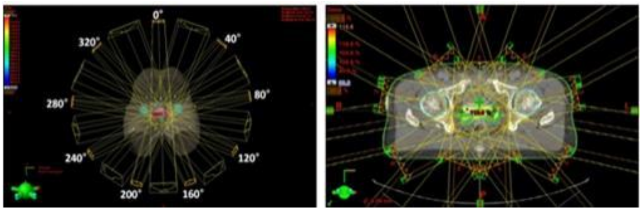

Figure 1. IMRT 9 portals for treatment plan

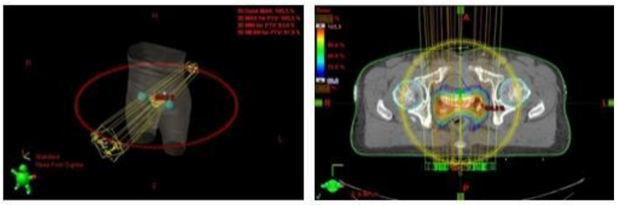

Figure 2. VMAT (2 Arc) for treatment plan

Figure 3. Rando phantom and OSLD inside the LINAC

Table 1. Comparison of VMAT and IMRT mean photoneutron dose measured in the abdomen (unit: mSv)

Classification	Abdomen	
	VMAT	IMRT 9 portals
Total photoneutron dose	48	150.6
Measurement (mean±St.D)	1.60±0.38	5.02±0.88

Table 2. Comparison of VMAT and IMRT mean photoneutron dose measured in the thyroid (unit: mSv)

Classification	Thyroid	
	VMAT	IMRT 9 portals
Total photoneutron dose	33	84.3
Measurement (mean±St.D)	1.10±0.11	2.81±0.29

Table 3. Probability of secondary cancer occurrence by treatment technique during radiotherapy for prostate cancer

Classification	VMAT	IMRT 9 portals
Cancer incidence	3.5×10^{-3} 3.5 per 1,000	10.6×10^{-3} 10.6 per 1,000

V. DISCUSSION

Linear accelerators that generate high energy of 10 MV or more must be mindful of the risk of radiation exposure of surrounding normal organs due to the dose of photoneutrons. Several studies have been reported on the measurement of photoneutron dose [5], but there are limitations to the indirect method using the Monte Carlo N-Particle eXtended code for geometric conditions. However, this study has significance in that it obtained quantitative values that were actually measured using OSLN dosimeters. In addition, it is a meaningful study in that it studied the probability of cancer occurrence through radiation exposure dose of normal tissues, which is important in the actual radiation treatment planning.Neutron dose according to IMRT portal increase was studied. It was analyzed that the average neutron dose increased significantly by .416 times as the number of IMRT surveys increased [1]. That is, it can be seen that the dose of photoneutrons increases when the number of irradiation gates increases in the same treatment technique.

During radiation therapy, as a study on the significance of additional exposure dose other than the prescribed dose, the risk of exposure dose was suggested by measuring scattered rays reaching the treatment table again [7]. As such, since the additional exposure dose generated in the radiation treatment room is also important, care must be taken to always receive the minimum amount of radiation Due to the risk of radiation exposure, this study investigated the occurrence of abnormal blood test findings within a few minutes when exposed to a dose of 100 mSv or more [8]. According to the results of this study, a total dose of 150.6 mSv is exposed to the colon during radiation therapy for IMRT prostate cancer, indicating that blood test abnormalities can occur immediately.In particular, it was studied that the thyroid gland is sensitive to radiation and increases the incidence of thyroid cancer in excess of 50 mGy or after an incubation period of 5 to 10 years after radiation exposure. According to the study results of this experiment, the total dose to the thyroid gland during IMRT radiation treatment for prostate cancer was 84.3 mSv, which exceeded the reference dose mentioned in the study of Iglesias et al. In other words, it indicates that there is a possibility of secondary cancer due to the thyroid radiation dose.

The limitation of this study is that it was not possible to design and study more diverse radiation treatment plans. However, the actual measurement of photoneutron dose and the probability of secondary cancer occurring during radiotherapy of prostate cancer were analyzed. Therefore, it is thought that it will be used as a useful reference data in relation to the stochastic effect of radiation.

VI. CONCLUSIONS

Photoneutron doses generated during IMRT and VMAT, which are radiotherapy methods for prostate cancer, were measured. Due to this dose, the probability of secondary cancer caused by exposure to the colon and thyroid gland was analyzed.As a result of analyzing the incidence of thyroid and colon cancer, it was found that 10.6 people per 1,000 people with IMRT and 3.5 people with VMAT had a secondary chance of getting cancer.This study will study the risk of secondary radiation exposure that may occur during radiation therapy, and will be used as basic data related to stochastic effects in the future.

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