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Evaluation of Photoneutron Dose in the Medical Linear Accelerators by Manufacturer

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Abstract

Background/Objectives: *The irradiation head of high-energy linear accelerator consists mainly of lead (82-Pb) or tungsten (74-W) characterized with a high atomic number. According to Report 79 of the National Council on Radiation Protection Measurement (NCRP) in the USA it is reported that there is a generation of photoneutrons through interaction with photons. The purpose of this study was to identify the amount of photoneutrons caused by changes in the field of irradiation under the same conditions, and to investigate the effects of photoneutrons on the interior space of the radiation therapy room using the radiotherapy equipment of Varian and Elekta.*

Methods/Statistical analysis: *In this study, Varian Clinac iX and Elekta Versa HD Apex were used, and an optically stimulated luminescence dosimeter (OSLD) and reader Auto200 were used for determining the dose evaluation. The photoneutron measurement was noted at 10MV energy at 200MU, dose rate 300MU / min, and the irradiation field was measured by a dosimeter located at a predetermined point while adjusting the irradiation field to 10 × 10 ㎠, 20 × 20 ㎠, 30 × 30 ㎠.*

Findings: *As a result of the measurement of photoneutrons by position according to the change of field, the field was increased proportionally as the field was determined to be wider in this case, The amount of photoneutrons in the center of the radiation therapy increased by 18% at 20 × 20 ㎠ and 35% at 30 × 30 ㎠, when the irradiation field was 10 × 10 ㎠.*

As a result of measurement of photoneutrons by location according to the manufacturer's equipment, it was found that the amount of photoneutrons increased more rapidly in Elekta than in Varian, as the field of radiation therapy increased based on the central dose of radiation therapy.

Improvements/Applications: *Due to the structural characteristics of the linear accelerator, it is difficult to fundamentally block the generation of neutrons. However, since neutrons may have a potential effect on the outbreak of cancers in the surrounding organs, it is necessary to find ways to measure and apply neutron* *generation for each condition, which is especially important when establishing treatment plans with proper awareness of radiation-related workers in order to minimize neutron outbreaks*

Keywords : *LINAC, High energy, Photonuclear reaction, Photoneutron, OSLD*

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1. INTRODUCTION

With the development of science, the equipment used for radiation therapy is gradually becoming standardized to use a higher energy and higher dose in these cases.

The irradiation head of a high-energy linear accelerator consists mainly of lead(82-Pb) or tungsten(74-W) with high atomic numbers. As noted, Report 79 of the National Council on Radiation Protection Measurement (NCRP) in the USA reported that there is a generation of photoneutrons through interaction with photons[1,2].

Previous studies have reported that photoneutrons from photonuclear reactions generate at 6.74MeV for lead and 7.41MeV for tungsten, and that photoneutrons increase rapidly from 10MeV to 6MeV and show maximum values in the 14MeV region[3]. In addition, research on the effects of photoneutrons on patients in the radiation therapy room[4], and studies on particles generated by photonuclear reactions including photoneutrons have been published[5].

According to Report 103 of the International Commission on Radiation Protection (ICRP), photoneutrons have a radiation weight of 5 to 20 times greater than that of photon rays[6], which means that even small doses have a greater effect on the human body. In this regard, photoneutrons affect patients. not only inside or outside the radiation therapy room due to the property of multiscattering. This is an important consideration in the installation of radiation shielding facilities in healthcare environments. To this end, neutrons have been studied not only for medical linear accelerators, but also for the search of container cargo brought into customs through airports and ports[7]. As such, photoneutrons are the cause of continuous regulation and management by related organizations, but for patients inside the radiation therapy room, they have been passively dealing with safety management without considering the effects of exposure to these elements, because the benefits are greater than the damage rendered in the diagnosis of treatment[8].

Although it is difficult to fundamentally block the generation of photoneutrons due to the structural characteristics of the linear accelerator, photoneutrons are known to have a potential to affect the outbreaks of potential secondary cancers of surrounding organs[9]. As a quantitative evaluation of photoneutrons is required, the neutrons should be measured according to the conditions of each medical institution.

2. MATERIALS AND METHODS

2.1. Materials

The medical linear accelerators used in this study are Clinac iX (Varian, USA) in Hospital B and Versa HD Apex (Elekta, Sweden) in Hospital K in Korea[Figure 1].

(a) (b)

Figure 1. Linear accelerator (a) Varian Clinac iX (b) Elekta Versa HD Apex

In order to measure the dose of photoneutron generated in the linear accelerator, Optically Stimulated Luminescence Dosimeter (OSLD, LANDAUER, USA) and reader Auto200(LANDAUER, USA) were used[Figure 2].

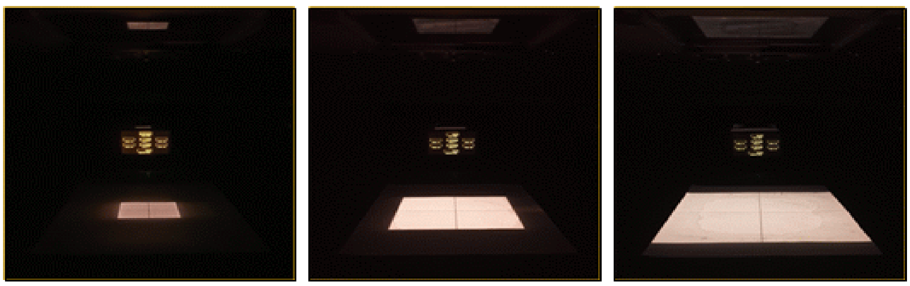
(a) (b)

Figure 2. Dosimeter and reader (a) OSLD (b) Auto200

2.2 Methods

The energy of Clinac iX(Varian, USA) and Versa HD Apex(Elekta, Sweden) equipment was 10 MV, and 200MU was dosed at 300MU/min based on typical daily treatment dose.

Irradiation field can be adjusted from 0 × 0 ㎠ to 40 × 40 ㎠, and in the study, photoneutrons generated by changing to three conditions of 10 × 10 ㎠, 20 × 20 ㎠ and 30 × 30 ㎠ were measured three times depending on the equipment[Figure 3].



(a) (b) (c)

Figure 3. Field size (a) 10×10 ㎠ (b) 20×20 ㎠ (c) 30×30 ㎠

In this case, the dosimetry was performed by placing the OSLD at the center of the left, right and leg sides 250cm apart and 10cm outside the door of the treatment room, considering the center of treatment at the SSD 100cm and the size of the different radiation treatment rooms of the two medical institutions[Figure 4].

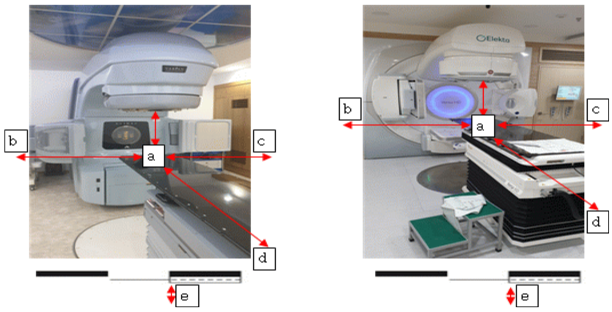


Figure 4. Measuring position of OSLD (a) Beam center(SSD 100 ㎝), (b) Left 250 ㎝, (c) Right 250 ㎝

(d) Leg(Table) 250 ㎝, (e) Outside the door 10 ㎝

In the previous paper using Truebeam, the amount of photoneutrons generated after installing lead plates, copper plates, and aluminum plates in the field of irradiation was found to be extinguished after about 100 seconds, regardless of the type of additional plate[10]. Therefore, in this experiment, the following experiment was conducted with a time difference of about 2 minutes after one beam on time.

3. Results

3.1 Photoneutrons by location at 10×10 ㎠

In this context, the differences of generated photoneutrons by location were measured according to manufacturer's equipment in 10×10 ㎠.

It is noted that the Varian generated 1,070.11mSv at the treatment center, 0.11mSv at 250 cm left, 0.08mSv at 250cm right, 0.10mSv at 250cm from the leg, and 0.01 mSv at 10 cm outside the treatment room door.

In effect the Elekta generated 1,064.37mSv at treatment center, 0.12mSv at 250cm left, 0.12mSv at 250cm right, 0.06mSv at 250 cm from the leg, and 0.01 mSv at 10 cm outside the treatment room door[Table 1].

Table 1: Comparison of Varian and Elekta at field size 10×10 ㎠ (unit; mSv)

Division	Varian	Elekta
Center of treatment	1,070.11	1,064.37
Left side 250□	0.11	0.12
Right side 250 ㎝	0.08	0.12
Leg side 250□	0.10	0.06
Outside the door 10□	0.01	0.01

3.2 Photoneutrons by location at 20×20 ㎠

The differences of generated photoneutrons by location were measured according to manufacturer's equipment in 20 × 20 ㎠.

Here the Varian company generated 1,162.05mSv at the center of treatment, 0.18mSv at 250cm on the left, 0.06mSv at 250cm on the right, 0.05mSv at 250cm from the leg, and 0.01mSv at 10cm outside the treatment room door.

Next, the Elekta generated 1,359.09mSv at the treatment center, 0.33mSv at 250cm left, 0.28mSv at 250cm right, 0.20mSv at 250cm from the leg, and 0.01mSv at 10 cm outside the treatment room door[Table 2].

Table 2: Comparison of Varian and Elekta at field size 20×20 ㎠ (unit; mSv)

Division	Varian	Elekta
Center of treatment	1,162.05	1,359.09
Left side 250cm	0.18	0.33
Right side 250cm	0.16	0.28
Leg side 250cm	0.05	0.20
Outside the door 10cm	0.01	0.01

3.3 Photoneutrons by location at 30×30 ㎠

The differences of generated photoneutrons by location were measured according to manufacturer's equipment in 30 × 30 ㎠.

In fact, the Varian generated 1,371.19mSv at the treatment center, 0.18mSv at 250cm left, 0.24mSv at 250cm right, 0.12mSv at 250cm from the leg, and 0.01mSv at 10cm outside the treatment room door.

Likewise, the Elekta generated 1,506.72mSv at the treatment center, 0.24mSv at 250 cm left, 0.43 mSv at 250 cm right, 0.15mSv at 250cm from the leg, and 0.05 mSv at 10 cm outside the treatment room door[Table 3].

Table 3: Comparison of Varian and Elekta at field size 30×30 ㎠ (unit; mSv)

Division	Varian	Elekta
Center of treatment	1,371.19	1,506.72
Left side 250cm	0.18	0.24
Right side 250cm	0.24	0.43
Leg side 250cm	0.12	0.15
Outside the door 10cm	0.01	0.05

4. Discussion

In general radiation therapy equipment is gradually diversified into Tomotherapy, Cyberknife, Proton, Vero, ViewRay, and Halcyon, etc. Unlike the past, special treatment methods such as 3Dimention conformal Radiation Therapy (3D CRT), Intensity Modulated Radiation Therapy (IMRT), Image Guided Radiation Therapy (IGRT), and Respiratory Gated Radiation Therapy (RGRT) have also been developed to work in combination with radiation therapy equipment to treat many diseases.

It is emphasized that high-energy X-rays above 10MV interacted with the components of the irradiation head generated photoneutrons, and photoneutrons appeared to be a disadvantage of acting as an unnecessary dose to normal tissues irrelevant to radiation therapy[11].

Therefore, this study compared and evaluated the amount of photoneutrons according to the change of irradiation field with the amount of photoneutrons according to the equipmentas characterized by each manufacturer.

The measurement results of photoneutrons by location according to the change of field showed that the amount of photoneutrons increased proportionally as the field was increased. In this case, the amount of photoneutrons in the center of radiation treatment increased by 18% at 20 × 20 ㎠ and 35% at 30 × 30 ㎠ when the irradiation field was 10 × 10 ㎠. Additionally, the Sohrabi assessed that as the field of radiation increases, the probability that photons cause photonuclear reactions increase, resulting in increased photoneutrons[12]. Therefore, it is necessary to set up an optimized field considering the size of the tumor during treatment planning in relation to these results.

As is known from previous studies, photoneutrons are likely to affect the outbreak of potential secondary cancers of the surrounding organs[9]. To reduce this possibility, it is important for radiographers and radiation workers to be aware that photoneutral radiation generated in the radiation therapy room is uneccessarily exposed to patients.

In addition, for this reason, more careful attention should be givent to the patient's exposure to neutrons and the radiation protection of the operator, and it is necessary to find ways to set up the treatment planning (selection of X-ray, use of filter, method of treatment, etc.) and carefully measure neutrons by using measuring equipment according to each condition and systemtically put into data to apply them to the treatment planning system.

5. Conclusion

It is important to note that this study made photoneutron dose assessment by using 10MV energy in medical linear accelerators by the manufacturer.

It is concluded that in the result of measuring and comparing the difference of photoneutrons according to the equipment of each manufacturer, the treatment center dose showed similar values between the two equipments at 10 × 10 ㎠, but as the field increased, Elekta's generation amount increased more rapidly than Varian's.

In these terms, due to its structural characteristics, the linear accelerator, it is difficult to fundamentally block the generation of neutrons. However, in order to reduce the generation of neutrons, radiation-related workers, including radiographers, should find ways to put neutron generation into data according to conditions in process of making planning for radiation treatments and apply them during the radiotherapy.

Acknowledgment

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