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Analysis on Distribution of Effective Dose Rate around Patients for Treatment of Thyroid Cancer with I-131

Sang-Tae Kim[1], Min Baek[2] and Jung-Keun Cho[3*]

[1]Radiation Safety Division, Nuclear Safety and Security Commission, Republic of Korea
[2]Radiation Protection and Emergency Preparedness Bureau, Nuclear Safety and Security Commission, Republic of Korea
[3]Department of Radiological Science, Jeonju University, Republic of Korea; cjk0129@naver.com

Abstract

It is required to evaluate the effective dose rate that may influence the family and caregivers of patients in order to realize the radiation protection for people around thyroid cancer patients when treating them with the administration of I-131. To this end, this study measured the surrounding effective dose rate that is emitted in accordance with the rotation angle of patients. For accurate measurement, this study analyzed the height, rotation angle and elapsed time at the distance of 90 cm by manufacturing a wooden frame of geometric form. The surrounding effective dose rate distribution for vertical plane was the highest at the distance of 100 cm and height of 90 cm from the patients 24 hours after the oral administration of I-131 with the mean of 80.77±4.2 μSv/h. This study conducted the experiment based on the three groups, which were the control group of normal fluid intake (2 liter/day), the experimental group A (1 liter/day) with a small amount of fluid intake and the experimental group B (3 liter/day) with a larger amount of fluid intake than the normal fluid intake, in relation to the reduction degree of surrounding effective dose rate through fluid intake. AS for the dose distribution at the distance of 100 cm and the height of 90 cm 24 hours after the oral administration of I-131, the experimental group A had 101.2 μSv/h, whereas the experimental group B had 37.24 μSv/h and the control group had 72.58 μSv/h. As a result of comparing the control group with the experimental group A and B, this study confirmed the reduction effect of radiation exposure by approximately 51 percent depending on the extent of fluid intake when treating thyroid cancer patients with I-131.

Keywords: Low-Temperature Heat Source, Low-pressure Turbine, Organic Rankine Cycle, Vapor Generator

1. Introduction

Due to the drastic increase in the number of thyroid cancer patients in recent years, the number of thyroid treatments using I-131 is also rapidly increasing. According to the statistical data of Health Insurance Review Agency, the number of I-131 treatment has increased about 15 times as compared with the number 20 years ago[1]. The number of I-131 related hospitalization treatment has recently decreased with the self-purification efforts of medical professionals in relation to the excessive treatment issue of thyroid cancer. Nonetheless, the number thereof is still deemed very high. The criteria of effective dose rate, which are the nuclear safety commission notice No. 2012-37, determines discharge on the basis of 70μSv/h at 1m and the initial phase administration amount of I-131 that is 33mCi (1.22GBq) due to the radiation emitted from the body of patients in relation to the hospitalization period

**Author for correspondence*

and discharge timing of patients who are administered with radioactive iodine and I-131 at Dept. of Nuclear Medicine after receiving thyroid resection surgery that is commonly conducted by Korean medical professionals for thyroid cancer treatment. It is very important to evaluate an accurate dose since the criteria for discharge decision can establish and leverage the principle of radiation protection depending on the degree of radioactivity to be emitted from patients.

Radiation exposure caused by medical operation will be increased with an increase in the dose of I-131, which is the radioactive isotope to be used for treatment of thyroid cancer patients. It is necessary to establish a clear criterion as to the defense system of radiation released from patients since radioactive substances are injected to patients. I-131 released beta-ray due to the collapse of beta and it is converted into Xe-131, where the one used in treatment is the beta-ray of 606 keV w whose range is short.

It is very important to note that the salivary gland, which the thyroid surrounding tissue, may lose its function permanently by I-131 that, is the thyroid compatible nuclide due to radiation exposure for high-capacity treatment with I-131. I-131 is mainly accumulated in thyroid. Also, it is distributed in mouth, salivary gland, stomach, colon, large intestine, sacroiliac, bladder, etc. On this account, it is exposed to radiation during treatment with I-1312. Radioactive iodine is mainly released in urine. However, a small amount thereof is released in saliva, sweat and excrement. I-131 is volatile; thus, it is required to manage radiation exposure caused by breath or cough of patients[3,4].

The amount of remaining radiation in the body of patients after administering I-131 depends on the residual tissue after thyroid surgery, digestive function and fluid intake of urinary tract. Thus, a rapid release of I-131 remaining in the body through fluid intake during treatment with I-131 treatment will have an impact on the reduction of radiation exposure5. On that account, this study conducted a comparative analysis on the reduction effect of radiation exposure based on the control group of normal fluid intake (2 liter/day), the experimental group A (1 liter/day) having a small amount of fluid intake and the experimental group B (3 liter/day) having more than normal fluid intake amount. In addition, patients may become radiation source depending on the view due to radioactive isotope injection although they are not radiation source from the legal perspective. Thus, it is required to conduct a study on the surrounding effective dose rate in order to predict the radiation exposure amount that patients, medical staffs, caregivers and also unspecified number of people may receive since the use of radioactive drugs is on the rise. So far, there have been some studies on the safety of medical radiation exposure as to the dose released from thyroid cancer patients during treatment with I-1316.

One study was conducted for the measurement of surrounding effective dose caused by F-18-FDG isotope injected to human body in PET/CT test that has been increasingly utilized in recent years. In overseas, there have been several studies that focused on the measurement of dose that a medical staff could receive from patients by using radioactive isotope. AAPM (American Association of Physicists in Medicine) proposed the measure for screening the dose rate by utilizing TG-108 calculation method. There was also one measurement study that compared and analyzed the surrounding effective dose rate with TG-108 method by installing a dosimeter on the ceiling. In South Korea, there have been several studies that focused on the evaluation of surrounding effective dose rate released from X-ray examination.

However, this study analyzed the surrounding effective dose rate with measurement error, which was irradiated from the geometrically accurate location with the fixed distance and angle, in order to measure the dose released from patients in three-dimensional way since the domestic and overseas studies on the measurement methods of surrounding effective dose rate had depended heavily on the subjective judgment of measurers in accordance with the location of detector and patients that were the radiation source. As for the actual measurement, this study measured the time difference by leveraging the measurement point of multi-dimensional structure so that a quick measurement could be conducted for patients of various physical conditions regardless of their height, weight and age. As a result of analyzing the measurement data, this study determined the measurement criteria for each height level in accordance with the rotation angle of patients in relation to the point of 90 cm that had statistically low error range with the highest dose rate. Through this experiment data, this study aimed to help establish a criterion of radiation defense system and also predict the radiation exposure dose that may influence an unspecified number of people due to the discharge of patients in addition to those patients having I-131 treatment for their thyroid cancer.

2. Materials and Methods

2.1 Materials

This study selected only those patients (15 people) who were administered with 150 mCi out of the hospitalized patients for I-131 treatment of thyroid cancer at S Hospital for 90 days from August to November 2014. This study measured the surrounding effective dose rate of the 48 measurement points in accordance with the rotation angle for both clockwise and counterclockwise direction after manufacturing a wooden frame. As for the measurement time difference, this study measured the change in the surrounding effective dose rate with the following time difference: immediately after the administration, 6 hours after the administration, 12 hours after the administration, 24 hours after the administration, 48 hours after the administration and 96 hours after the administration. To examine the reduction effect of radiation exposure, this study confirmed the extent of the reduction effect of radiation exposure by comparing the change in the surrounding effective dose rate in accordance with the fluid supply based on the following three groups: the experiment group A with fluid intake of 1 liter/day, the experiment group B with fluid intake of 3 liter/day and the control group with fluid intake of 2 liter/day.

The experiment was conducted with the production of geometric wooden frame of a fixed location in order to measure accurately the surrounding effective dose rate and also reduce the measurement time. The concept of manufactured frame is shown in Figure 1. Two GM counters were attached to the hula hoop (diameter of 100cm) made of the solid material in the 180-degree direction. As for the height of the frame that could hold each hula hoop, the 4 frames were located 50 to 170 cm high from the floor in the interval of 40 cm. As for the hula hoop, the 12 measurement points were configured in a single ring through installing two GM counters in a symmetrical structure and rotating them by 30 degrees. GM counter was utilized after conducting the verification and correction. As a result of the correction, the mean value of correction factor was 8.5. As for the uncertainty of measurement, the uncertainty of measurement for Cs-137 line source radioactivity was 3.9 percent, whereas the uncertainty of measurement for the measuring instrument was 5.1 percent. The expanded uncertainty of measurement was 9.2 percent. Thus, it can be concluded that an instrument with good grade was utilized in this study.

2.2 Organic Rankine Cycle Apparatus

The surrounding effective dose rate distribution for each height was measured at the height of 50 to 170 cm in the height interval of 40 cm from the point of 50 cm high from the ground. The rotation angle was measured at 0 to 180 degrees in the left and right directions depending on the rotation angle in the interval of 0 to 30 degrees from the patients. In regard to the calculation of the 12 rotation angle measurement points at hula hoop and the 4 wooden frame measurement points, it was possible to calculate

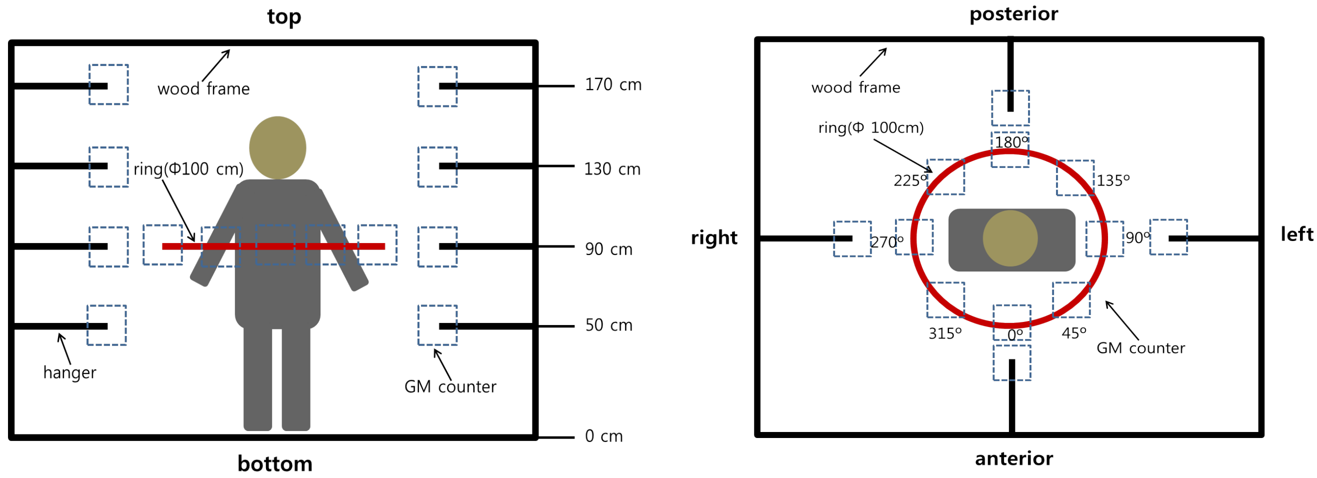

Figure 1. Wooden frame structure for the measurement of surrounding effective dose rate (A. Front view, B. Top view).

the geometric surrounding effective dose rate for each person from the 48 locations. In addition, the calculated value from the distance of 1m was compared in order to prove the accuracy of measured value. The result thereof was shown in Table 1 [Equation 1]. To verify the reduction effect of surrounding effective dose rate over time, this study measured the extent of surrounding effective dose rate reduction caused based on the following 6 time intervals: immediately after the administration of 1-131, 6 hours after the administration of 1-131, 12 hours after the administration of 1-131, 24 hours after the administration of 1-131, 48 hours after the administration of 1-131 and 96 hours after the administration of 1-131.

$D_{1m}(t) = 4.3\times10^{-2}\ C_0 e^{-0.05t}$ (mSv/h) (1)

C_0: Initial I-131 administration dose for patients (GBq)

t: Elapsed time after administration of I-131 (h)

3. Results

3.1 Effective Dose Rate in accordance with the Height and Rotation Angle of Patients

The mean of surrounding effective dose rate distribution in accordance with the height 6 hours after the administration of 1-131 isotope to patients is shown in Table 2. For both the experimental group and the control group, the dose distribution in accordance with the height was the highest at the point of 90cm high. 1-131 is provided in the form of capsule. Most of it is absorbed through the gastric mucosa of digestive system after the oral administration to human body. It is mainly accumulated in the gastric mucosa wrinkle. The discharge time thereof is also longer than the other organs. The location of gastrointestinal tract that is mainly accumulated is 90 to 100 cm for the body of an oriental person. This is the reason why the degree of surrounding effective dose rate distribution is high in accordance with the height. However, the average height of 30 patients who participated in the experiment was 159 cm, which was substantially smaller than the national average height. In addition, the gastrointestinal tract of most participating patients was located near the point of 90 cm even though it varied depending on the shape of stomach. Also, the gastric mucosa had the largest dose distribution even 48 hours after the oral administration. The mean and standard deviation of the experimental group A at the height of 90 cm and the rotation angle of 0 degree after 24 hours were 101.2±6.1 μSv/h, whereas the experimental group B had 37.24±4.2 μSv/h and the control group had 72.58±6.6 μSv/h. This study confirmed that the dose rate was the highest and also the error rate was low at the height of 90 cm for the measurement of surrounding effective dose rate in accor-

Table 1. Comparison between the measured and calculated values of surrounding effective dose rate in accordance with the time of I-131 administration of the experimental group and control group (height of 90 cm and fluid intake of 2l/day) ($p<0.5$, Mean ± SD)

Elapsed time after Administration (Hour)	Calculation	Measurement
6	176.8	178.4±3.3
12	131.0	129.4±4.7
24	71.9	72.6±4.2
36	39.4	37.5±3.1
48	21.6	22.1±2.8
60	11.9	9.8±2.3
72	6.5	5.7±1.1

Unit: μSv/h

dance with the height. On this account, this study set the standard height of surrounding effective dose rate measurement at 90 cm.

The spatial dose distribution based on the rotation angle of patients at the standard height of 90 cm was the highest at the front rotation angle of 0 degree for patients. The reason why there was a difference in the error range of effective dose distribution depending on the rotation angle of 0 to 360 degrees in the interval of 30 degrees based on the center of human body was that each patient had a difference depending on the discharge in accordance with the thyroid tissue site and fluid intake extent in which I-131 was concentrated because I-131 was absorbed and discharged in human body through digestive system and urinary tract for treatment of thyroid cancer.

3.2 Reduction Effect of Radiation Exposure in accordance with Fluid Intake

For high-capacity iodine treatment, this study confirmed the reduction effect of radiation exposure for the experimental group A with fluid intake of 1 liter/day, the experimental group B with fluid intake of 3 liter/day and the control group with fluid intake of 2 liter/day during the 3 day hospitalization period. All experimental group A and B and the control group were instructed to drink water at the pre-determined time before the administration of I-131. This study confirmed the reduction effect of radiation exposure of approximately 51 percent in the comparison experiment between the experimental group and control group through fluid intake from the reduction curve of surrounding effective dose rate. The surrounding effective dose rate distribution was measured at 101.2 ± 6.1 μSv/h, 37.24 ± 4.2 μSv/h and 72.58 ± 6.6 μSv/h for the experimental group A with 1 liter/day, the experimental group B with 3 liter/day and the control group, respectively for the radius of 100 cm and height of 90 cm 24 hours after the oral administration of I-131.

Through this, this study confirmed the reduction effect of surrounding effective dose rate by means of the extent of fluid intake for I-131 treatment of thyroid cancer. The physical reduction phase of I-131 is approximately 192 hours. However, this study confirmed that the time slot for the reduction of initial phase dose rate from the reduction curve of surrounding effective dose rate was approximately 6 hours after the administration as the biological reduction phase was reduced through a large quantity of fluid intake in the experimental group A. Moreover, it is possible to confirm the extent of reduction of radiation exposure for each time slot through the

Table 2. . Effective dose rate in accordance with the rotation angle after the administration of I-131 ($P<0.5$, MEAN ± SD)

Height(cm) Deg.	50	90	130	170
0	58.8±2.2	72.6±4.2	66.9±3.3	60.2±3.4
45	54.7±4.5	67.5±3.5	63.7±2.8	57.2±5.5
90	56.1±3.3	69.4±3.8	64.2±4.1	56.7±4.9
135	55.7±5.0	66.3±4.1	63.4±2.8	55.3±3.8
180	57.0±3.8	68.7±2.9	65.2±2.2	56.5±3.3
225	57.1±4.2	67.4±5.2	64.7±3.7	54.8±3.5
270	57.7±4.4	70.8±4.9	66.1±5.3	59.5±4.8
315	55.2±6.0	69.2±4.6	65.3±4.9	58.4±3.5

Unit: μSv/h

Table 3. . Change in surrounding effective dose rate over time (P<0.5, MEAN ± SD)

Elapsed time after administration(Hour)	Treatment Group A (1L/day)	Control Group (2L/day)	Treatment Group B (3L/day)
6	180.1±4.8	178.4±3.3	175.7±5.5
12	155.5±10.9	129.4±7.7	76.4±5.1
24	101.2±10.1	72.6±5.2	37.2±4.2
36	67.9±7.7	37.5±3.1	21.7±3.3
48	52.1±6.2	22.1±2.8	17.2±2.8
60	33.9±5.3	9.8±2.3	7.3±1.1
72	20.1±3.2	5.7±1.1	3.4±0.8

Unit: μSv/h

reduction curve of surrounding effective dose rate over time (Table 3).

4. Conclusions

This study measured the radiation dose released from such radiation source as patients during high-capacity iodine treatment of thyroid cancer patients that have increased about 5 times in the last 10 years. Moreover, This study measured and analyzed the multi-dimensional surrounding effective dose rate in accordance with the height and 360-degree rotation angle by manufacturing the geometric frame.

The highest surrounding effective dose rate was measured at the point of 90 cm among all the experimental groups. The mean of surrounding effective dose rate was 72.58 μSv/h at the distance of 100 cm and height of 90 cm. The mean was 80.77±4.2 μSv/h at the rotation angle of 0 degree; thus, it had the highest spatial dose distribution. As shown in Figure 1, this was because I-131 was mainly accumulated in the digestive system and urinary tract during the process of absorption and discharge. The experimental group A that took 5 liter of water for three days of hospitalization had a higher reduction effect by about 51 percent from the reduction curve of surrounding effective dose than the experimental group B that took 3 liter of water. this study also confirmed that the time slot for the reduction of initial phase dose rate from the reduction curve of surrounding effective dose rate was approximately 6 hours after the administration as the biological reduction phase was reduced through a large quantity of fluid intake in the experimental group A. It was confirmed that approximately 90 percent of administered radiation was released at the time of discharge after the patients received 150 mCi of I-131 and took 3 liter/day of water during the period of hospitalization for two nights and three days for I-131 treatment of thyroid cancer. This study will help confirm the distribution of multi-dimensional surrounding effective dose rate for treatment of high-dose iodine, predict an amount of radiation exposure that an unspecified number of people including patients and general public may receive and establish the criteria of radiation defense system.

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