INVESTIGATION OF EXTERNAL RADIATION DOSE RATE FROM PATIENTS TREATED WITH IODINE 131(^{131}I)

Win Mar[1], Lae Lae Kyaing[2]

Abstract

Radioisotopes are widely used to diagnose disease and as effective treatment tools. Since many years radioactive iodine ^{131}I has been used to treat thyroid disease. The external measurements of dose rate (μSv/hr) of thyroid cancer patients for various distances are obtained at Department of Nuclear Medicine in Yangon General Hospital. These results are satisfied the inverse square law. From these results the maximum permissible exposure time for various distances from thyroid cancer patients are calculated. It is found that the maximum permissible exposure time is the longest time for the people that stay away from the patients after giving iodine treatment. Finally, it is concluded the further from the patients treated iodine, the longer the maximum permissible exposure times.

Keywords: *hyperthyroidism, external dose rate, exposure time*

Introduction

Radiations are naturally present in our environment and exist since the birth of this planet.It comes from outer space (cosmic), the ground (terrestrial), and even from within our own bodies. It is present in the air, the food, the water and in the construction materials used to build our homes. Beta particles are fast, energetic electrons (high speed electrons) .They are ejected from the nucleus of unstable radioactive atom. They are single, negatively charged and have a small mass. They are more penetrating than (α) particles, but can be stopped by a few millimeters of aluminum, so cannot penetrate deeply into tissues. ^{131}I is a beta emitter and hence is used for radiotherapy of hyperthyroid and thyroid cancer patients.

Radiation Effects on Population

The effect of radiation on living things

All living things are made of cells. Each cell has a central nucleus which carries the special code (DNA) of the living organism. Radiation can ionise the chemicals in the nucleus of the cell so that the code is changed. If radiation damages blood cells it can cause vomiting, loss of hair and increase the likelihood of infection. High doses of radiation can destroy cells completely and cause death.

Practical Means of Radiation Protection

External Radiation Protection

The three basic methods used to reduce the external radiation hazard are time, distance, and shielding. Good radiation protection practices require optimization of these fundamental techniques.

[1] Dr, Associate Professor, Department of Physics, Meiktila University.
[2] Dr, Associate Professor, Department of Physics, Meiktila University.

(i)Time

The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field.

(ii) Distance

The amount of radiation an individual receives will also depend on how close the person is to the source.

(iii) Shielding

When reducing the time or increasing the distance may not be possible, one can choose shielding material to reduce the external radiation hazard.

Internal Radiation Protection

Internal radiation exposure results when the body is contaminated internally with a radionuclide. Thus, internal radiation protection is concerned with preventing or minimizing the deposition of radioactive substances in personnel.

Table 1 Recommendations for Annual Effective/ Equivalent Dose Limits

	ICRP	**NCRP**
Public Limits (Annual):		
1.Effective dose limit		
a. Continuous or frequent irradiation	1 mSv	1mSv
b. Infrequent irradiation	5 yr average<1mSv/yr	5mSv
Educational and Training Limits (Annual):		
1. Effective dose limit	-	1mSv
2. Equivalent dose limit		
a. Lens of the eye	-	15mSv
b. Skin, hands and feet	-	50mSv

Metabolism of ^{131}I

Iodine is an essential component of thyroid hormones, so the thyroid gland takes up iodine very easily. Normally, iodine is supplied to the body in foodstuffs and drinking water. There are three kinds of half-life's,(i) Physical half-life(ii)Biologic half-life and (iii) Effective half-life that should be considered when radioactive iodine is used to study or treat a hyperthyroid and thyroid cancer patient.

Table 2 Physical, biologic and effective half- life of ^{131}I

^{131}I Physical half life	**^{131}I Biologic half-life**		**^{131}I Effective half-life**	
	normal thyroid compartment	**extra thyroid compartment**	**thyroid compartment**	**extra thyroid compartment**
8.04 days	80 days	12 days	7.3 days	8 hours

Figure 1 Iodine ^{131}I

Survey Meter Dose Rate Test

The aim of the test was to find out that the dose rate measurements are in accordance with inverse square law. Mathematically the inverse square law is expressed with following equation.

$$I \propto \frac{k}{d^2}$$

The purpose was to find out if variations in the distance affect dose rate measurements. A syringe with 888 MBq of ^{99m}Tc activity was placed at 77 cm height. The height was estimated for a normalized patient's whole body. Dose rate measurements were taken with the 6150 AD 5/H at 1.0m, 1.5m, 2.0 m and 2.5 m at 77 cm height. In order to validate the dose rate results of the survey meter, dose rate test performed with activity of 888 MBq ^{99m}Tc. The results are presented in Table (3).

Figure 2 Survey meter (6150 AD 5/H)

Table 3 Dose rate results

Activity MBq	Dose rate (µSv/hr) at1.0 m	Dose rate (µSv/hr) at1.5 m	Dose rate (µSv/hr) at2.0 m	Dose rate (µSv/hr) at2.5 m
888	340	85	21	5

Table 4 Inverse square dose rate validation

r_1	r_2	r_3	$R_1= r_1/4$	$R_2= r_2/16$	$R_3= r_3/64$
4	16.19	68	1.00	1.01	1.06

Patient Procedure

At a group consisted of fifteen patients, were performed external dose rate measurements. They signed agreement for receiving a therapy and all patients feel positive about participating in the study. The patient population consisted of 12 female and only 3 male at thyroid cancer group. Age ranged between 29 years to 60 years old. Thyroid cancer patients were given activities between 1110 MBq and 2590 MBq.

Radiation Dose Rate Measurement

The dose rate from the patient was monitored with survey meter (6150AD models) at horizontal distances of 1.0 m, 1.5 m, 2.0 m and 2.5 m for thyroid patient. The effective point of the patient measurements was taken to be in the center of the detector. Vertical movement of the survey meter was utilized to obtain the maximum reading each time. The highest dose rate measurement depends on closest position of the survey meter to residual extra thyroid functioning tissue, which retains radioiodine. Thyroid cancer patients were measured during three days (every day at same time) until the measured level fall down to permitted limit (2.5 m – 8 µSv/hr). That means that the residual activity is less than 800 MBq when patients were released to go home with orally given and written instructions for their further behavior in home conditions.

Determination of errors

The result of a calculation using the Monte Carlo method is the average number of "histories" performed during the simulation. The histories are generated by random sampling and a value of the quantity studied is allocated to each "history". Let p(x) be the probability function of a "history" of value x. Mx variable is given by p(x).

$$Mx = \int_a^b x\ p(x)\ dx \qquad (2)$$

The values of p(x) and thus Mx are not known exactly, but the ture mean; (x) can be estimated using the Monte Carlo method.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{3}$$

where (x_i) value of corresponding to the "history" (i), and (N) is the total number of "histories". The variance (σ^2) can be estimated using following formula.

$$\text{variance} = \sigma^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \tag{4}$$

The quantity $\overline{(x_i - m_i)(x_j - m_j)}$ is called the "covariance" between X_i and X_j:

$$\text{cov}(x_i, x_j) = \overline{(x_i - m_i)(x_j - m_j)} \tag{5}$$

The above equation suffers from the serious drawback that its value changes with the units used for the measurements of X_i, X_j. To eliminate this effect, the covariance is divided by the product of the standard deviations σ_i, σ_j and the resulting ratio is called the correlation coefficient $\rho(x_i, x_j)$. Thus,

$$\rho_{ij} = \rho(x_i, x_j) = \frac{\text{cov}(x_i, x_j)}{\sigma_i \sigma_j} \tag{6}$$

Results, Discussion and Conclusion

Results

The experimental data of twelve patients for distances 1.0m, 1.5m, 2.0m and 2.5m at first day, second day and third day are recorded in Table (5),(6) and (7). The external dose rate from twelve patients with iodine 131(I^{131}) Vs various distances are drawn and as shown in Figure (3), (4) and (5).From the experimental dose rate, the mean dose rates and the standard deviations at 1^{st} day,2^{nd} day and 3^{rd} day are calculated by using equation (3) and (4). These results are listed in Table (8), (9) and (10). According to Table (1), the effective dose limit for continuous or frequent radiation (annual) is 1mSv. From the Public limits (annual), the maximum permissible exposure time that stay 1m distances from the thyroid cancer patients were calculated. The correlation between dose rate and administered activities for twelve thyroid cancer patients at 1^{st} day, 2^{nd} day and 3^{rd} day are calculated by using equation (6) and recorded in Table (11). The correlation coefficients are positive and in the range from 0.2 to 0.4.A linear correlation coefficient has an absolute value between 0 and 1. With one is indicated a perfect linear relationship exists. In our case, there is a positive correlation of less than 0.5. The experimental data of three iodine patients with higher administered activity for distances 1.0m, 1.5m, 2.0m and 2.5m at 1^{st} day, 2^{nd} day and 3^{rd} day are recorded in Table (12), (13) and (14).The external dose rate of three higher administered activity patients at each distance (1.0m, 1.5m, 2.0m and 2.5m) are plotted and as shown in Figure (6), (7), (8) and (9).

Table 5 Dose rates of different distances on the 1st day for twelve thyroid cancer patients

Sr No.	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
1	1110	30	17	14	11	8
2	1110	30	22	16	14	12
3	1110	30	26	21	14	13
4	1110	30	25	20	17	13
5	1110	30	23	17	12	10
6	1110	30	28	18	14	7
7	1110	30	23	14	13	11
8	1110	30	28	23	20	16
9	1110	30	25	19	13	11
10	1110	30	28	17	16	13
11	1110	30	23	17	11	10
12	1110	30	27	23	20	15

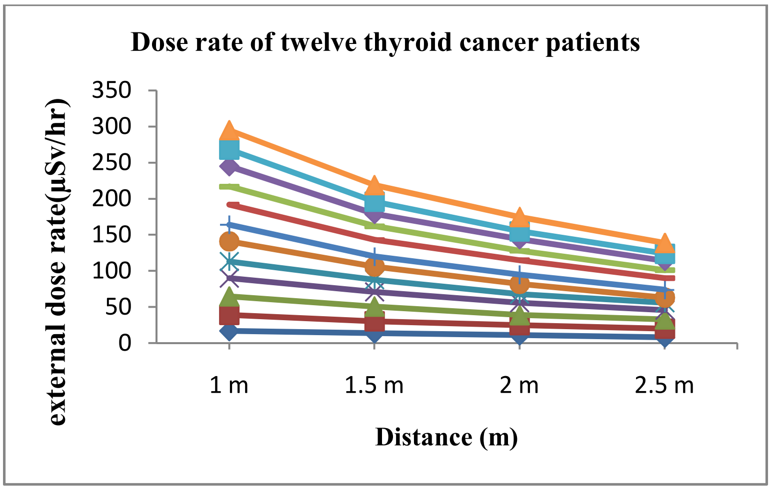

Figure 3 Dose rate of twelve thyroid cancer patients for 1st day

Table 6 Dose rates of different distances on the 2nd day for twelve thyroid cancer patients

Sr No.	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
1	1110	30	13	11	10	8
2	1110	30	23	20	18	16
3	1110	30	24	15	13	10
4	1110	30	14	13	11	10
5	1110	30	7	6	4	3
6	1110	30	25	23	14	11
7	1110	30	15	12	10	9
8	1110	30	21	17	15	12
9	1110	30	13	10	8	7
10	1110	30	19	14	12	11
11	1110	30	14	12	11	9
12	1110	30	25	23	19	10

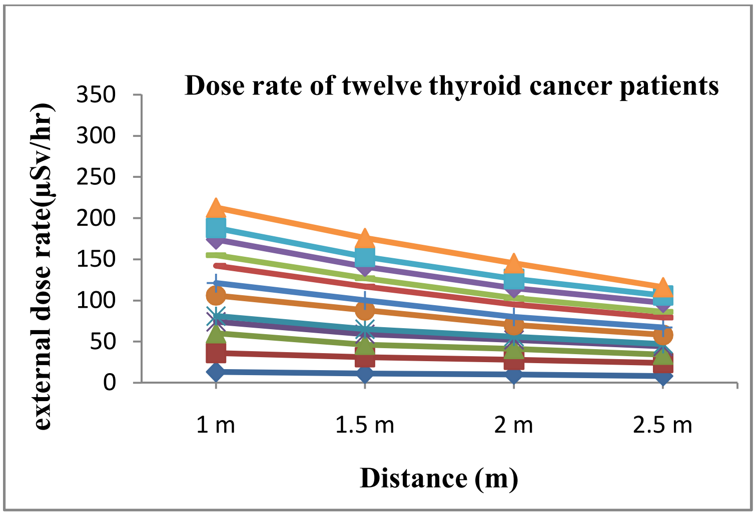

Figure 4 Dose rate of twelve thyroid cancer patients for 2nd day

Table 7 Dose rates of different distances on the 3rd day for twelve thyroid cancer patients

No	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
1	1110	30	12	10	9	8
2	1110	30	13	7	6	4
3	1110	30	15	13	10	9
4	1110	30	12	8	7	6
5	1110	30	2	1	0	0
6	1110	30	18	15	12	10
7	1110	30	14	10	9	8
8	1110	30	20	14	10	9
9	1110	30	18	12	10	8
10	1110	30	6	4	3	2
11	1110	30	12	10	9	7
12	1110	30	29	22	18	14

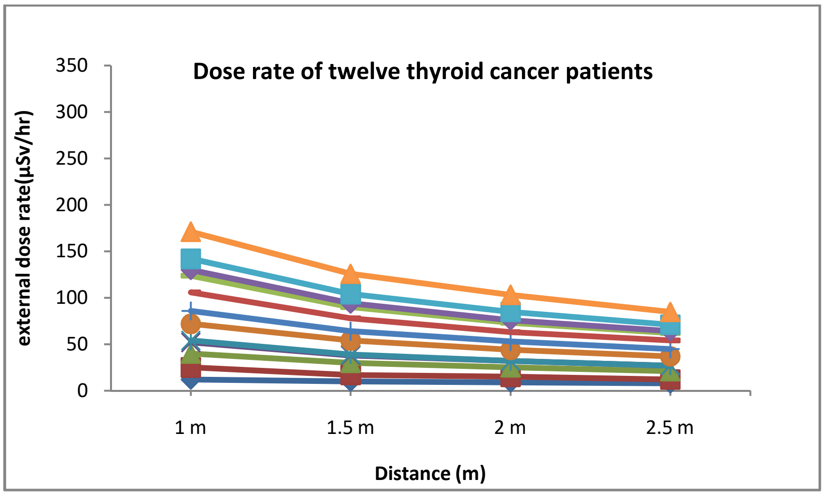

Figure 5 Dose rate of twelve thyroid cancer patients for 3rd day

Table 8 Mean dose rate, standard deviation for various patient distances (1st day)

Distance (m)	Mean dose rate (µSv/hr)	Standard deviation	Dose rate range (µSv/hr)
1.0	25	3.25	17-28
1.5	18	3	14-23
2.0	15	3.06	11-20
2.5	12	2.59	7-16

Table 9 Mean dose rate, standard deviation for various patient distances (2nd day)

Distance (m)	Mean dose rate (µSv/hr)	Standard deviation	Dose rate range (µSv/hr)
1.0	18	5.88	7-25
1.5	15	5.25	6-23
2.0	12	4.11	4-19
2.5	10	3.05	3-16

Table 10 Mean dose rate, standard deviation for various patient distances (3rd day)

Distance (m)	Mean dose rate (µSv/hr)	Standard deviation	Dose rate range (µSv/hr)
1.0	14	6.83	2-29
1.5	11	5.43	1-22
2.0	9	4.47	0-18
2.5	7	3.68	0-14

Table 11 Correlation coefficients for 1st day, 2nd day and 3rd day

distance	1st day	2nd day	3rd day
1.0 m	0.2	0.2	0.3
1.5 m	0.2	0.2	0.3
2.0 m	0.2	0.3	0.3
2.5 m	0.2	0.3	0.3

Table 12 Dose rates of different distances on the 1st day for higher administered activity of three thyroid cancer patients

No	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
10	1850	50	28	23	18	12
11	1850	50	30	25	24	18
12	2590	70	85	63	41	30

Table 13 Dose rates of different distances on the 2nd day for higher administered activity of three thyroid cancer patients

No	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
10	1850	50	15	14	13	10
11	1850	50	25	22	20	17
12	2590	70	80	60	45	35

Table 14 Dose rates of different distances on the 3rd day for higher administered activity of three thyroid cancer patients

No	Activity		Dose rate (µSv/hr)			
	MBq	mCi	1 m	1.5 m	2 m	2.5 m
10	1850	50	7	5	3	2
11	1850	50	22	16	15	13
12	2590	70	62	42	32	23

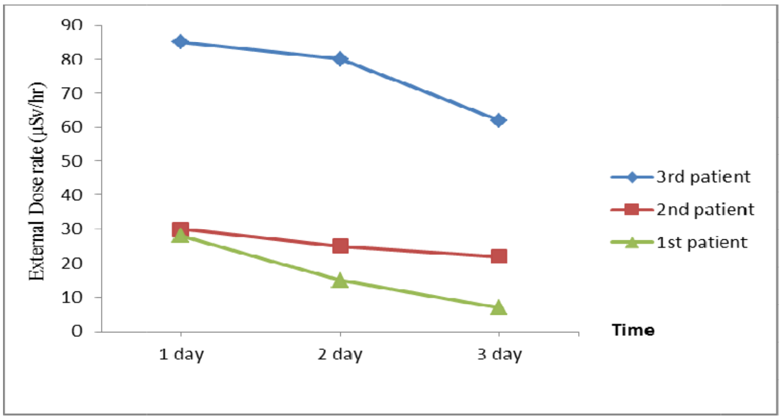

Figure 6 The external dose rate of three higher administered activitypatients at 1m

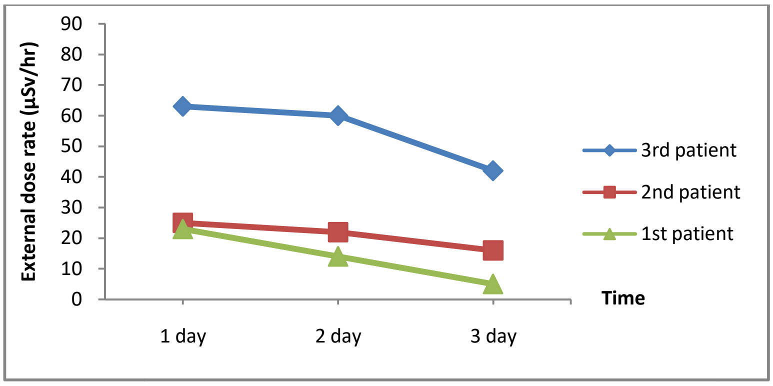

Figure7 The external dose rate of three higher administered activity patients at 1.5m

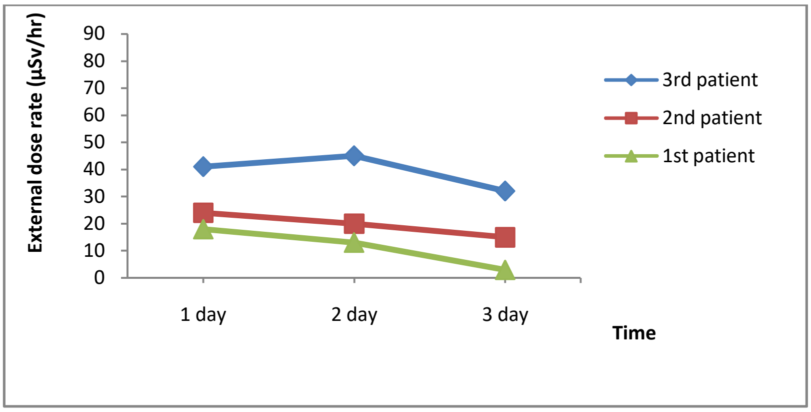

Figure 8 The external dose rate of three higher administered activitypatients at 2m

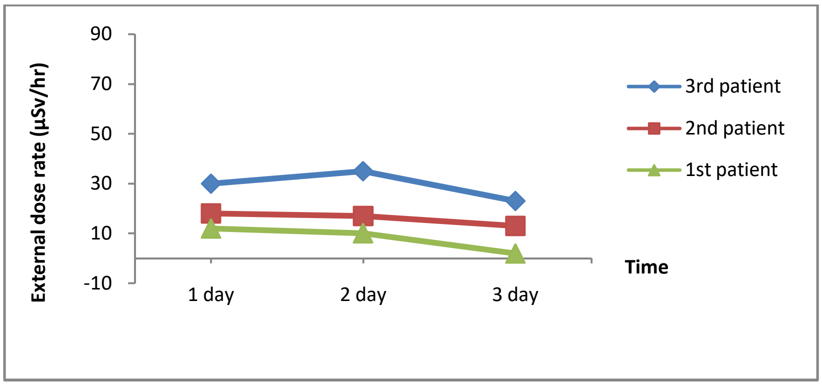

Figure 9 The external dose rate of three higher administered activity patientsat 2.5m

Discussion

^{131}I is well used radionuclide for the treatment of both hyperthyroidism and differentiated thyroid cancer. ^{131}I has received the greatest emphasis because of its unique applications in medicine. At the same distance for each day, the external dose rates of twelve thyroid cancer patients are different, although the same activity of iodine is treated to them. It is seen that every iodine patients have different effective half-life of radioactive iodine and different disease conditions. It is also found that, the further from the patients with treated iodine it is, the less external dose rate from the patients, according to the Inverse squared law. In three thyroid cancer patients, the greater administered activity, the higher external dose rate at the same distance for each day. It is cleared that the external dose rates from the patients are more decreased on the third day.

On the first day, all the people who are at least 1m away from the patients treated with the administered from 1110 MBq to 1850 MBq are safe. At the most highest administered activity (2590 MBq) far from 1m, maximum permissible exposure time for the first day lasts for twelve hours. It is suggested that to stay further away from the patients who have higher administered activities. To sum up, administered activity is effective not only for thyroid cancer but also for those who are at least 1 m away from the thyroid cancer patients.

Conclusion

In this study external dose rate measurements of fifteen patients were performed and based on the gained results we can conclude the following: it has several advantages such as lower health costs, lower doses to nursing staff and psychologic benefits for patients and family members. Emphasizing adherence to the new instructions for radiation protection is very important. Also reducing the time of stay near the radioactive patient will reduce the effective doses to the other person and will improve better radiation protection.

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