Iranian Journal of Medical Physics
Vol. 13, No. 1, March 2016, 36-42
Received: November 06, 2015; Accepted: May 09, 2016

IJMP

Original Article

Measurement of the Radiation Dose Rates of Patients Receiving Treatment with I-131 Using Telescopic Radiation Survey Meter

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Abstract

Introduction
In order to discharge the patients receiving treatment with large radiation doses of ^{131}I for thyroid cancer, it is necessary to measure and evaluate the external dose rates of these patients. The aim of the study was to assess a new method of external dose rate measurement, and to analyze the obtained results as a function of time.

Materials and Methods
In this study, a telescopic radiation survey meter was utilized to measure the external dose rates of a sample population of 192 patients receiving treatment with high-dose ^{131}I at one, 24, and 48 hours after dose administration.

Results
The proposed technique could reduce the occupational radiation exposure of the physicist by a factor of 1/16. Moreover, the external dose rates of both genders rapidly decreased with time according to bi-exponential equations, which could be attributed to the additional factors associated with iodine excretion, as well as the physiology of the body in terms of ^{131}I uptake.

Conclusion
According to the results of this study, telescopic radiation survey meter could be used to measure the external dose rates of patients receiving treatment with ^{131}I. Furthermore, the average difference in the radiation exposure between female and male patients was calculated to be less than 17%.

Keywords: Radiation protection, Radiation dose, Iodine, Radiation Monitoring

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1. Introduction

Patients with thyroid cancer commonly receive targeted therapy with radioiodine-131 (^{131}I). Patients receiving more than 1.11 GBq (>30 mCi) of ^{131}I typically require hospitalization under virtual isolation conditions for several days after ^{131}I dose administration [1, 2].

In consideration of radiation safety precautions for the attending personnel, general public, and patients in adjacent rooms, it is essential to note that ^{131}I emits negative beta particles (maximum energy approximately 807 keV), as well as a prominent 364 keV gamma photon. Furthermore, it delivers a major portion of the radiation dose to thyroid tissue remnants. The penetrating gamma ray poses a potential radiation hazard to other individuals outside the treatment room. In order to minimize the risk of radiation exposure for hospital personnel, patient families, and general public, it is of paramount importance to measure the external dose rates of patients and decide whether they could be discharged from the hospital [3-5].

Several studies have discussed the issue of patient discharge after treatment with radioiodine [1, 6-9]. Releasing criteria of these patients is mainly based on one of the following factors: whether the administered activity in the patient drops below 1.110 GBq (>30 mCi) or the dose rates at the distance of one meter from the patient are less than 30 µSv/h [10-12].

According to the ALARA principle, in the measurement of the external dose rate of the patient, the radiation protection of the health physicist performing the procedure should be optimized in order to control occupational exposure.

Several methods have been proposed for the evaluation and measurement of patient external dose rates at the distance of one meter. In some hospitals, an online patient monitoring system, which is based on a ceiling radiation detector, is mounted over the patient's bed and attached with a network system to evaluate the external dose rates. This system software calculates the expected time of falling below the limit value of patient discharge. In this process, the occupational exposure of the physicist to the external dose rate of the patient is often neglected. Since this system is rather costly, it is not widely used in hospitals. However, a portable survey meter is commonly utilized in the hospitals where the physicist stands in front of the patient to measure the required dose rate, which is associated with a relatively high risk of acquired occupational exposure [2]. In such case, addition of a movable barrier or increasing the distance between the patient and physicist could diminish the risk of occupational exposure.

This study aimed to assess a new method of external dose rate measurement using a telescopic radiation survey meter and analyze the measurement results as a function of time so as to quantify any differences in the radiation doses of female and male patients receiving treatment with ^{131}I.

2. Materials and Methods

In order to maximize the distance between the patient and health physicist during the measurement of external dose rates, a telescope radiation survey meter (GRAETZ X5DE, Germany) was used in this study. The telescope is smoothly extendable to a total length of four meters, and the survey meter detects and measures the doses of beta and gamma rays in microsieverts with associated uncertainties of less than10% at the confidence level of 95% provided by the calibration procedure within the measurement range of 1.0-20 µSv/h as approved by the Physikalisch-Technische Bundesanstalt (PTB), Germany. Moreover, an additional movable shielding barrier is used to optimize radiation protection during the measurements and minimize the risk of the associated occupational exposure. This survey meter is annually calibrated at the Secondary Standard Dosimetry Laboratory (SSDL) of Syria.

Table 1. Patient Groups

Patient Group	I-131 Administered Dose (Activity Level)	Number of Patients		
		Male	Female	Total
Group A	3.700 GBq (100 mCi)	16	93	109
Group B	5.550 GBq (150 mCi)	23	41	64
Group C	7.700 GBq (200 mCi)	6	13	19
Total		45	147	192

In total, 192 patients were randomly selected and received ^{131}I therapy for thyroid cancer in Al-Bayrouni University Hospital of Damascus, Syria during February-August 2011. The administered activity levels in this study were 3.7, 5.55, and 7.7 GBq (100, 150, and 200 mCi). Patients were categorized into three groups of A, B, and C based on the administered radiation doses (Table 1).

Measurement of patient external dose rates was performed at the distance of one meter from the effective point of measurement and standing point of the patient for three body levels of thyroid, bladder, and knee at one, 24, and 48 hours after dose administration.

3. Results

Mean values of the measured radiation external dose rates for female and male patient groups are presented in tables 2 and 3, respectively.

Table 2. Mean of measured external radiation dose rates in female patient groups at different times

Group	Time after Dose Administration (hours)	Average Dose Rate (µSv/h)			
		Thyroid Level	Bladder Level	Knee Level	Mean Value
Group A	1	128.04±24.31	153.63±28.9	129.09±23.71	136.92±25.64
	24	35.74±14.91	42.20±15.96	34.98±12.54	37.64±14.47
	48	14.56±13.03	16.47±10.74	12.74±9.40	14.59±11.06
Group B	1	185.15±37.40	222.83±45.08	209.39±38.47	205.79±40.32
	24	54.63±23.55	65.44±28.25	54.49±23.16	58.19±24.99
	48	27.24±17.04	26.66±18.60	21.88±16.15	25.26±17.26
Group C	1	280.92±63.88	329.69±69.86	282.08±54.10	297.56±62.61
	24	63.23±21.67	75.62±26.49	63.15±23.73	67.33±23.96
	48	22.54±9.93	27.77±12.67	23.62±11.18	24.64±11.26

Table 3. Mean of measured external radiation dose rates in male patient groups at different times

Group	Time after Dose Administration (hours)	Average Dose Rate (µSv/h)			
		Thyroid Level	Bladder Level	Knee Level	Mean Value
Group A	1	120.19±20.33	134.06±33.77	113.56±23.67	122.60±25.92
	24	35.31±9.59	42.19±13.26	37.69±11.14	38.40±11.33
	48	17.13±9.56	19.63±9.42	15.81±6.85	17.52±8.61
Group B	1	178.74±39.52	220.30±44.83	220.30±37.32	206.45±40.56
	24	58.70±22.81	67.74±28.16	54.04±23.06	60.16±24.68
	48	23.13±16.56	27.04±18.17	21.35±15.71	23.84±16.81
Group C	1	258.67±55.78	316.67±62.41	243.33±39.78	272.89±52.66
	24	78.17±20.39	94.50±27.03	79.33±20.26	84.00±22.56
	48	28.17±12.24	33.00±16.70	25.17±10.65	28.78±13.20

In female patient groups, mean of dose rate at the distance of one meter was within the range of 136.92-272.89 µSv/h one hour after dose administration. At 24 hours after dose administration, mean of dose rate at the distance of one meter was within the range of 37.64-67.33 µSv/h, while it was within the range of 14.59-25.26 µSv/h after 48 hours.

As for the male patient groups, mean of dose rate at the distance of one meter was within the range of 122.60-272.89 µSv/h one hour after dose administration, while this value was within the range of 38.40-84.00 and 17.52-28.78 µSv/h at 24 and 48 hours after dose administration, respectively.

In this study, P value of less than 0.0001 was considered significant for the measured external dose rates of both patient groups at the confidence level of 95%. Furthermore, dose rates at the bladder level were observed to be higher compared to thyroid and knee levels in both genders and patient groups.

4. Discussion

In the most recent publication regarding the patients receiving treatment with ^{131}I, the measurement of external dose rates was performed using a handheld dosimeter [13, 14]. In the present study, use of a telescopic survey meter to measure the external dose rates of the patients during the isolation period proved to be stable and easily effectuated by the health physicist.

Patient discharge criterion, which is thoroughly respected and applied in this hospital, is based on external radiation dose rate values (optimal rate: <30 µSv/h). In this regard, utilization of a telescopic survey meter ensures higher radiation protection for the physicist as the associated occupational exposure dose could be reduced by a factor of 1/16 due to the increased distance by four times. This procedure is in compliance with the ALARA principle of radiation safety for medical staff.

The relationship between the external dose rate (EDR) and different times after dose administration for all patient groups was fitted based on bi-exponential equations (R^2=1). Fitting equations for female patient groups were as follows:

$$EDR\_GroupA = 80.56e^{-0.10t} + 66.15e^{-0.03t}$$
$$EDR\_GroupB = 23.75e^{-0.21t} + 195.14e^{-0.05t}$$
$$EDR\_GroupC = 78.61e^{-0.027t} + 242.63e^{-0.09t}$$

Fitting equations for male patient groups were as follows:

$$EDR\_\text{GroupA} = 53.28e^{-0.24t} + 83.48e^{-0.033t}$$
$$EDR\_GroupB = 163.76e^{-0.07t} + 55.67e^{-0.022t}$$
$$EDR\_GroupC = 203.29e^{-0.06t} + 84.85e^{-0.03t}$$

The relationship between the external dose rates of female and male patient groups and different times after radioiodine dose administration and the related fitting curves are shown in figures 1 and 2, respectively.

According to the findings of the current study, fitting equations could be used to estimate the external dose rates of male and female patients within a specific time during patient isolation. According to the theoretical radioactive decay law, the external dose rate decreases with time following an exponential equation [15]. However, the results of the present study were indicative of an association between the administered dose rate and time following the bi-exponential equations, which is in congruence with the findings of previous studies in this regard [14, 16]. This could be attributed to the effects of additional factors associated with radioiodine uptake and biokinetics inside the patient’s body, such as the emissions and excretion of ^{131}I in the urine. The relationship between the external dose rates of female and male patients with time is depicted in Figure 3. According to these curves, the differences in the external dose rates between male and female patients were not significant. According to the information in tables 1 and 2, mean of the differences in this regard were determined at 11%, 3%, and 17% for A, B, and C patient groups, respectively. Therefore, the average difference value of the external dose rates was calculated at 10%.

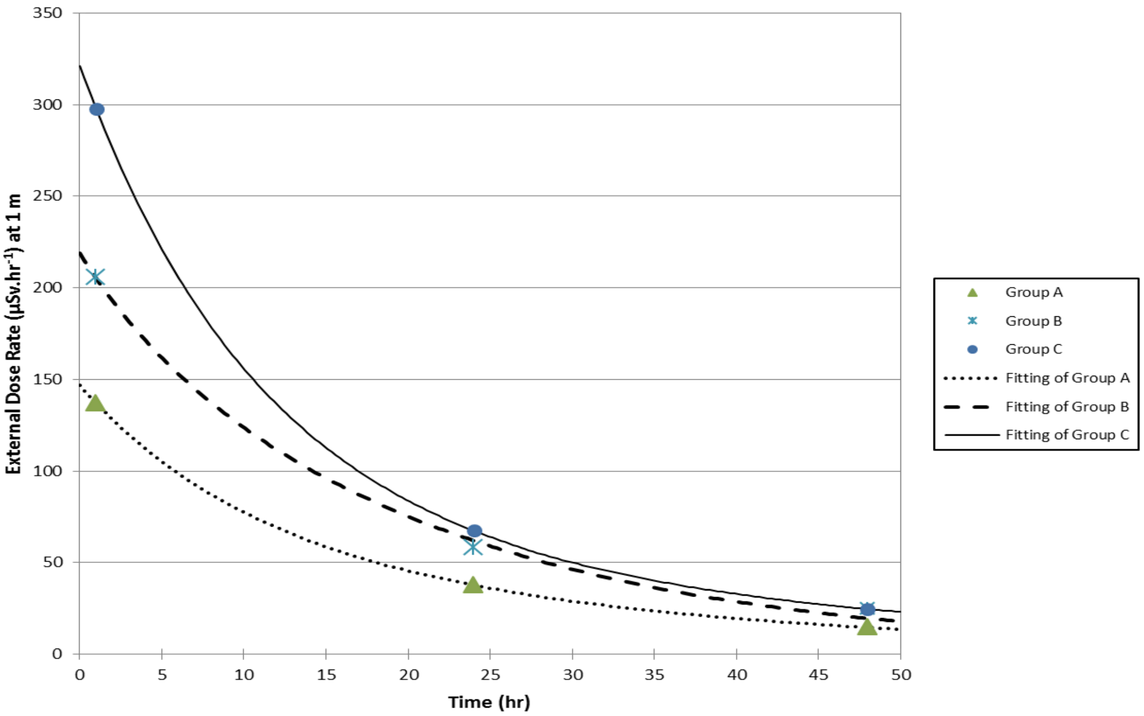

Figure 1. Variation of mean of dose rate at distance of one meter for female patient groups with time

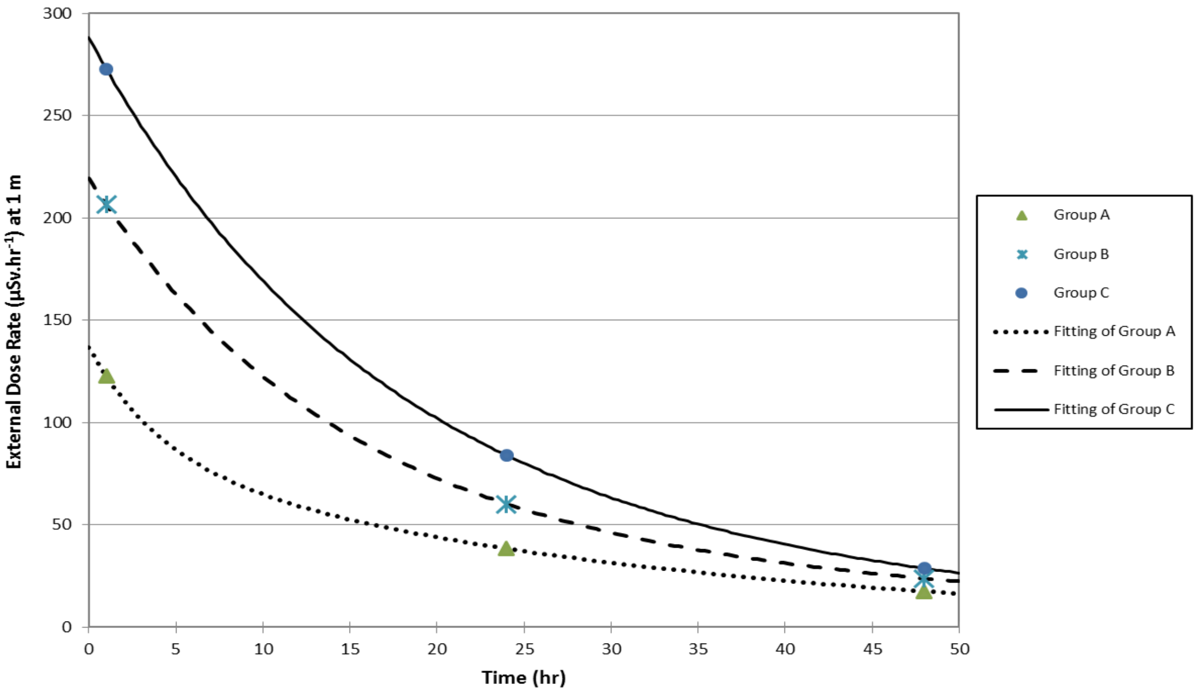

Figure 2. Variation of mean of dose rate at distance of one meter for male patient groups with time

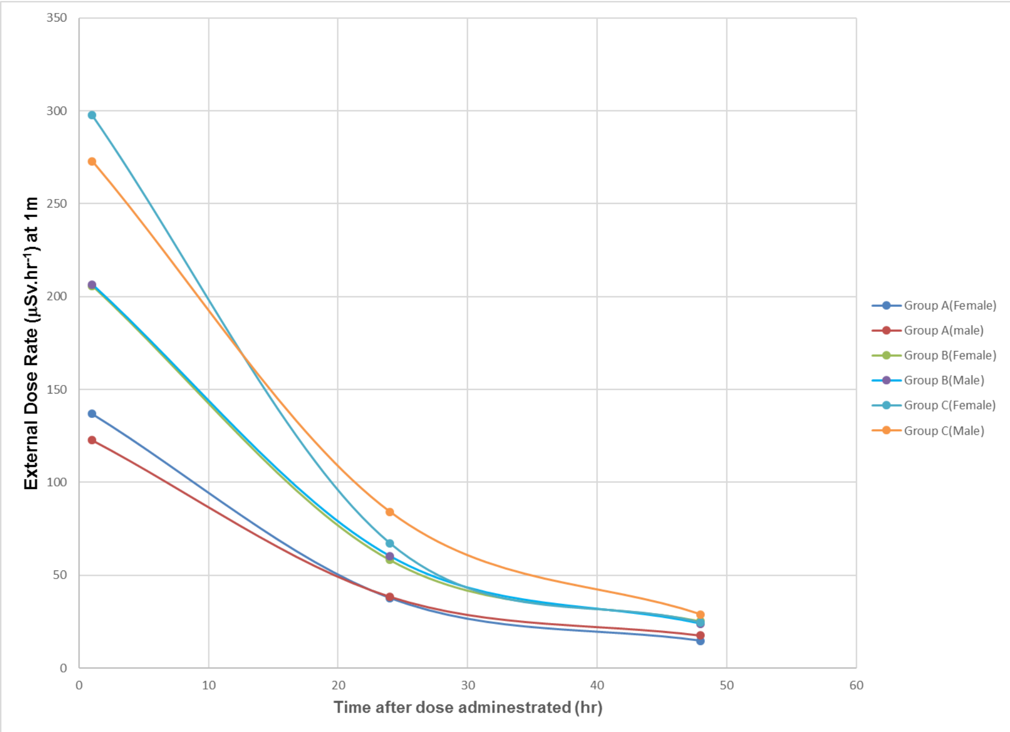

Figure 3. Comparison of measured external dose rates in female and male patient groups

5. Conclusion

In this study, the digital telescopic radiation survey meter could successfully measure the external dose rates of the patients receiving treatment with ^{131}I. According to our findings, maximizing distance from the patient leads to the higher radiation protection of the health physicist reducing the risk of the associated occupational exposure. Furthermore, the obtained results of this study indicated that the difference in the external dose rates between female and male patients was not significant, and the average difference value in this regard was determined at 10%. On the other hand, patient external dose rates decreased rapidly with time following the bi-exponential equations, which could be attributed to the effects of additional factors associated with radioiodine uptake and biokinetics inside the patient's body.

Acknowledgment

Hereby, we extend our gratitude to Prof. Ibrahim Othman, Director General of the Syrian Atomic Energy Commission, for his continual support and guidance in this study. We would also like to thank Dr. Mohammad Said Al-Masri, Head of the Protection and Safety Department, for his cooperation in this research project.

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