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Experimental and Analytical Dose Assessment of Patient's Family Members Treated with I-131

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***Abstract*—**Radiation exposure to the patient's family members is one of the major concerns during thyroid cancer radionuclide therapy. The aim of this study was to measure the total effective dose of the family members by means of thermoluminescence personal dosimeter, and compare with those calculated by analytical methods. Eighty-five adult family members of fifty-one patients volunteered to participate in this research study. Considering the minimum and maximum range of dose rate from 15 μsv/h to 120 μsv/h at patients' release time, the calculated mean and median dose values of family members were 0.45 mSv and 0.28 mSv, respectively. Moreover, almost all family members' doses were measured to be less than the dose constraint of 5 mSv recommended by Basic Safety Standards. Considering the influence parameters such as patient dose rate and administrated activity, the total effective doses of family members were calculated by TEDE and NRC formulas and compared with those of experimental results. The results indicated that, it is fruitful to use the quantitative calculations for releasing patients treated with I-131 and correct estimation of patients' family doses.

***Keywords*—**Effective dose, thermoluminescence, I-131, Thyroid cancer.

I. Introduction

DIFFERENTIATED thyroid carcinoma (DTC) occurs as one of the common endocrine tumor, with an annual incidence of 1.2-2.6 per 100,000 males and 2.0-3.8 per 100,000 females [1]. Radioiodine therapy (^{131}I) is one of the most effective and partly inexpensive treatment modality for DTC after thyroidectomy operation. The objective of radioiodine therapy is to ablate the thyroid or treat the metastatic region. It should be noted DTC is treated with 3700 MBq to 7400 MBq of radioiodine [2], [3].

Since the radioiodine is a beta/gamma emitter, the potential radiation risks always exist due to both external and internal irradiation. Internal exposures in consequence of radioactive secretions/excretions from patient may be prevented via staying away from a closed contact of the patient during the first few days after treatment [4]-[6]. However, the radiological hazards due to external irradiation to other individuals (e.g. staff of the hospital, the patient's family members and public) causes serious concern in radioiodine therapy and may not be reduced easily. Hospitalization is an effective solution decreasing the integral effective dose to the other individuals as low as reasonably achievable [4].

The International Commission of Radiological Protection (ICRP) has recommended 1 mSv/year as the general population dose limit [7]. However, according to the Basic Safety Standards (BSS) recommendations, individuals such as the patient's family members who "knowingly and willingly" help in the support and comfort of patients undergoing medical treatment is excused from aforementioned dose limit [8]. BSS permits a dose limit of 5 mSv per episode of treatment for the patient's family members. However, in order to keep the dose as low as reasonably achievable, dose constraints have been suggested by European Commission (EC) to family members and close friends of patients treated with radioiodine [9].

Some consensuses of international guidelines about the release of patients treated with radioiodine from hospital are as follows [4], [10]-[12]:

I. Retained activity of ^{131}I within a patient's body should be less than 1110 MBq.
II. Measured dose rate of patient should be less than 70 μSv/h at 1 meter.
III. The total effective dose equivalent from the patient to the other individuals should be retained less than 5 mSv (Patient-specific calculation).

In some countries (e.g. Germany, Switzerland and the Czech Republic) the released dose rate guidelines are stricter [13]. Also the other European countries and the United States prefer to use the patient-specific calculation [6]. Therefore, some investigators have endeavored to improve patient-specific calculations, and several researches have been conducted assessing the integral effective dose of the patient's family members [14], [15].

Mathieu et al. [16] measured the effective dose of family members (adult and children) of thyroid cancer patients using TLD, and reported the effective doses of less than 0.5 mSv in all cases. Barrington et al. [17] carried out a same study, in which adults` dose was ranged from 0.2 to 5.8 mSv with the children's doses ranged from 0.2 to 7.2 mSv. Grigsby et al. [18] reported the dose range of 0.01 mSv to 1.09 mSv for family members.

According to the national regulations in Iran, patients receiving over than 1110 MBq should be quarantined in hospital. Furthermore, according to the current national guidelines, if the external dose rate at 1 meter away from the patient was less than 70 μSv/h, the patient could be released.

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The objective of this study is to assess the effective dose of family members whose patients undergo the radioiodine therapy. The assessments have been carried out by thermoluminescence personal dosimeters and the results were compared with the total effective doses obtained from the proposed formulas by the Nuclear Regulatory Commission (NRC) and the Total Effective Dose Equivalent (TEDE) approaches.

II. Materials and Methods

The family members of fifty-one self-caring DTC patients treated with ^{131}I were studied at Research Center for Nuclear Medicine (RCNM), Shariati hospital, Iran. Table I illustrates the characteristics of patients and their family members.

Detailed recommendations about restriction of behavior were given to the patients and their family members at release time. The restriction time period was two weeks, independent of the release external dose rate. The given advices were presented in Table II.

The administered activity of radioiodine was ranged from 100 to 200 mCi. The external dose rate at 1 meter away from the patient was measured by a Geiger-Moller counter (Radiation Alert, Monitor 5, SE International Co., USA) within 2, 12, 24, 36 and 48 hours after ^{131}I administration. Radioiodine treated in-patients could be released if their measured external dose rates were less than 70 μSv/h (except those of patients who participated in the dose rate study).

The analytical calculation approaches were based on TEDE and NRC formulas. The TEDE formula can be obtained via the integration coming as:

$$TEDE = \int_{t_1}^{\infty} a \times e^{-\lambda_{eff} t} \quad (1)$$

where; t_1 is the time interval between radioiodine administration and release time, λ_{eff} is effective decay constant which is derived from the exponential curve of measured dose rate as shown in Fig. 1, and a is the patient`s dose rate at maximum uptake.

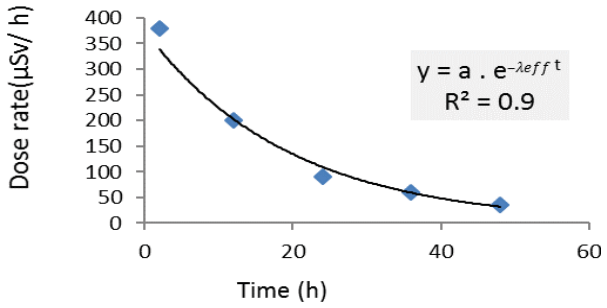

Fig.1 Exponential curve of patient external dose rate. The curve is used for calculating the effective decay constant (λ_{eff})

Also, the NRC [12] has suggested the following formula to determine infinite dose of family members as:

$$D(\infty) = \left[\frac{34.6\Gamma Q_0}{100}\right]\left[E_1 T_p (0.8)\left(1 - e^{-\frac{0.693(0.33)}{T_p}}\right)\right] + (E_1 F_1 T_{1eff} + E_2 F_2 T_{2eff}) e^{-\frac{0.693(0.33)}{T_p}} \quad (2)$$

where: D (∞) is family member dose (rem), Γ is the exposure rate constant for ^{131}I (2.2 R/mCi-h at 100 cm), Q_0 is the administered activity of ^{131}I (mCi), E_1 and E_2 are the occupational factors for the extra thyroidal and intra thyroidal components, respectively; and they are assumed to be 0.125 and 0.25 according to duration of hospitalization, F_1 and F_2 are the uptake fractions of the extra thyroidal and intra thyroidal components, respectively, and they are assumed to be 0.95 and 0.05 according to duration of hospitalization, T_P is physical half-life for ^{131}I (8.04 days), T_{1eff} and T_{2eff} are effective half-lives (in days) for the extra thyroidal and intra thyroidal components, respectively.

In order to measure the actual total effective dose of family members, one personal TLD dosimeter (TLD-100) was delivered to each family member wearing it on their chest region for a continues limited period of 7 to 21 days.

The measured dose value by TLD was adjusted to the infinite time (i.e. total effective dose) using:

$$D_{Infinite} = \frac{D_{TLD}}{1 - e^{-\lambda_{eff} t}} \quad (3)$$

where $D_{Infinite}$ is the total effective dose, D_{TLD} is the measured personal dose equivalent by TLD, and t is the number of days that the TLD was worn.

The minimum measured dose (MMD) of the TLD-100 was calculated to be 0.1 mSv, therefore TLD values less than aforementioned value were excluded from this study. The statistical analysis consisted of Kolmogorov-Smirnov test, Kruskal-Wallis test, Wilcoxon rank sum test and Spearman Correlation test was performed using SPSS v.17 software.

III. Results and Discussion

A. Comparative Study of TEDE and NRC Dose with TLD Measurements

According to Kolmogorov-Smirnov test, as the TLD, TEDE and NRC dose values did not follow a normal distribution, statistical analysis should be performed with non-parametric test. The appropriate parameters for exploratory analysis were median, minimum and maximum values of the range.

A descriptive analysis was presented in Table III. The results demonstrate that generally the TEDE formula gives better estimation of TLD doses than the NRC formula.

Statistically significant differences were observed between the effective doses of family members in the three methods (i.e. P <0.001 in Kruskal-Wallis analysis). The range of variations in estimated dose by NRC was higher than that of TEDE and TLD methods in the analysis (Fig. 2).

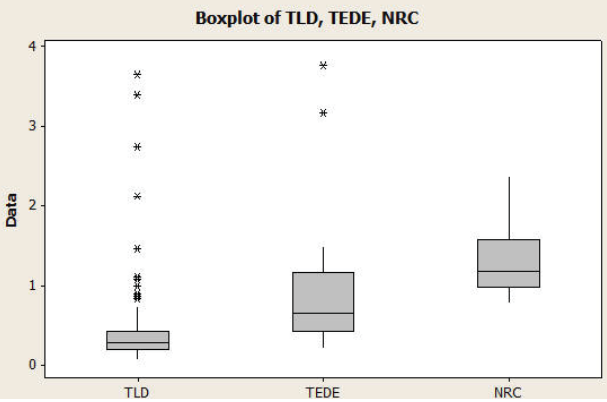

Fig. 2 Box-plot showing the distribution of the calculated (NRC and TEDE) and measured TLD dose values

The measured TLD dose values were less than those calculated by both analytical methods, because:

i. Analytical methods estimate each patient`s family member doses at a fix distance (e. g 100 cm).
ii. Patients and their family members' self-absorption were often being neglected in analytical methods.

Moreover, the calculated dose values were not the same in NRC and TEDE methods, since the effective half-life in (2) was a presumptive value in NRC method, whereas has been derived from actual patient's dose rate curve (i.e. Fig. 1) in TEDE method. Moreover, in 85% of cases, NRC dose value was greater than TEDE as the result of Wilcoxon signed-rank statistical test (Z= -6.2, p< 0.001).

B. Effect of Half Life

Fig. 3 shows the distribuation of in the NRC, TEDE and TLD doses values versus the effective half life.

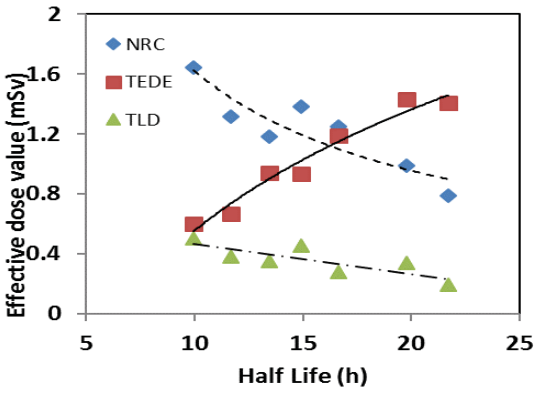

Fig. 3 Calculated (NRC and TEDE) and measured TLD dose values of family members vs. radioiodine effective half life in patients

The results indicate that both the NRC and TEDE formula were greater than TLD dose values. However, with the assumption of an acceptable value of 100% in overestimation, the TEDE formula may be a better estimation at the half life values less than 17 h, whereas the NRC formula would be better at the values greater than 17 h. Thus neither TEDE nor NRC formula could be an ideal estimation for the effective dose of family members alone. Moreover, there was a significant negative correlation between the subtraction of the TEDE from NRC dose Value [Diff (NRC-TEDE)] and the effective half life (the Spearman`s r = 0.81, P <0.001).

C. Effect of Dose Rate

Table IV presents the mean and median dose values of estimated (TEDE, NRC) and measured (TLD) at release external dose rates of patients.

It was found a statistically significant differences between the dose rate groups and the NRC, TEDE and TLD doses (Kruskal-Wallis, P<0.001). Further analysis shows a positive correlation between the release external dose rate and dose values of obtained by NRC, TEDE and TLD approches (Spearman`s r =0.69, 0.81 and .028, p = 0.001, 0.001 and 0.009, respectively). The results indicate that TEDE gives a better estimation of dose at external dose rate values less than 70 µSv/h.

According to the definition of TEDE dose, the positive correlation was predictable. However, it may be explained in NRC method by the residual activity in the patients' body which affects the dose rate values. It should be noted, higher release dose rate may increase the radiation exposure hazard and potential dose to other individuals as demonstrated in TLD dose values.

D. Effect of Administrated Activity

It was found a statistical significant difference between administered activity in NRC and TEDE dose values (Kruskal- Wallis, P = 0.001 and 0.05, respectively). The administered activity in NRC and TEDE dose were positively correlated. (Spearman`s r =0.47 and 0.31, p < 0.001 and = 0.004, respectively). However, there was not any correlation between the TLD dose and administered activity.

Table V presents a descriptive analysis about administered activity and dose values.

According to the definition of NRC formula, the positive correlation was predictable. However, it may be explained in TEDE method by release external dose rate related to the administrated activity and effective half-life. TLD dose values show no relationship with administered activity, because it may be strongly influenced by how the individuals followed the precaution instructions, the time spent close to the patient or the degree of patient`s care requirements.

IV. Conclusion

By following the precaution restrictions, all of the measured total effective doses were found to be well below the recommended dose limits for adult family members of patients treated with radioiodine therapy.

This study has provided information on the criteria for patient release based on TEDE and NRC analytical dose estimation of family members. TEDE or NRC approach could not be an ideal estimatation for the effective dose of family members alone. Patient specific release dose calculation is strongly affected by radioiodine effective half life and patient

external dose rate that could be helpful in choosing the suitable method. The NRC may be a better estimation than TEDE at the half life values greater than 17h. On the other hand, TEDE is more useful in external dose rates less than 70 μSv/h.

TABLE I
AGE AND SEX CHARACTERISTIC OF PATIENTS AND THEIR FAMILY MEMBERS

	Mean age (Years)	Gender	
		Female	Male
Patients	39.55	40	11
Adult of Family –members	42.98	30	55

TABLE II
RESTRICTION INSTRUCTIONS TO PATIENTS AND THEIR FAMILY MEMBERS

1. Do not use public transportation for getting back to your home after release
2. Keep 2 meters distance away from others
3. Avoid close contact with children under 2 years old
4. Sleep alone in a separate bed for 1 week after releasing
5. Postpone returning to work for 1 week after releasing
6. Avoid attending at public places such as cinema for 2 weeks after releasing

TABLE III
DESCRIPTIVE ANALYSIS OF NRC, TEDE AND TLD DOSE VALUES

		Statistical value	SD
NRC Dose (mSv)	Mean	1.35	.05
	Median	1.19	
	Std. Deviation	.45	
	Minimum	.79	
	Maximum	2.37	
	Skewness	1.1	.26
	Kurtosis	.84	.52
TEDE Dose (mSv)	Mean	.83	.07
	Median	.66	
	Std. Deviation	.65	
	Minimum	.22	
	Maximum	3.75	
	Skewness	2.69	.26
	Kurtosis	8.5	.52
TLD Dose (mSv)	Mean	.45	.05
	Median	.28	
	Std. Deviation	.46	
	Minimum	.1	
	Maximum	3.64	
	Skewness	4.94	.26
	Kurtosis	29.91	.52

TABLE IV
COMPARISON OF THE MEAN AND MEDIAN DOSE VALUES OF NRC, TEDE AND TLDIN FOUR PREDEFINED EXTERNAL DOSE RATE GROUPS

Dose Rate		NRC Dose(mSv)	TEDE Dose(mSv)	TLD Dose(mSv)
< 30 μSv/h	Mean	1	.43	.28
	Median	1.19	.38	.26
30 to 50 μSv/h	Mean	1.37	.89	.35
	Median	1.19	.73	.29
50 to 70 μSv/h	Mean	2.24	1.12	.99
	Median	2.37	1	.43
> 70 μSv/h	Mean	1.38	3.31	.65
	Median	1.58	3.16	.8

TABLE V
COMPARISON OF THE MEAN AND MEDIAN DOSE VALUES OF NRC, TEDE AND TLD IN FIVE ADMINISTERED ACTIVITY GROUPS

Administered activity		doseNRC	doseTEDE	doseTLD
100 mCi	Mean	1.06	.68	.28
	Median	.79	.53	.27
125 mCi	Mean	1.37	.89	.67
	Median	.99	.64	.34
150 mci	Mean	1.41	.73	.44
	Median	1.19	.63	.27
175 mCi	Mean	1.38	.95	.30
	Median	1.38	1.16	.27
200 mCi	Mean	1.58	1.96	.61
	Median	1.58	1.09	.75

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REFERENCES

[1] Kitagawa W, Shimizu K, Akasu H, Tanaka S. (Endocrine surgery. The ninth report: the latest data on and clinical characteristics of the epidemiology of thyroid carcinoma). Journal of Nippon Medical School = Nippon Ika Daigaku zasshi. 2003;70(1):57-61.
[2] Maxon HR. Quantitative radioiodine therapy in the treatment of differentiated thyroid cancer. The quarterly journal of nuclear medicine: official publication of the Italian Association of Nuclear Medicine. 1999; 43(4):313-23.
[3] American Thyroid Association Guidelines Taskforce on Thyroid N, Differentiated Thyroid C, Cooper DS, Doherty GM, Haugen BR, Kloos RT, et al. Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer. Thyroid: official journal of the American Thyroid Association. 2009; 19(11):1167-214.
[4] American Thyroid Association Taskforce On Radioiodine S, Sisson JC, Freitas J, McDougall IR, Dauer LT, Hurley JR, et al. Radiation safety in the treatment of patients with thyroid diseases by radioiodine 131I: practice recommendations of the American Thyroid Association. Thyroid: official journal of the American Thyroid Association. 2011; 21(4):335-46.
[5] Barrington SF, Anderson P, Kettle AG, Gadd R, Thomson WH, Batchelor S, et al. Measurement of the internal dose to families of outpatients treated with 131I for hyperthyroidism. European journal of nuclear medicine and molecular imaging. 2008;35(11):2097-104.
[6] Grundel M, Kopka B, Schulz R. 131I exhalation by patients undergoing therapy of thyroid diseases. Radiation protection dosimetry. 2008; 129(4):435-8.
[7] Watanabe H. (Explanation of the draft, "release of patients after therapy with unsealed radionuclides" of the International Commission on Radiological Protection: the 2nd report). Nihon Hoshasen Gijutsu Gakkai zasshi. 2004;60(5):689-97.
[8] Collins BJ, Chiappetta G, Schneider AB, Santoro M, Pentimalli F, Fogelfeld L, et al. RET expression in papillary thyroid cancer from patients irradiated in childhood for benign conditions. The Journal of clinical endocrinology and metabolism. 2002;87(8):3941-6.
[9] Frigren S. Radiation Protection following Iodine-131 therapy (exposures due to out-patients or discharged in-patients) Directorate-General Environment, Nuclear Safety and Civil Protection. 1998(European Commission).
[10] International Commission on Radiological P. Release of patients after therapy with unsealed radionuclides. Annals of the ICRP. 2004;34(2):v-vi, 1-79.
[11] Criteria for the release of individuals administered radioactive materials--NRC. Final rule. Federal register. 1997;62(19):4120-33.
[12] Fesenko SV, Voigt G, Spiridonov SI, Sanzharova NI, Gontarenko IA, Belli M, et al. Analysis of the contribution of forest pathways to the radiation exposure of different population groups in the Bryansk region of Russia. Radiation and environmental biophysics. 2000;39(4):291-300.
[13] Authorities HotERpC. 131I therapy: Patient release criteria

[14] Likhtarev IA, Kovgan LN, Vavilov SE, Gluvchinsky RR, Perevoznikov ON, Litvinets LN, et al. Internal exposure from the ingestion of foods contaminated by 137Cs after the Chernobyl accident. Report 1. General model: ingestion doses and countermeasure effectiveness for the adults of Rovno Oblast of Ukraine. Health physics. 1996;70(3):297-317.
[15] Fatome M. (Management of accidental internal exposure). Journal de radiologie. 1994;75(11):571-5.
[16] Mathieu I, Caussin J, Smeesters P, Wambersie A, Beckers C. Recommended restrictions after 131I therapy: measured doses in family members. Health physics. 1999;76(2):129-36.
[17] Barrington SF, Kettle AG, O'Doherty MJ, Wells CP, Somer EJ, Coakley AJ. Radiation dose rates from patients receiving iodine-131 therapy for carcinoma of the thyroid. European journal of nuclear medicine. 1996;23(2):123-30.
[18] Grigsby PW, Siegel BA, Baker S, Eichling JO. Radiation exposure from outpatient radioactive iodine (131I) therapy for thyroid carcinoma. Jama. 2000;283(17):2272-4.