Nuclear Medicine, Radiation Protection.

Measurement of External Radiation Exposure to Household Contacts of Outpatients Treated with Radioactive Iodine (^{131}I).

Salman, Kh[1]. Wagih, Sh[1]. Munshi, T[1]. Almalki, M[2], Zatari, S[1]. Zahid, Kh[1]. El-Morsy, S[1] and Abd-Al Moety, D[1].

[1]King Abdalla Medical City (KAMC) and [2]Ministry of Health (KSA).

ABSTRACT:

Background: Outpatients treated with low dose radioactive iodine (^{131}I) represent radiation hazard to caregivers and family members. Detailed radiation safety instructions (RSI) should be given by qualified professionals in a clear and proper way to avoid radiation overexposure. We aimed at measurement of cumulative radiation exposure (CRE) to household contacts of outpatients treated with low dose ^{131}I (up to 1110MBq) together with looking for factors that can significantly affect CRE figures.

Methods: Detailed RSI were properly explained to 61 patients and to one or more household contacts (87 out of 296) by radiation safety officer (RSO). Thermo-luminescent dosimeters (TLDs) were dispensed to all contacts after ensuring understanding how and when to be applied and after confirming that RSI can be conveyed properly to rest of household contacts. TLD's were collected fifth day after dispensing for measurement of CRE figures. The latter were correlated with different patients and contacts factors. **Results:** CRE figures were well below radiation exposure constraint of caregivers and family members living in the same house with the patient, ranging from 0.071 to 1.026 mSv. Single adult contact had CRE more than 1 mSv and the remaining 295 contacts had CRE below this limit. No single demographic or educational factor had statistically significant correlation with CRE. Lower CRE figures were found for contacts of thyroid cancer patients and contacts who received direct RSI from RSO. **Conclusion:** All CRE figures of household contacts of outpatients treated

with low dose ^{131}I therapy were well below radiation exposure constraint, denoting proper compliance of outpatients treated with ^{131}I in King Abdalla Medical City (KAMC) and their household contacts to given RSI.

Household contacts of thyroid cancer patients and those who received direct RSI from RSO had relatively lower CRE figures, raising the concept of giving RSI to all household contacts by qualified professionals.

Keywords: Radiation exposure, Household contacts, ^{131}I therapy.

Corresponding Authors: Wagih, Sh. **E-mail:**dr.sherinyassin@gmail.com.

INTRODUCTION:

The use of radioactive iodine (^{131}I) therapy in thyroid disorders is continuously increasing since its first application and success in management of thyroid disorders in 1940's. It has a great value in patients with thyroid diseases due to its safety and being relatively inexpensive. It can be used successfully in treatment of hyperthyroidism, toxic multi-nodular goiter, and differentiated thyroid cancer. The given doses of ^{131}I on therapeutic bases commonly range from 185 to 7400 MBq, according to underlying thyroid disease. Thyroid cancer patients with post-operative thyroid remnants or with remote functioning metastases are treated with larger doses. Patients treated with ^{131}I represent radiation hazard to the community, particularly to caregivers and family members **(1, 2, and 3)**.

This fact raises the concept of radiation safety that becomes an essential component in the use of ^{131}I as a therapeutic modality. Each country has its own precautions for limiting radiation exposure to the public, medical staff, patient's family and caregivers with whom a treated patient may come in contact.

The main radiation hazards from patients treated with ^{131}I is from direct external exposure to caregivers and family members, but, it is worth to mention that there is internal exposure, which is far below external exposure. This could expose household contacts to radiation, yet, many studies stated that the risk of internal exposure is low but not negligible **(4, 5 and 6)**. Despite being insignificant compared to external exposure, it is more recommended for pregnant women and young children to

Avoid also internal exposure due to higher sensitivity of fetal and pediatric thyroid glands to induction of thyroid cancer [7, 8].

In association with ^{131}I therapy, either low ^{131}I dose or post discharge after 2-3 days hospitalization for high ^{131}I dose , each center offering this medical service gives specific protective recommendations and radiation safety instructions (RSI) the main aim of which is reduction of exposure to the public, caregivers , family members and the whole community. These recommendations have the same aim of achieving the principle of reducing radiation exposure to levels that are as low as reasonably achievable (ALARA) [1].

The International Commission on Radiation Protection (ICRP) has recommended a dose constraint to the public of 1 mSv/year; this is applied for visitors to patients treated with radioactive material who are not essential to patient care or comfort as well as for young children and pregnant ladies who live with the patient [5]. Adult family members and caregivers living in the same house with the patient are allowed to receive a higher dose of 5 mSv per episode, providing that the average dose for consecutive five years does not exceed 1 mSv [9]. The release criteria for patients receiving therapeutic amounts of radiopharmaceuticals were also reported to be based on the prevailing National Council on Radiation Protection and Measurements (NCRP) recommendations of 5 mSv annually for adult family members caring for or living with the patient treated with ^{131}I.

The NCRP also recommends a 1mSv exposure limit annually for pregnant women and children [10]. This dose is also recommended by the International Atomic Energy Association (IAEA), with the dose to any comforter shall be constrained so that his or her dose is unlikely to exceed 5mSv [11]. The dose to children visiting the patient should be similarly constrained to less than 1mSv [11].

The European commission (EC) dose constraints allow 3 mSv for family members aged 10-60 years and 15mSv for those above 60 years [9].

To our knowledge, Kingdom of Saudi Arabia (KSA) has no single study to assess numerically external radiation exposure to family members and caregivers after outpatient low dose ^{131}I therapy or after hospital discharge post high dose ^{131}I therapy.

The current study was done to measure external cumulative radiation exposure (CRE) to contacts of patients treated with low dose ^{131}I on outpatient basis in our community.

Also, we planned to detect whether CRE figures are within the radiation exposure constraint or exceed this limit, reflecting compliance of Saudi population to RSI. Besides, different factors that may have positive or negative significant impact on those figures are going to be studied. This study will be able to put the standard precautions given to patients treated with ^{131}I during their post therapy period.

The present work aimed at measuring CRE to household contacts of patients treated with low dose ^{131}I on outpatient basis in KSA together with looking for patients and contacts factors that can significantly affect these CRE figures.

MATERIALS AND METHODS:

This is a prospective study conducted from April 2015- July 2017. Inclusion criteria included well-oriented self-dependent adult patients referred for outpatient low dose ^{131}I therapy and have the facility to use separate bedroom and bathroom for few days post therapy with no pregnant ladies at home during the post treatment period. ^{131}I therapy was indicated either for treatment of toxic goiter or for post-operative ablation in patients with well differentiated thyroid cancer. Detailed radiation safety instructions (RSI) were thoroughly explained to the patient and to one or more contact by radiation safety officer (RSO) in a clear way with provision of hard copies of the same instructions. An informed consent was obtained. After demonstrating how and when to apply thermo luminescent dosimeters (TLDs), they were dispensed for all household contacts to measure external CRE, followed by ^{131}I intake. TLDs were collected on fifth day post ^{131}I therapy for readings and for measurement of CRE figures for all contacts.

The given RSI included the use of a separate bedroom and bathroom in the post therapy period with toilet flushing three times after use together with washing hands thoroughly on coming out of the bathroom. Also, patient has to use separate dinning tools that should be washed after each use separately. The patient should also drink a lot of fluids (water, juices, etc.) to pass urine frequently and has to avoid sexual intercourse for two to three weeks and use a suitable contraceptive method to avoid pregnancy for a period of six months after treatment. Besides, nursing women should stop breast feeding. Wash everything related to the patient (off clothes, towels and linens) separately for one week. The patient should take time off his work, its length depends on the type of work and the given ^{131}I dose.

Taking a shower and changing all clothes daily is a must in the few days post therapy and prior to ^{131}I whole body scan. All these instructions should be followed strictly keeping in mind the golden rules of time, distance and shielding, emphasizing their value in reducing radiation CRE figures to household contacts.

Statistical Analysis:

Statistical analysis was carried out on STATA version13.Numeric variables were presented as the mean and standard deviation or the median and quartiles with comparisons using Mann Whitney, Kruskal Wallis or parametric tests (t-test or ANOVA), according to data distribution and number of groups. Categorical variables were presented as percentages and were compared by chi square test. CRE values were divided into tertiles and ordinal logistic regression with robust standard error performed with CRE as the dependent variable and patient and contact demographic variables as the independent ones. Multivariable regression was performed using forced entry of variables that promise of association (by a p value of < 0.1 or odds ratio <0.5 or > 2.0) on univariante analysis.

RESULTS:

Characteristics of included 61 patients are shown in ***Table (1),*** out of them 38 patients had well differentiated thyroid cancer and 23 patients with toxic goiter. Direct explanation of RSI by qualified professional (RSO) was done to all patients, together with one or more family member of 55 patients, with assurance of their ability to convey these instructions properly to the rest of family members and caregivers.

Table (1): Characteristics of 61 patients included in the study.

Characteristic		**Thyrotoxic (n=23)**	**Thyroid cancer (n= 38)**	**P Value**
Age (Y):	Mean ± SD	36.4±14.7	43.6±17.3	0.103
	Range	16-47	18-85	
Gender (N,%):	Male	7 (30.4)	5 (13.2)	0.182
	Female	16 (69.6)	33 (86.8)	
level of education:	Illiterate	2 (8.7)	13 (34.2)	
(N,%)	Primary	3 (13.0)	5 (13.2)	
	High School	11 (47.8)	8 (21.1)	0.059
	University	6 (26.1)	12 (31.6)	
	Post - graduate	1 (4.3)	0 (0)	
Direct Education from RSO (N, %):				
	Patient only	3 (13.0)	3 (7.9)	0.664
	Patient & family member/s	20 (87.0)	35 (92.1)	
Actual dose given (MBq):				
	Range	410.7-740	1088-1110	<0.001*
	Mean ± SD	518± 137	1095± 37	

*Statistically significant

The included 61 patients had 296 contacts; their characteristics are shown in ***Table (2)***. All contacts had CRE figures ranging from 71-1026 uSv. One adult contact had CRE of 1026 uSv, representing the only contact with CRE more than 1mSv, while the remaining contacts (99.7%) had CRE less than 1 mSv, 75% of household contacts had CRE figures less than 0.5 mSv (less than 10% of the 5 mSv constraint). For the 49 contacts ≤ 12 years, all had CRE less than their constraint of 1 mSv, with CRE figures ranging from 79.1 to 758 uSv and 75% had CRE figure less than 50% of the radiation exposure constraint for children (1mSv). No statistically significant differences in CRE between contacts of patients aged less than or more than 40 years. This is also the same as regards CRE figures of contacts of male and those of female patients with insignificant p value. Again, no significant association between patient's level of education and CRE figures was found. Yet, the 6 contacts of the single patient with post graduate education had the lowest mean (153±54uSv) and median (139uSv) CRE figures compared to contacts of illiterate patients or contacts of those with other education levels.

Table (2): Characteristics and TLD readings of 296 contacts.

Characteristic	All Contacts (n:296)	Contacts of patients with toxic goiter (n=117)	Contacts of Thyroid cancer patients (n= 179)	P Value
Age (Y): Mean ± SD	28.3 ±17.4	27.9±17.8	28.4±17.2	0.837
Age category (N,%) :≤12Y	49 (16.6)	23 (19.7)	26 (14.5)	
>12 to ≤40 Y	178 (60.1)	61 (52.1)	117 (65.4)	0.075
>40 Y	69 (23.3)	33 (28.2)	36 (20.1)	
Gender (N,%): Male	128(43.2)	49 (41.9)	79 (44.1)	
Female	168 (56.6)	68 (58.1)	100 (55.9)	0.702
Contact relation to the patient (N,%): Spouse	38 (12.8)	14 (12.0)	24 (13.4)	
Parent	32 (10.8)	17 (14.4)	15 (8.4)	
Son/Daughter	118 (39.9)	44 (37.6)	74 (41.3)	0.122
Sibling	53 (17.9)	26 (22.2)	27 (15.1)	
Helper	13 (4.4)	2 (1.7)	11 (6.1)	
Other	42 (14.2)	14 (12.0)	28 (15.6)	
Direct RSI Education from RSO (N,%):	87 (29.3)	39 (33.1)	48 (26.8)	0.248
CRE (uSv):				
Mean ± SD	262± 149	258±152	265±146	
Median	209	216	209	0.912
Q2-3	159-322	170-294	157-354	
Range	71-1026	79-992	71-1026	

While for studied contacts factors, it was found that contacts age, gender and receiving direct RSI from RSO had no statistically significant correlation with CRE figures. Female contacts had numerically lower mean and median CRE values as compared to male contacts. Also, contact relation to the patient had no significant correlation with CRE figures, yet, helpers had the highest mean (308±127) and median (290 uSv) CRE figures compared to all other relatives. Whereas, parents had the lowest mean and median CRE figures of 232±117uSv and 239 uSv respectively.

Tables (3) and (4) show the distribution of the low (<176uSv) versus high (>176 uSv) CRE levels categorized by different criteria of patients and contacts respectively.

Table (3) shows that the distribution of CRE to contacts in either group is not appreciably different among contacts of patients from different age and gender categories. It may be noted however that a higher percentage of contacts of patients below 40 years (35.1%) had CRE <176 uSv as compared to that of contacts of older patients (31.7%). Also, more contacts of female patients were in the lower radiation exposure category (34.5%) compared to contacts of male patients (29.5%). For all levels of patient education, contacts were more or less, distributed evenly among radiation exposure groups. It is worth noting that five out of six contacts of the single patient with postgraduate education were in the lower CRE category (< 176 uSv). As for the association between the patient's indication for ^{131}I therapy and the CRE of his/her contacts, it can be seen that there is a smaller proportion of thyrotoxic patient contacts in the lower CRE tertile as compared to that of thyroid cancer patient contacts (29.9% versus 35.8 % respectively) with insignificant p value ***(Table 4)***.

Helpers were the only class to have the majority of patient contacts in the higher radiation exposure category (76.9% with radiation exposure figure >176 uSv) and only 23.1% belonging to the group who had radiation exposure level less than 176 uSv. Apart from helpers, spouses had the next higher incidence in the high exposure level as compared to that of all other relatives (23.7% in the lower CRE and 76.3% with radiation exposure level more than 176 uSv). A higher percentage of contacts who had received RSI directly from the RSO were in the lower CRE group (<176 uSv) as compared to those who had not received direct RSI from RSO and received them indirectly from the patient or from other family member (39.1% versus 31.1% respectively), again with no significant p value ***(Table4)***.

Table (3): Comparison of distribution of contacts' CRE within the lower tertile (<176uSv) versus the higher two tertiles (>176uSv) categorized by different patient characteristics.

Character	Categories	Number of contacts in lower tertile versus upper two tertiles (N, %)		P value
		Below 176 uSv	More than 176uSv	
Patient's age category	40 and below	53 (35.1%)	98 (64.9%)	0.458
	> 40	46 (31.7%)	99 (68.3%)	
Patient's gender	Male	18 (29.5%)	43 (70.5%)	0.503
	Female	81 (34.5%)	154 (65.5%)	
Patient's Level of Education	Illiterate	27 (33.3%)	54 (66.6%)	0.080
	Primary	11 (26.2%)	31 (73.8%)	
	High School	30 (31.3%)	66 (68.7%)	
	University	26 (36.6%)	45 (63.4%)	
	Post-graduate	5 (83.3%)	1 (16.7%)	
Diagnosis	Thyrotoxicosis	35 (29.9%)	82 (70.1%)	0.231
	Thyroid cancer	64 (35.8%)	115 (64.2%)	

Table (4): Comparison of distribution of contacts' CRE within the lower tertile (<176 uSv) versus the higher two tertiles (>176uSv) categorized by their different characteristics.

Character	Categories	Number of contacts in lower tertile versus upper two tertiles		P value
		Below 176 uSv	More than 176uSv	
Family member age category	40 and below	77 (33.9%)	150 (66.1%)	0.805
	> 40	22 (31.9%)	47 (68.1%)	
Family member age category	12 and below	16 (32.7%)	33 (67.3%)	0.421
	Above 12 years	83 (33.6%)	164 (66.4%)	
Family Member Gender	Male	41 (32%)	87 (68%)	0.731
	Female	58 (34.5%)	110 (65.5%)	
Family Member Relation to the patient	Spouse	9 (23.7%)	29 (76.3%)	0.173
	Parent	14 (43.8%)	18 (56.2%)	
	Son/ daughter	35 (29.7%)	83(70.3%)	
	Sibling	19 (35.8%)	34 (64.2%)	
	Helper	3 (23.1%)	10 (76.9%)	
	Other	19 (45.2%)	23 (54.8%)	
Direct RSI education from the RSO	No	65 (31.1%)	144 (68.9%)	0.338
	Yes	34 (39.1%)	53 (60.9%)	

Univariante ordered logistic regression of CRE tertiles on patient-related factors showed that the only factor that had a significant association with CRE was postgraduate education. Family members of the single patient with postgraduate education had significantly lower CRE values.

Also, being a contact of a female Patient or a contact who accompany the patient for receiving direct RSI from RSO resulted in relatively lower CRE figures. All other factors had odd ratio (OR) very close to 1.0, besides having no significant association with CRE figures. Multivariate regression models show that after adjustment of other factors, having ^{131}I therapy for thyroid cancer exposes household contacts to less radiation exposure compared to contacts of thyrotoxic patients who received significantly lower ^{131}I doses. Also, receiving direct RSI education from RSO remained the only factor that owes negative association with CRE figures, the latter appears to be a more important factor, retaining an OR of 0.621. However all these associations did not reach the statistically significant level of $p < 0.05$ ***(Table5)***.

Table (5): Multivariate ordinal regression of CRE of family members on different patients and contacts factors.

Variable in the equation	OR	P value	95%CI
Model 1			
Thyroid ca. v. thyrotoxicosis	0.507	0.706	0.015-17.241
Actual dose given	1.041	0.696	0.851-1.273
Pt. education (higher to lower)	0.865	0.154	0.408-1.152
Direct RSI education from RSO	0.757	0.484	0.348-1.648
Model 2			
Thyroid ca. v. thyrotoxicosis	1.001	0.953	0.948-1.059
Pt. education (higher to lower)	0.703	0.176	0.422-1.171
Direct RSI education	0.801	0.548	0.87-1.655
Model 3			
Pt. education (higher to lower)	0.702	0.162	0.428-1.153
Direct RSI education	0.802	0.538	0.398-1.617
Model 4			
Pt. education (higher to lower)	0.689	0.127	0.427-1.112
Model 5			
Pt. education (higher to lower)	1.01	0.959	0.683-1.493
Direct RSI education	0.621	0.151	0.325-1.187

DISCUSSION:

Radiation safety is a cornerstone in the protocol of ^{131}I therapy; CRE figures should not exceed the annual dose constraint of 5 mSv to adult caregivers and family members by applying different radiation protection procedures, keeping in mind the three main items of time, distance and shielding.

In the current study CRE to 296 household family members of 61 patients who received ^{131}I therapy dose ranging from 11.1 mCi (410.7 MBq) to 30 mCi (1110 MBq) on outpatient basis had a mean value of 262±149 uSv (range: 71 to1026 uSv) with a median value of 209 uSv and median seventy fifth percentile of 322uSv (range:294-354). It is worth to mention that only one adult contact exceeded CRE value of 1 mSv, reaching 1026 uSv.

This represents the highest CRE figure in our study, which is far below the constraint of 5 mSv.

The remaining 295 contacts (99.7%) showed CRE below 20% of the constraint of 5mSv. More importantly, we have to spot the light on the figure of the seventy fifth percentile of CRE; this figure for the whole group of contacts was equal to or less than 354 uSv, meaning that 75% of contacts had CRE below one tenth of the adult radiation exposure constraint.

So, contacts of ^{131}I treated patients in our study had successfully achieved CRE figures evidently below the radiation exposure constraint that are comparable to figures stated in many other reports.

Grigsby et al 2000, reported a range of radiation exposure rate from 0.01 to 1.09 mSv to 65 household caregivers and family members of patients who received ^{131}I therapy dose ranging from 2.8 GBq to 5.6 GBq, they also reported exposure to 17 household pets within the radiation exposure constraint ranging from 0.2 to 1.11 mSv with a mean value of 0.37 mSv **(12)**.

Also, ***Rutar et al*** reported an exposure range of 0.17- 4.09 mSv for contacts of patients who received ^{131}I doses ranging from 0.94 to 4.77 GBq, still less than the radiation exposure constraint of 5 mSv ***(13)***. The relatively higher radiation exposure rate in their group is mostly related to different patient settings with higher dose of ^{131}I given to patients. While ***Mariiott et al, 2007*** reported maximum radiation exposure dose in their study of 0.283 mSv to caregivers of 25 self-helped patients receiving 3.7 GBq on outpatient basis **(4)**.

Other studies also revealed comparable results with all reported mean values of cumulative radiation exposure dose less

Than 1 mSv for contacts of patients who received ^{131}I therapy on outpatient basis **(14, 15)**.

In addition to adult contacts, TLDs were also dispensed to young children in the current study that included 49 children aged 12 years or less, representing 16.6% of the whole family members.

The CRE figures for this group ranged from79.1-758 uSv. All values were less than the reported 1 mSv dose constraint for children with a compliance of 100% to this constraint. Besides, the seventy fifth percentile of CRE of this group of contacts was below the constraint of 0.5 mSv. No statistically significant difference in CRE figures of children between contacts of patients treated with ^{131}I for toxic goiter and those treated for cancer thyroid was found. It was reported by ***Barrington et al 1999*** that 89% of children comply with the 1 mSv dose constraint. They concluded that hyperthyroid patients could continue to be treated with ^{131}I on an out-patient basis if given appropriate radiation protection advice with particular consideration to be given for children aged 3 years or younger **(16)**. On the other hand ***Mathieu et al, 1999*** found that the median dose received by children who are family members of 18 hyperthyroid patients who were given 200-600 MBq on outpatient basis was 0.13 mSv with 88% received less than the constraint of 0.5 mSv compared to 100% for relatives of thyroid cancer patient group (22 patients) who received 3700-7400 MBq on outpatient basis. They explained this by the higher ^{131}I retention by the thyroid gland in the former group, suggesting more extended and stringent restriction periods based on residual thyroid activity. **(17)**

Looking for any patients' factors that can significantly affect the CRE; we studied the effects of patient's gender, age, and patient's educational level and ^{131}I dose given as regards their relation to contacts' CRE level. No single factor proved to have significant correlation with CRE figures. Slightly higher incidence of lower radiation exposure level was found in contacts of female patients, contacts of patients less than 40 years of age and contacts of the single patient with postgraduate education. Still noteworthy is the fact that contacts of all other education categories of patients had CRE figures well below radiation exposure constraint. This can be due to the fact that RSI were actually well understood and followed strictly as long as RSI were properly explained to the patient in a simple and straight forward way by qualified professionals.

In the present work, comparison of CRE figures between contacts of patients with thyroid cancer and those of hyperthyroid patients was done statistically by more than

One method, with a general direction that CRE appears to be relatively less with contacts of thyroid cancer patients, yet, the difference is not statistically significant. Thus radiation exposure may tend to be lower to contacts of thyroid cancer patients in spite of the fact that they received higher ^{131}I doses. This in agreement with the results of some studies where contacts of ^{131}I treated hyperthyroid patients had significantly higher exposure rate compared to that rate in contacts of patients treated for cancer thyroid, attributing this to more thyroid gland retention of ^{131}I in the former group **(17, 18)**. So, it appears that the dose of ^{131}I is not the most important determinant of the post-therapy radiation exposure level to contacts and that factors related to available functioning thyroid tissue with tracer retention may play an important role. Also, factors related to patients' contacts were studied to assess for any significant impact on CRE level. While the age and gender of the contacts of patients appeared to have no statistically significant association with the level of their CRE, the type of relation to the patient and the attendance of RSI education sessions from qualified professionals looked like important ones. With all forms of statistical analyses, it was always that contacts who received direct RSI from the RSO had higher incidence of lower radiation exposure levels than those who did not. Their absolute CRE readings from TLDs were lower, with 39.1% of them in the lower radiation exposure category (less than 176 uSv) versus 31.1% of those who did not receive direct RSI from the RSO. Our results showed that receiving direct RSI remained the most consistently associated factor with lower radiation exposure level in all regression models. This highlights the role of direct education of contacts from qualified professionals and raises the importance of giving direct education about RSI compared to most other studied factors.

An overall analysis of the association between CRE figures and the type of the relation between the patient and his/her contacts was done by multiple statistical methods. Helpers had CRE figures numerically higher than all other contacts. It was found that only one helper (7.7%) received direct RSI education while the proportion of direct education was around 30% for all other categories. This emphasizes the value of giving direct RSI education to all household contacts including the helpers.

In univariante ordinal regression analysis, only being a helper or being a contact of ^{131}I treated patient with post-graduate education level had association with the level of radiation exposure.

Yet, CRE figures of helpers were well below the radiation exposure constraint and only single patient had postgraduate study. Several multivariate models were built in a trial to find a combination of factors that determine the level of radiation exposure. However, with the presence of many factors and the possible existence of confounding from multiple variables, the models were not very stable with marked changes in OR estimate with factor inclusion or exclusion. It should be noted however that receiving direct RSI by the contact from the RSO remained relatively the most stable factor in the analysis, retaining an ability to reduce exposure by 20-40% after adjustment of all other factors.

The absence of significant correlation between different studied factors and CRE figures is in agreement with what was reported by ***Kuo et al 2017*** who studied many factors looking for any association between them and the radiation exposure to household environment and contacts. They stated that no factor had significant association with environmental radiation exposure, reflecting absence of significant association between any of these factors and radiation exposure to family members. They expect the latter to be lower than environmental exposure unless family members were in close contact with the patient for a long period [(19)]. On the other hand ***Martin et al*** 2016 confirmed our finding of absent significant correlation between radiation exposure and patient education level [(20)].

CONCLUSION:

CRE figures of all household contacts of patients treated with ^{131}I therapy are below radiation exposure constraint, denoting proper compliance of outpatients treated with low dose ^{131}I in King Abdalla Medical City (KSA) and their household contacts to RSI irrespective of demographic or educational factors. No single studied factor had significant effect on CRE figures; yet, contacts of patients treated with ^{131}I for thyroid cancer and contacts who received direct RSI from qualified professionals had relatively lower CRE figures, raising the concept of giving detailed direct RSI to all contacts of patients treated with ^{131}I.

Acknowledgment: The study team would like to express their profound gratitude and acknowledgment to King Abdulaziz City for Science and Technology (www.Kacst.edu.sa) of Saudi Arabia for its financial support and on-going encouragement. This work was funded through the Strategic Technology Program –The national Plan for Science, Technology and Innovation (http://maarifa.kacst.edu.sa) grant number # AT-34-431.

REFERENCES:

1- ***Sisson JC, Freitas J, McDougall IR, et al.*** Radiation Safety in the Treatment of Patients with Thyroid Diseases by Radioiodine 131I: Practice Recommendations of the American Thyroid Association. The American Thyroid Association Taskforce on Radioiodine Safety. Thyroid. 21(4): 335-346; 2011.

2- De-***Klerk JMH.*** 131I Therapy: Inpatient or outpatient? The journal of Nuclear Medicine. 41(11): 1867-1879; 2000.

3- ***Al-maskery I, and Bererhi, H.*** Radiation Exposure Levels in Family Members of Omani Patients with Thyrotoxicosis Treated with Radioiodine (131I) as Outpatients. Sultan Qaboos Univ. Med J. 9(2): 148–152; 2009.

4- ***Marriott CJ, Webber CE, and Gulenchyn KY.*** Radiation exposure for "care-givers'' during high-dose outpatient radioiodine therapy. Radiat. Prot. Dosim. 123 (1): 62–67; 2007.

5- ***International Commission on Radiological Protection (ICRP).*** Release of patients after therapy with unsealed radionuclides. ICRP Publication 94. Ann. ICRP. 34: v-vi, table10.7, p47; 2004.

6- ***Jacobson A, Plato P, and Toeroek D.*** Contamination of the home environment by patients treated with iodine-131: initial results. Am. J. Public Health. 68 (3): 230-235; 1978.

7- ***Schneider S, and McGuire S.*** Regulatory analysis on criteria for the release of patients administered radioactive material. NUREG-1492. U.S. Nuclear Regulatory Commission, Washington, DC; 1996.

8- ***National Council on Radiation Protection and Measurements (NCRP).*** Dose limits for individuals who receive exposure from radionuclide therapy patients. Commentary No.11. National Council on Radiation Protection and Measurements, Bethesda; 1995.

9- ***Besli LU, Demir M, Yweyin N, et al.*** Radiation dose of caregivers could be reduced in thyroid carcinoma patients requiring high dose of radioactive iodine: A case report. Iran J. Nucl. Med. 24 (2): 144-146; 2016.

10- ***National Council on Radiation Protection and Measurements (NCRP)***. Management of radionuclide therapy patients. NCRP Report No.155. National council on Radiation protection and Measurements, Bethesda, MD; 2006.

11- ***International Atomic Energy Agency (IAEA).*** Radiological protection for medical exposure to ionizing radiation, Safety Guide no. RS-G-1.5. International Atomic Energy Agency, Vienna; 2002.

12- ***Grigsby, W. Siegel B.A, Baker S. et al.*** Radiation exposure from outpatient radioactive iodine (131I) therapy for thyroid carcinoma. JAMA 283 (17): 2272–2274; 2000.

13-***Rutar FJ, Augustine SC, Colcher P, et al .***Outpatient treatment with 131I –Anti–B1 Antibody: radiation exposure to family members. J Nucl Med. 42 (6): 907-915; 2001.

14- ***Pant GS, Sharma SK, Bal CS, et al.*** Radiation dose to family members of hyperthyroidism and thyroid cancer patients treated with 131I. Radiat. Prot. Dosimetry. 118 (1): 22-27; 2006.

15- ***Cappelen,T, Unhje, JF, and Amundsen A.l .*** Radiation exposure to family members of patients with thyrotoxicosis treated with 131I. Eur. J. Nucl. Med. Mol. imaging. 33 (1): 81-86; 2006.

16- ***Barrington SF, O'Doherty MJ, Kettle AG, et al.*** Radiation exposure of the families of outpatients treated with radioiodine (iodine131) for hyperthyroidism. Eur. J. Nucl. Med. 26 (7): 686-692; 1999.

17-***Mathieu I, Caussin J, Smeesters P, et al.*** Recommended restrictions after 131I therapy: measured doses in family members. Health Phys. (76): 129-136; 1999.

18- ***Monsieurs M, Thierens H, Dierkx RA, et al.*** Real-life radiation burden to relatives of patients treated with 131I: A study in eight centers in Flanders (Belgium). Eur. J. Nucl. Med. 25 (10): 1368-1376; 1998.

19- ***Kuo S., Ho T., Liou M. et al:*** Higher body weight and distant metastasis are associated with higher radiation exposure to the household environment from patients with thyroid cancer after radioactive iodine therapy. Medicine, 96(35):7942; 2017.

20-***Martin R., Silva F., Colon MA., Roman D., Gonzalez TB:*** Evaluation of Household Radiation Exposure and Safety after Ambulatory Radioiodine Ablation therapy. Journal of thyroid cancer. 1(1): 35-41, 2016.