EXPOSURE RATES (VERSUS TIME AFTER ADMINISTRATION), IN RELATION WITH CLINICAL FACTORS, FOR THYROID CARCINOMA PATIENTS TREATED WITH IODINE-131

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INTRODUCTION

While the therapeutic use of iodine-131 for thyroid carcinoma patients offers enormous benefit to them, it contributes also significantly to the radiation exposure of individuals and population. A critical quantity for decisions relating radiation protection system based on restrictions recommended by authorities is the residual I-131 activity in patient's body. When this value is larger than a threshold level, it may keep the patient hospitalised for a short period of usually 2 to 3 days with an additional period of 7 days at home, where he must sleep separately and avoid close contact with other people [1]**.** Essential for radiation protection issues is the careful collection of radioactive urine, radioactive waste and avoidance of any contaminations by perspiration and saliva. Longer hospital stay would increase the total cost of the treatment and limit the availability of the isolation room. So the patient has then to return home, having always in mind that in spite of the fast washout of the I-131 from his body, even the second week still contributes significantly to the total radiation burden to relatives and friends [1]. Radiation hazards concerning relatives and friends can be kept to a truly negligible level (a small fraction of the annual dose limit of only 1mSv [2]), only if it is provided that:

a) reasonable standards of personal hygiene and cleanliness are followed, b) urine or saliva contaminations are avoided and c) patient's close contact with relatives or friends is kept to a minimum. These measures should be followed for a time period of 2-8 days after hospital discharge, a period that depends on administered and retained I-131 activity.

This work tries to estimate the correlation between several clinical factors and the residual activity of I-131 in patient's body and proposes a method for a more simple measurement of the total body activity during patient's stay in the treatment centre - hospital.

MATERIALS AND METHOD

The measurements took place in General Hospital ´´White Cross´´, Piraeus, Greece. 73 patients with well-differentiated thyroid carcinoma involved in this study and had all undergone near-total thyroidectomy. Patient's related data as gender, age, weight and height were recorded, as well as patient's file information like date and extent of surgery, presence of thyroid remnants and tumour histology. In all patients, thyroid function tests including TSH were performed and thyroid uptake using a single probe system (Captus 600 – Capintec INC) was measured. At 4 - 7 days after administration a 10min image was obtained using a gamma camera (Starcam 400 - GE), equipped with a large field of view high-energy collimator for metastasis and pinhole collimator for thyroid remnants detection. Additional information for liquid consumption (in litters) and emptying of the bowls during hospitalisation was also recorded.

The administered activity ranged from 1100 to 5550 MBq (mean value 3450 MBq). Exposure rates at a distance of 1m from patient were measured using a calibrated ionisation chamber filled with air (BICRON Surveyor 2000) that scans in front of the patient's body looking for the height with the maximum exposure rate. The measurements were taken 3, 24, 48 hours (and 72 hours, if patient was still at the hospital) after I-131 administration for ablation or treatment for distant metastasis and expressed as mR h^{-1}. Correlations between exposure rates normalised to the administered activity and all the above parameters were calculated.

Based on the assumption that the I-131 radiopharmaceutical has its maximum dispersion through patient's body 3 hours after administration, the residual activity is calculated by the formula:

$$A_t = E_t \cdot (A_3 / E_3) \qquad (1)$$

where A_3, A_t is the activity 3 and t hours after administration respectively, while E_3 and E_t is the maximum corresponding exposure rate value at a distance of 1m from patient's body. In this work, E_3 is patient's reference exposure rate value, while the ratio E_3/A_3 is considered as his "*exposure rate constant*" at this distance.

RESULTS AND DISCUSSION

Seventy three (73) thyroid cancer patients (12 males and 61 females) were treated as inpatient. The BMI (Body Mass Index) values ranged between 17 and 44 kg/m^2 (mean value 26 kg/m^2). All patients were hospitalised for 2-4 days and were discharged when the dose rate measurement at 1m was less than 30μSv h^{-1}. Thyroid uptake and TSH value, ranged between 0 and 28% and between 17 and 340 (μIU/ml) respectively. Gamma-camera images showed metastases in 11 cases.

A scale/score adjusted to the parameters of: degree of metastases, liters of water consumed, bowl emptying, TSH, uptake, and BMI values as shown in Table 1. Ascending score value implies growing difficulty for radiopharmaceutical washout. A final score-factor was then extracted for each patient.

Table 1: Score values (0-4) for different parameters.

Parameters	Score				
	0	**1**	**2**	**3**	**4**
Metastasis	**M- 0** Absence of metastasis	**M - 1** Neck lymph-node	**M – 2** Chest lymph-nodes or 1-2 lung metastasis	**M - 3** Diffuse lung metastasis	**M - 4** Bone metastasis
Liquids (L)	> 6 L	3 – 6 L	< 3 L		
TSH (μIU/ml)	< 20	20 – 30	30 – 100	> 100	
Uptake (24 h)	< 2 %	2 – 7 %	7 – 15 %	15 – 22 %	22 – 30 %
Bowl emptying	YES	NO			
BMI (kg/m^2)	Underweight (< 21)	Normal (21-27)	Overweight (> 27)		

Correlation coefficients between exposure rates normalized to the administered activity and the above parameters, according to the score factor, calculated for the end of the 2nd and 3rd hospitalization days are shown in Table 2. Right column of this table includes weighting factors (corresponding to each clinical parameter) that are proposed according to statistical processing results. These weighting factors are a quantitative expression of the degree in which each clinical parameter affects patient's residual activity.

Table 2: Correlation coefficients between exposure rates normalized to the administered activity and the measured parameters 48h and 72h after administration. Weighting factors proposed for each clinical parameter according to statistical processing results are shown in the right column.

Parameters	Correlation with Exposure Rate / Administered Activity ratio (mR h^{-1} MBq^{-1} @ 1m)		Proposed Weighting Factor
	48h	**72h**	
Metastasis	r= 0.41 p= 0.0003	r= 0.49 p= 0.014	**0.35**
Liquids (L)	r= -0.32 p= 0.005	r= -0.38 p= 0.05	**0.2**
TSH (μIU/ml)	r= -0.14 p= 0.22	r= -0.2 p= 0.34	**-**
Uptake (24 h)	r= 0.61 p < 0.0001	r= 0.81 p < 0.0001	**0.4**
Bowl emptying	r = 0.26 p= 0.026	r= 0.24 p= 0.24	**0.05**
BMI (kg/m^2)	r= 0.015 p= 0.9	r= -0.07 p= 0.75	**-**

The mathematical expression for the relation between residual activity and administered activity has then the form of the equations 2 and 3:

***48h*:**

R (MBq) = [0.07 x (0.35 M + 0.2 L + 0.4 U + 0.05 B) + 0.028] x A / 100 (2)
(*r = 0.74*)

***72h*:**

R (MBq) = [0.07 x (0.35 M + 0.2 L + 0.4 U + 0.05 B) - 0.006] x A / 100 (3)
(*r = 0.87*)

where:

R: the remaining activity in MBq
A: the administered activity in MBq
M: the degree of metastasis
L: the number of liquid consumed in liters
U: the uptake value (24h)
B: the bowl emptying (yes or no)

for the end of 2nd and 3rd hospitalization day respectively.

The exposure rate 48h after I-131 administration, normalized to the administered activity ($mR.h^{-1}.MBq^{-1}$) is significantly correlated with water consumed ($r = -0.32$, $p = 0.005$) and thyroid uptake values ($r = 0.61$, $p < 0.0001$) (table 2). The mean residual I-131 activity 48h after administration, as calculated using the formula (1), increases from 7% of administered activity for uptake values <2%, to 28% for uptake values between 22-30%. The mean residual activity 72h after administration increases from 4 to 23% for the above uptake values (figure 1). Also for low liquid consumption (< 3L) the mean residual activity is 15% of the administered (48h later), but for high liquid consumption (> 6L) the mean residual activity is only 7% (figure 2). If there is no metastasis the residual activity reach the 9% (after 48h). The presences of metastasis result in higher residual activity and reach the 32% in case of bone metastasis (figure 3). The presence of metastasis may multiply the percentage of the residual activity by a factor of 3.4.

Figure 1

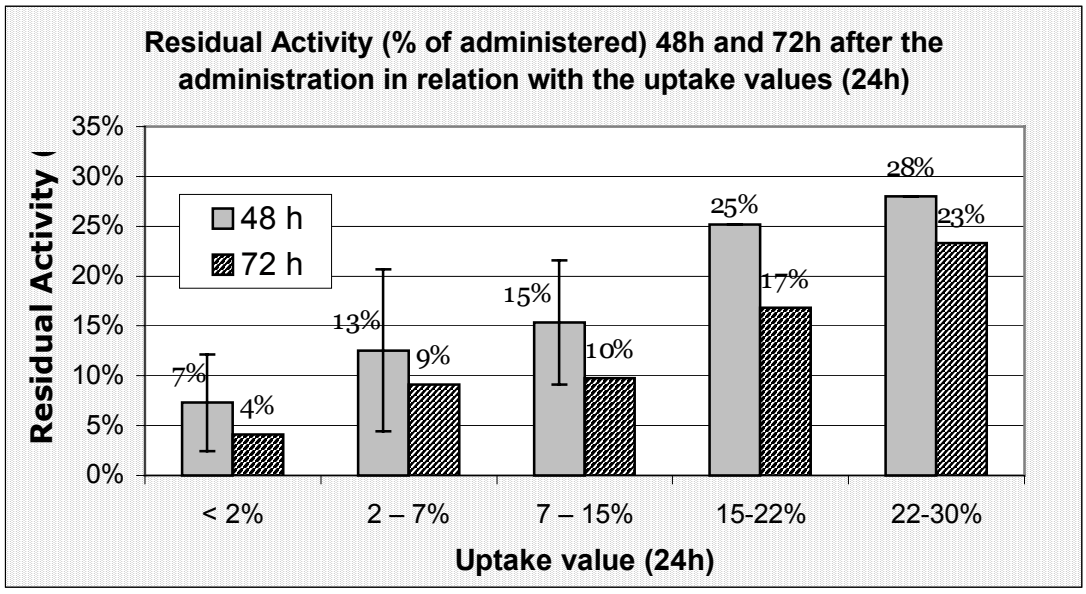


Figure 2

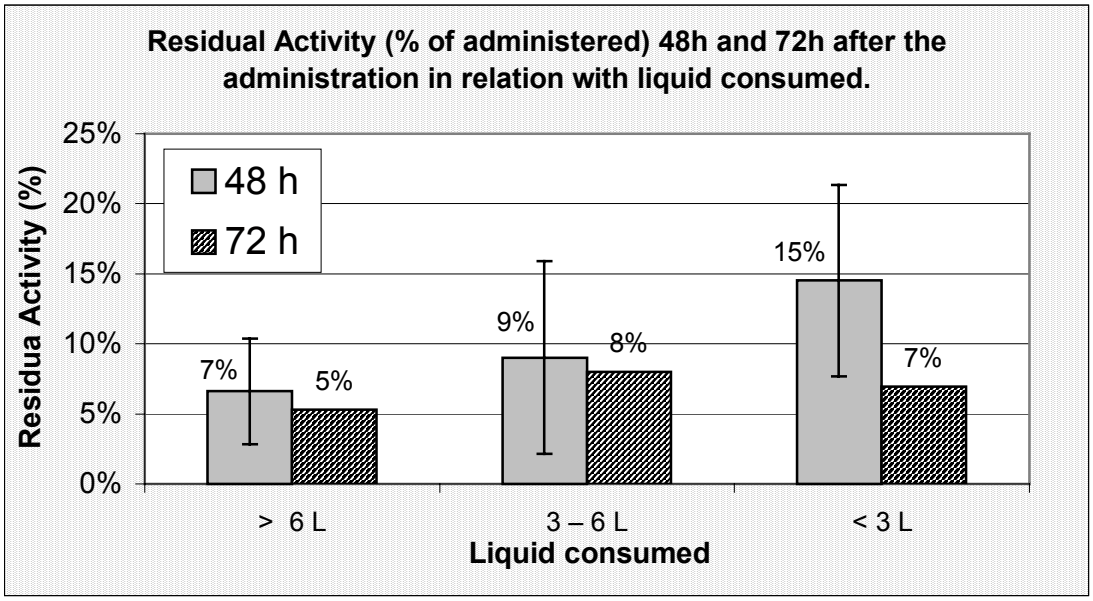
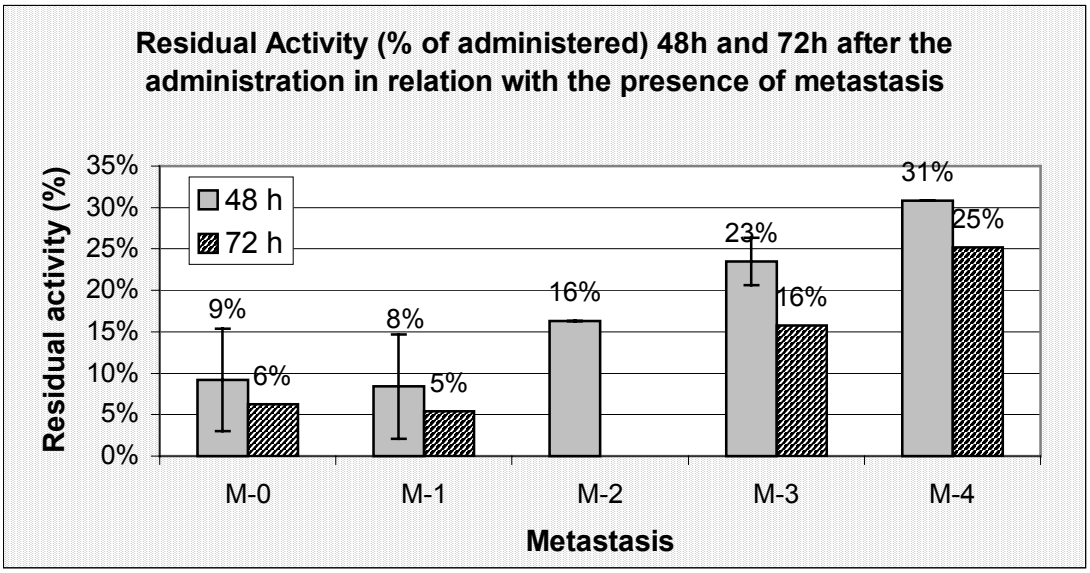


Figure 3



CONCLUSIONS

The period for which a patient treated with I-131 should remain in the hospital is a significant problem in terms of social and financial impact. It is difficult to make a categorical decision on the time for patient discharge, especially for cases where the patient and/or relatives do not respect the restrictions included in the instructions given. The highest measured doses in partners and children of a patient were mainly related to the non-observance of the advice given [3].

This work analyses the relation between the "critical quantity" named residual I-131 activity in patient's body and various clinical parameters and reveals that the main factors affecting the amount of residual activity are the liquid consumption and the thyroid uptake value. Therefore, good management of patients receiving iodine-131 treatment should attempt to maximize thyroid uptake and speedup radioactivity washout in order to keep the dose to other patient's organs as well as radiation burden to homemade as low as possible.

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