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Radioactive discharge from patients with thyroid cancer under ^{131}I treatment and its safe disposal to the public sewer system

Substancje radioaktywne uzyskiwane od chorych z rakiem tarczycy poddanych jodoterapii i ich bezpieczne wprowadzanie do publicznych systemów kanalizacyjnych

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Introduction: The treatment of thyroid cancer using unsealed sources of radioactive materials is usually associated with a large amount of ^{131}I. The major problem for hospital treatment of these patients is the disposal of waste which requires special protection.

Materials and methods: 152 patients with thyroid cancer admitted to the nuclear medicine department of Said Al-Shohada Hospital for ^{131}I treatment were studied. Exposure from patients was measured using a Victorian 190F survey dosimeter. ^{131}I excreted from these patients during isolation was calculated.

Results: More than 70% of administered ^{131}I was excreted after 24 hours, 90% after 48 hours and 96% after 72 hours of the isolation. The mean biological half-life of ^{131}I in patients with thyroid cancer was found to be 13.9±1.9 hours. There was no significant difference between the mean effective half-life in patients treated for the first time and the second time at 95% significant level.

Conclusions: The results of this study showed that the difference in the discharge rate of ^{131}I from patients with thyroid cancer receiving first and second treatment was not significant. The mean discharge rate after the first 24 hours was more than 70%, and it was more than 96% after the third 24 hours of drug administration. The results can be used to design a safe collecting and discharge method of the waste.

Key words: thyroid cancer, radioactive waste discharge, biological half-life, radiation dose.

Introduction

The treatment of thyroid cancer using unsealed sources of radioactive materials is usually associated with a large amount of ^{131}I. To protect the public, it is required to isolate the patients until the retained radioactive drug in the patient body is reduced to an acceptable level [1]. The excretion of the radiopharmaceutical from the patient's body is subject to two factors: physical and biological half-life of the administered material [2]. Since the physical half-life of ^{131}I is much longer than its biological half-life in cancerous thyroid tissue, its excretion mostly depends on its biological activity [3]. The major problem in hospital treatment of these patients is waste disposal. There are various recommended methods for disposal of the waste. The most convenient method is to dispose the patient's urine directly into the public sewer system. To reduce the dose disposed to the public sewer system to an acceptable level as suggested by the International Commission on Radiological Protection (ICRP) (1990) [4], it is necessary to reduce the radioactive concentration of the material being disposed at the time of discharge to about 370Bq/Lit. The most common practice is to store the waste for an appropriate time for physical decay, then after appropriate decay time and dilution, discharge it in the public sewer system. The activity excreted from these patients must be accurately measured for the purposes of suitable planning and patient administration.

Certain previous studies provide a guideline for 30% and 50% excretion of the administered activity [5].

Laranson et al [6] measured ^{131}I excretion from the treated patients with thyroid cancer. The presented results were of limited value as the number of patients was limited.

In this study the activity discharged from 152 patients with thyroid cancer treated with ^{131}I to the sewer system as aqueous waste during the hospitalization period was measured.

Materials and methods

152 patients referred to the nuclear medicine department of Said Al-Shohada Hospital from the beginning of this study were selected. 107 of them were those receiving their first (group I) and the rest were those receiving their second treatment dose (group II). The results obtained for the two groups were analyzed separately and compared with student t test for any differences in the thyroid function.

Wstęp: Leczenie nowotworów tarczycy przy pomocy preparatów radioaktywnych najczęściej wiąże się z zastosowaniem dużych dawek ^{131}I. Głównym problemem związanym z zastosowaniem tego leczenia w warunkach szpitalnych jest utylizacja odpadów promieniotwórczych, która wymaga ścisłych zabezpieczeń.

Materiały i metody: W badaniach oceniano 152 chorych z rakiem tarczycy, którzy byli leczeni jodem radioaktywnym na oddziale medycyny nuklearnej w szpitalu Said Al-Shohada.

Wyniki: Ponad 70 proc. podanego ^{131}I wydalane było po 24 godz., 90 proc. po 48 godz., a 96 proc. po 72 godz. w czasie odosobnienia chorego. Średni biologiczny czas półtrwania ^{131}I u chorych z rakiem tarczycy wynosił 13,9±1,9 godz. Nie zaobserwowano istotnych statystycznie różnic pomiędzy efektywnym czasem półtrwania ^{131}I u chorych poddanych jodoterapii po raz pierwszy i drugi.

Wnioski: Wyniki badania wskazują, że nie ma różnic w eliminacji ^{131}I u chorych z rakiem tarczycy poddawanych pierwszorazowo lub wtórnie jodoterapii. W ciągu pierwszych 24 godz. ponad 70 proc. podanego ^{131}I było wydalone, a po 72 godz. ponad 96 proc. Powyższe wyniki mogą zostać wykorzystane do zaprojektowania bezpiecznych metod zbierania i utylizacji odpadów promieniotwórczych po zabiegach jodoterapii.

Słowa kluczowe: rak tarczycy, usuwanie odpadów radioaktywnych, biologiczny czas półtrwania, dawka promieniowania.

The hospital has two separate isolation rooms for radioactive iodine therapy. The study was performed from 21 September 2001 to 20 November 2002. ^{131}I was administered to the patients in the form of NaI at different amounts.

The dose was measured using a Victorian 190F dosimeter fixed on the doors of the isolation rooms. The dosimeter is a gas filled survey meter calibrated for measuring the absorbed dose for a pre-set time or the dose rate in nGy, μGy or mGy. To reduce random fluctuation and errors, the cumulative dose for each patient at each time was measured for one minute. The measurements were repeated every 24 hours. The first measurements for each patient were performed immediately after ^{131}I administration. All the measurements were done with the same geometrical set-up. The distance between the dosimeter and the patient was 1 meter in all cases. The dosimeter was fixed on the door at the belt level of the patients. Usually each patient was retained in the hospital isolation room for three days, but in some cases with lower activity administration and high activity discharge rate the retention time was 2 days.

Results

Distribution of the administered activity is shown in table 1. In this table, group I comprises those patients being treated with ^{131}I for the first time while group II comprises those being treated for the second time.

The mean and SD of the measured dose rate per 37MBq (or per mCi) of administered activity at 1 meter for different groups of patients and at different times are shown in Table 2.

The mean effective half-lives for ^{131}I obtained from the results of this investigation are 12.2±0.27 and 12.8±0.9 hours for both groups of patients. (These are calculated using data from Table 2 and equation $A=A_0\exp(-0.693t/T_{eff})$, where A is the measured dose at time t, A_0 is the measured dose at t=0 and T_{eff} is the effective half-life. T_{eff} is measured for 24, 48 and 72 hours and the mean is calculated and is assumed as mean T_{eff}) [7]. The differences between the two mean effective half-lives were compared using t-test. The difference is not significant at 95% significant level ($P<0.05$).

Table 3 shows the retention percentage of the activity in the patients' bodies at 24, 48 and 72 hours after administration of ^{131}I. The percentage was obtained by dividing the results of each measurement for a patient by the first measurement for the same patient. The percentage distribution of the discharged activity during the first, second and third 24 hours from the administration time are shown in Figure 1. These percentages were calculated by subtracting the retention percentage from 100.

Table 1. Distribution of the patients in terms of administered ^{131}I (in GBq). Group I and II are the groups of patients treated for the first and second time, respectively

administred drug	3.7	4.625	5.55
number of patients in group I	60	28	19
number of patients in group II	28	5	12

Table 2. Distribution of the mean and SD of the measured dose rate at the belt level per 37MBq (per mCi) of administered ^{131}I at 1 meter for different groups of patients at 0, 24, 48, and 72 hours after administration (μGy/h/37MBq or mCi)

Time	t=0 h	t=24 h	t=48 h	t=72 h
measured dose in group I	2.2±0.51	0.55±0.28	0.14±0.08	0.04±0.03
measured dose in group II	1.93±0.45	0.48±0.13	0.14±0.09	0.05±0.03

Table 3. The remaining percentage of the radiopahrmaceutical in the patient's body after 24 48 and 72 hours

remaining percentage of the radiopharmaceutical in patients	0-10	10-20	20-30	30-40	40-50	50-60
percentage of the patients after 24 hours	4	28	34	18	13	4
percentage of the patients after 48 hours	52	25.7	15.1	7.2	0	0
percentage of the patients after 72 hours	85.5	10.5	4	0	0	0

Discussion

In a nuclear medicine department large amounts of radioactive materials are used daily. Especially in those departments having ^{131}I therapy units, a large portion of the administered drug is disposed into the sewer system. The environmental agency requires the concentration of the radioactive materials in the sewer system to be evaluated. It is also important to provide an appropriate installation to retain the excreted radiopharmaceutical for an appropriate time and then discharge it into the public sewer system.

The Environmental Agency is currently reviewing the practice of disposing liquid radioactive waste to the public sewer systems [8, 9]. An important consideration is the restriction of the public and sewer workers from the discharge waste which should be below the dose limits (1mSv for workers and 0.3 mSv for public members).

The results of this study showed that the rate of activity excreted by the patients receiving different amounts of radiopharmaceutical ^{131}I for the treatment of thyroid cancer was not significantly different. Table 2 shows that more than 70% of the administered drug was discharged during the first, and more than 90% – after the second 24 hours of hospitalization in both groups. This finding is not in agreement with the results of Driver and Packer, which is about 85% after 3 days of isolation (10). The mean effective half-life of ^{131}I for both patients' groups obtained in this research was 12.5±0.6 hours. When comparing it with the physical half-life of ^{123}I, which is 8 days, we can show that $T_{eff \approx 0.9} T_{bio}$.

Assuming that the excretion of the administered activity from the patient is only through urine, and the urine is collected in a reservoir tank for extra decay and after an appropriate time is discharged to the public sewer system, the total activity (A_t) excreted from n patients with an isolation period of Δt for each patient and collected in the tank can be approximated as follows:

$$A_t = A_{10}\ (1-e^{-\lambda_b \Delta t})\ e^{-\lambda_p t} \sum_i^n e^{i\lambda_p \Delta t}$$

where A_{10} is the activity excreted from each patient (assuming this is the same for all patients), λ_b and λ_p are the biological and physical decay constants for iodine in patients with thyroid cancer.

If the volume of the collecting tank is assumed to be V, then the concentration of the activity in the tank (C) when it is full is:

$$C = A_t/V = A_t/mxn$$

where m is the amount of urine in liters, discharged from each patient during an isolation period and n is the number of the patients until the tank is full. Assuming that the concentration limit of the radioactive waste to the public sewer system is C_0 (Bq/lit) then the duration t (after the tank is filled) necessary to reach this level can be obtained using the following equation:

$$Cp = Ce^{-\lambda pt} = (A_t/mxn)e^{-\lambda pt} \leq C_0\ (Bq/lit)\ (b)$$

If a hospital has q therapy rooms then the activity to the tank will be qxA (where q can be assumed to be the number of therapy rooms or it can be assumed as an occupational factor, which is the number of therapy rooms and the occupational factor).

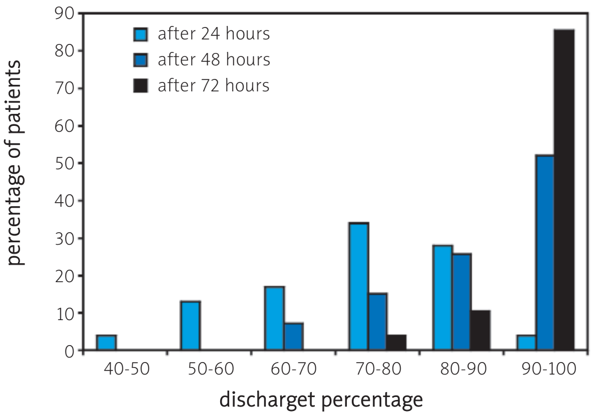

Fig. 1. Distribution of the percentage of radiopharmaceutical discharged from the patients after first, second and third 24 hours of drug administration

Conclusions

According to this study the mean biological half-life of ^{131}I for patients with thyroid cancer is 13.9±1.9 hours. It is also found that the excretion rate is not significantly different when comparing patients treated for the first and second time. The excretion rate after the first 24 hours is more than 70% and more than 95% after 72 hours of the drug administration. Based on the above results, a mathematical model for collected activity excreted from n patients treated with ^{131}I and the safe discharge is suggested.

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