

## Conference Paper

# Estimated Inpatient Hospital Stay in Individual Wards: Guidelines on Radiation Safety after Radioiodine Therapy

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## Abstract

Radionuclide therapy safety requirements are regulated by the Russian Radiation Safety Standards (RRSS), which state the maximum allowed radionuclide activity in the body and the equivalent dose rate (EDR) of gamma radiation. Therefore, it is necessary to estimate the time of an inpatient hospital stay in specially designed radionuclide therapy wards. The article presents the findings of individual <sup>131</sup>I biokinetics studies in 64 patients admitted to radioiodine therapy of thyrotoxicosis and differentiated thyroid cancer. We developed a method to calculate the time interval to reach the EDR of 20μSv/h and the recommended EDR of 3 and 0.3μSv/h for adults and children, respectively. It is based on the measurement of the <sup>131</sup>I excretion constant.

**Keywords:** Radioiodine therapy, Radiation safety, Guideline

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## 1. Introduction

Natural iodine and its isotopes are chemically and biologically identical [1]. Therefore, <sup>131</sup>I is used to investigate physiological characteristics of the iodine activity in the body [2]. Iodine is excreted by the kidneys mostly, its filtration rate remaining constant under constant conditions (blood pressure, fluid intake, blood volume, etc.) [3]. When the kidney activity decreases, for example, in patients who develop hypothyroidism after discontinuation of levothyroxine to achieve a high level of TSH (more than 30IU/L), urinary iodine excretion drops sharply [4]. Iodine accumulates and is trapped by normal and hyperfunctioning cells as well as tumor cells of the thyroid gland, which prolongs an inpatient hospital stay [1].

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The RRSS are stricter than the standards of the EU countries and the USA: outpatient radioiodine treatment can be provided only with administering  $^{131}\text{I}$  activities not exceeding 400MBq [5-6]. For the vast majority of patients with thyrotoxicosis, such activity will not lead to a sustained therapeutic effect (hypothyroidism) [7]. The current approach is to hospitalize patients for 3-4 days. Patients undergo dosimetry control in order to find out whether their EDR (1m from the body surface) is lower than  $20\mu\text{Sv/h}$  [5]. Contacts with adults are safe at the level of  $3\mu\text{Sv/h}$  [6]. Contacts with children should be limited until the level of  $0.3\mu\text{Sv/h}$  is reached [6].

Patients who have undergone dosimetry control are discharged. If the EDR exceeds the standards, the period of an inpatient hospital stay is extended. In such cases patients bear financial losses and hospital bed utilization is inefficient.

The article describes a mathematical model to calculate an inpatient hospital stay in radionuclide therapy wards. Prediction method errors are estimated. Formulas to calculate the time to reach EDR threshold values with respect to the administered activity are presented.

## 2. Materials and methods

64 patients were enrolled in the study. 22 of them were diagnosed with thyrotoxic disease, and 42 had differentiated thyroid cancer.

Equipment used in the study was the dosimeter-radiometer "MKC-AT1117M", equipped with a laser rangefinder; the SPECT-CT system "GE DISCOVERY 670 NM/CT", equipped with HEGP collimators.

According to the RRSS, the EDR was measured at the distance of 1m from the floor and from the surface of the body of a standing patient. The whole body scintigrams were obtained at the speed of 30cm/min with the image matrix of 1024x256 and the energy window of  $364 \pm 36\text{KeV}$ . Prior to that, background radiation scintigrams were taken under the same conditions.

After measuring the EDR in 25 patients, the dose rate conversion factor for  $^{131}\text{I}$  to remained activity in the patient's body was calculated immediately after the administration of  $^{131}\text{I}$  activity from 0.5 to 5.5GBq ( $2.0 \pm 1.2\text{GBq}$ ) as shown in Formula 1.

$$K = \frac{\sum_{i=1}^n \frac{A_i}{D_i}}{n}, \left[ \frac{\mu\text{Sv/h}}{\text{MBq}} \right] \quad (1)$$

where n is the number of patients, i is the patient's index number, A is the  $^{131}\text{I}$  administered activity, D is the EDR measured immediately after the administration.

To obtain the effective half-life reference  $T_{1/2}^{eff}$ , 2-hour, 48-hour or delayed whole body scintigrams with the administered therapeutic  $^{131}\text{I}$  activity were done.

The  $T_{1/2}^{eff}$  was calculated using Formula 2. The extrapolated EDR threshold ( $\dot{D}_{threshold} = 20/3/0.3\mu\text{Sv/h}$ ) was calculated by Formula 3.

$$T_{1/2}^{eff} = \frac{\ln(2)}{\ln(Z_0/Z_1)} \cdot (t_1 - t_0), [h] \quad (2)$$

where  $Z_0$  and  $Z_1$  are the values measured at times  $t_1$  and  $t_0$  (EDR or scintigram count).

$$T_{threshold}^{disease} = T_{1/2}^{eff} \cdot \frac{\ln(\dot{D}_0/\dot{D}_{threshold})}{\ln(2)}, [] \quad (3)$$

where  $\dot{D}_0$  is the EDR, which is calculated by Formula 4.

$$\dot{D}_0 = K \cdot A_0, \left[ \frac{\mu\text{Sv}}{h} \right] \quad (4)$$

where  $A_0$  is the administered activity.

The error of directly measured values (EDR [ $\mu\text{Sv/h}$ ], scintigram counts [counts]) is determined according to the technical documentation and the statistical spread of the measured values (CI = 95%). The error in indirect measurements was calculated by Formula 5.

$$\Delta_F = \sqrt{\left(\frac{\partial F}{\partial a} \Delta_a\right)^2 + \left(\frac{\partial F}{\partial b} \Delta_b\right)^2 + \left(\frac{\partial F}{\partial c} \Delta_c\right)^2 + \dots} \quad (5)$$

The  $T_{1/2}^{eff}$  measurement errors obtained by dosimetric (at the therapeutic stage) and spectrometric (at the planning stage of treatment using the tracer activity  $<10\text{MBq}$ ) methods were determined according to the reference time. The tracer activity is not applied to cancer patients in this study.

### 3. Results and discussions

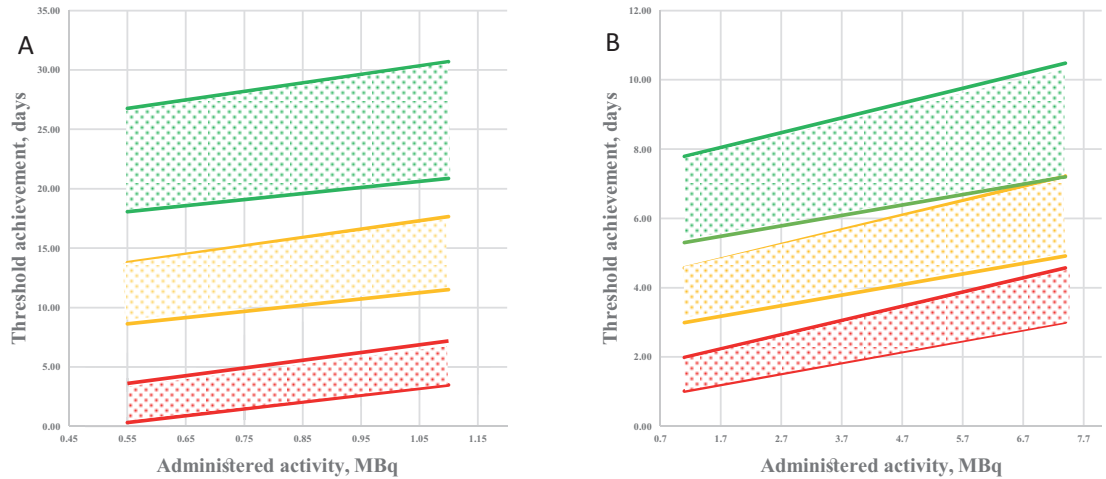
The dose rate conversion factor  $K$  is  $53 \pm 18$  ( $\epsilon = 33\%$ ). The dosimetric method of calculating the  $T_{1/2}^{eff}$  has a 15% error regardless of the activity administered. The scintigraphic method with the tracer activity has an 18% error.

The average effective half-life in patients with thyrotoxic disease with therapeutic activity from 0.5 to 1.1GBq is 81 hours, according to scintigraphy, and 79 hours by dosimetry.  $T_{1/2}^{eff}$  increases to 99 hours when the tracer activity is administered.

When the dosimetric method with the administered tracer activity is applied, the  $T_{1/2}^{eff}$  error at the therapeutic stage is 23%.

The mean effective half-life of patients with thyroid cancer with therapeutic activity administered from 1.1 to 5.5GBq ( $2.6 \pm 1.5\text{GBq}$ ) is 20 hours, according to whole body scintigraphy, and 20 hours, according to dosimetry.

Fig. 1 shows 95% CI time reaching  $\dot{D}_{\text{threshold}}$  at 20/3/0.3μSv/h interval in relation to the administered activity in thyrotoxicosis and thyroid cancer cases.



**Figure 1:** 95 % CI intervals for  $\dot{D}_{\text{threshold}}$  (20μSv/h – red, 3μSv/h – yellow, 0.3μSv/h – green) in thyrotoxicosis (A) and thyroid cancer (B) cases.

To simplify the mathematical model, the experimental data were approximated by the linear function  $y = kx + b$ . Three  $T_{\text{threshold}}^{\text{disease}}$  (A) equations (6, 7, 8) were obtained for patients with thyrotoxicosis (Th):

$$T_{20}^{\text{Th}} = 6.13 \cdot A + 1.41 \tag{6}$$

$$T_3^{\text{Th}} = 6.13 \cdot A + 7.83 \tag{7}$$

$$T_{0,3}^{\text{Th}} = 6.13 \cdot A + 19.04 \tag{8}$$

where A is in GBq;

and for patients with cancer (C) (9, 10, 11):

$$T_{20}^{\text{C}} = 0.36 \cdot A + 1.10 \tag{9}$$

$$T_3^{\text{C}} = 0.36 \cdot A + 3.39 \tag{10}$$

$$T_{0,3}^{\text{C}} = 0.36 \cdot A + 6.15 \tag{11}$$

where A is in GBq.

CI = 95% interval is calculated by the relative error formula for indirect measurements (12):

$$\frac{\Delta T_{\text{threshold}}^{\text{disease}}}{T_{\text{threshold}}^{\text{disease}}} = \sqrt{\left(\frac{\Delta T_{1/2}^{\text{eff}}}{T_{1/2}^{\text{eff}}}\right)^2 + \left(\frac{1}{\ln(\dot{D}_0/\dot{D}_{\text{threshold}})} \cdot \frac{\Delta \dot{D}_0}{\dot{D}_0}\right)^2} \tag{12}$$

The relative error of 95 % CI time interval to reach the EDR decreases, when the activity increases.

## 4. Conclusion

Based on the data presented, the rate of iodine excretion from the body increases with the increase in the  $^{131}\text{I}$  activity. This fact has to be taken into account when calculating the time of an inpatient hospital stay. When determining the effective half-life time for the tracer (diagnostic) activity, the spectrometric method shows an 18% relative error, while when the dosimeter is used, it is 23%. Also, the impact of thyroid tissue volume on the rate of iodine excretion is noticeable. It requires a further study to correlate the excretion rate and the volume of thyroid tissue. The findings of the current research were used to develop a program to calculate intervals of an inpatient hospital stay in radiation wards with the database established. Safety guidelines for patients after radioiodine therapy were worked out. More patients being examined, a 5% prediction error is expected to be achieved when an inpatient hospital stay and radiation hazards are calculated.

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