行政院國家科學委員會專題研究計畫 成果報告

全割除甲狀腺癌患者之放射性碘的生物分佈及體內劑量 研究成果報告(精簡版)

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行政院國家科學委員會專題研究計畫成果報告

全割除甲狀腺癌患者之放射性碘的生物分佈及體內劑量

Biodistributions and internal medical dosimetry of radioactive iodine for Thyroidectomy Patients

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2 INTRODUCTION

This work presents a revised biokinetic model of iodine for (near) total thyroidectomy using an in-vivo gamma camera technique. Iodine-131 has been widely applied in treating thyroid cancer. After initial treatment (near-total or total thyroidectomy), most patients are treated with ^{131}I for ablation of residual thyroid gland [1, 2, 3, 4]. However, estimations of cumulative absorbed doses for either patients or people around the patients remain controversial, despite established criteria for iodine biokinetic model for a healthy person from the ICRP-30 report [5].

3 BIOKINETIC MODEL OF IODINE

According to the ICRP-30 report, a typical human body can be divided into five major compartments in the biokinetic model of iodine: (1) stomach, (2) body fluid, (3) thyroid, (4) whole body, and (5) excretion, respectively as clearly illustrated in Fig. 1. Additionally, the simultaneous differential equations for obtaining the time-dependent correlation for each compartment are also indicated in Eq. 1~4.

case no.	Gender	age	weight(kg)	syndrome	status of remnant
1	Female	46	57	palillary thyroid cancer	complete ablation
2	Female	37	58	palillary thyroid cancer	minimal residual
3	Female	37	55	palillary thyroid cancer	complete ablation
4	Female	38	41	palillary thyroid cancer	minimal residual
5	female	47	62	Palillary thyroid cancer	complete ablation
6	Male	35	84	Palillary thyroid cancer	complete ablation

$$\frac{dq_1}{dt} = -(\lambda_R + \lambda_{12})q_1 \quad (1)$$
$$\frac{dq_2}{dt} = \lambda_{12}q_1 - (\lambda_R + \lambda_{25} + \lambda_{23})q_2 + \lambda_{42}q_4 \quad (2)$$
$$\frac{dq_3}{dt} = \lambda_{23}q_2 - (\lambda_R + \lambda_{34})q_3 \quad (3)$$
$$\frac{dq_4}{dt} = \lambda_{34}q_3 - (\lambda_R + \lambda_{42} + \lambda_{45})q_4 \quad (4)$$

Since the biological half life of iodine recommended by ICRP-30 for the stomach, body fluid, thyroid and whole body is 0.029d, 0.25d, 120d and 12d, respectively. Thus, the corresponding decay constants for each variable can be calculated [cf. Tab. 1].

4 PATIENTS' CHARACTERISTICS

Five patients aged 37~47 years underwent whole body scanning by gamma camera after postsurgical administration of ^{131}I for ablation of residual thyroid. Tab. 2 lists patients' characteristics.

5 EXPERIMENTAL SETUP

5.1 Gamma Camera

Figure 3 illustrates the gamma camera (SIEMENS E-CAM) located at Chung-Shan Medical University Hospital (CSMUH). The gamma camera's two NaI $48\times33\times0.5cm^3$ plate detectors were positioned 5cm above and 6cm below the patient's body during scanning. Each plate was connected to 2"-diameter 59 photo multiplier tube, PMT, for data recording. Ideally, the 2 detectors can capture ~ 70% of the emitted gamma ray. Each patient scanned was given 1.11GBq (30mCi) ^{131}I capsule for thyroid gland remnant ablation. The ^{131}I capsule was carrierfree with a radionuclide purity exceeding 99.9% and radiochemical purity exceeding 95.0%. All radiopharmaceutical capsules were fabricated by Syncor Int., Corp. The coefficient of variance (%CV) between capsules from the same fabricated batch was less than 1.0% confirmed by spot checks [7]. Thus, the position-sensitive gamma ray emitted from the ^{131}I dose administration for patient can, then, be analyzed and plotted.

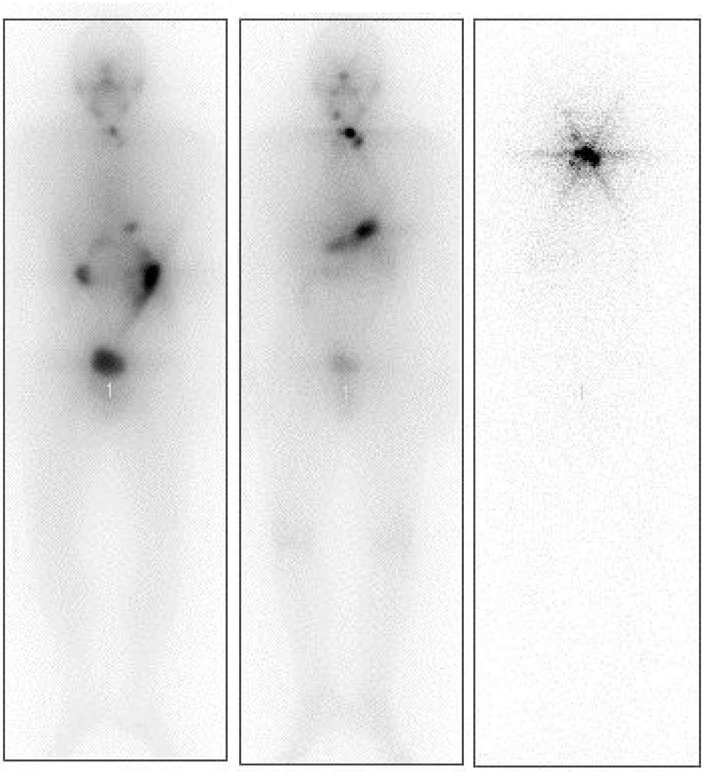

Fig.1. Whole-Body scan (a)2 d, (b)3.3 d, (c)8 d, after 1.1GBq ^{131}I administration showing intensely scintigraphic images.

6 RESULTS AND DATA INTERPRETATION

Each patient's data was analyzed and normalized as initial input data to obtain the optimal solution for Eqs. 1-4. Since every patient's analyzed data could be derived for an optimal solution, the final optimized revised biokinetic model for iodine was based on the biased average for all 5 patients. The biased average was based on a numerical weighting factor defined as the inversion of the sum of the square of individual uncertainities as shown in Eq. 5, 6 [8, 9, 10].

7 DISCUSSIONS

7.1 Original and Revised Biokinetic Model of Iodine

Defining the biological half-life of iodine in thyroid without considering the contributions from other compartments of the biokinetic model remains controversial. The thyroid plays a dominant role in the biokinetic model of iodine for healthy people, Conversely, either the whole body or the body fluid are the dominant compartments in the revised biokinetic model according to the analytical results for (near) total thyroidectomy patients. Furthermore, by precisely comparing the original and revised iodine biokinetic models [cf. Fig. 2, 5], the biological half-life of iodine in the thyroid of a healthy person can be evaluated directly by the time-dependent curve, whereas the time-dependent curve for thyroidectomy patients degrades quickly as a result of iodine's short biological half-life in the thyroid. Alternatively, withholding iodine from either the whole body or body fluid for thyroidectomy patients results in rapidly increasing percentage in subsequent in-vivo scanning. The $\boldsymbol{T}_{\mathbf{eff}}$ of iodine for a healthy person is 7.5 d and is dominated by the thyroid only. The effective half-life of iodine for thyroidectomy patients, conversely, is reduced to approximately 4.5 d and is controlled by the whole body and body fluid compartments. The different compartments dominating in the iodine biokinetic model requires the different analyses of dose evaluation and release criteria for patients from a public hygiene perspective.

1.1GBq ^{131}I-NaI, combined with imaging obtained from Siemens E-CAM coincidence γ-camera in CSMUH. The EDE of near-thyroidectomy patient was 0.560 Sv for the treatment of 1.1GBq ^{131}I. These τ_h calculated from the linear-fits for the individual organs were highest in the intestine (2.44 hr), and second highest in the lung (2.10 hr) (Table 3).

8 CONCLUSION

A revised biokinetic model of iodine for (near) total thyroidectomy patients using in-vivo gamma camera technology was accomplished in this work. A total number of 5 patients who underwent remnant ablation of the thyroid were scanned and analyzed to obtain the revised biokinetic model of iodine. The difference between the original and the revised iodine biokinetic model was the definition used for biological half-life of iodine in the thyroid gland. The revised value was derived directly from the definition of biokinetic model of iodine and the biased average from several iterations of a self-developed ***MATLab*** program. The change of biological half-life between two models also caused the T_{eff} of iodine to be reduced in the thyroid from the original 7.5d down to the revised 0.47d. The correlated evaluation of absorbed dose for patient was also corrected from the estimated 35.7cGy of MIRD-3 to 22.2cGy by applying the simplified model on the basis of the collision kerma, ***Kc***.

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