Original Articles/นิพนธ์ต้นฉบับ

Evaluation of Dosimetric Parameters from Patients Based on Whole Body ^{131}I Bio-Kinetic Clearance in Thyroid Cancer Therapy.

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Abstract

Objective: The study was designed to evaluate the bio-kinetic clearance of radioactive iodine (^{131}I) in the well-differentiated thyroid carcinoma patients treated with 1.11 GBq and to calculate organs and whole body absorbed dose with MIRDOSE3.1 computer software.

Materials and Methods: The whole body retention/excretion of ^{131}I in all patients was determined individually by using gamma camera with high-energy general all purpose (HEGP) at the specific time points after its administration.

Results: The effective half-live (T_{eff}) was estimated from the generated time-activity curves. The mean for effective half-life from whole body clearance curve was 26.2±10.8 hours. The calculated residence time (τ) was 38.0±15.6 hours. The retained activity of ^{131}I at 4, 24, 48, 72 and 144 hours was 77.8±11.4, 44.4±13.9, 23.8±12.4, 13.3±9.1 and 2.7±2.6 %, respectively. The mean for absorbed doses to whole body was 0.10 (0.04 mGy/MBq. The highest organ dose was uterus (0.11±0.05 mGy/MBq). The mean for effective dose was 0.11±0.04 mSv/MBq.

Conclusion: Retention and clearance rates of 131I could be obtained by in vivo measurements in individual patients. Evaluations of the Teff are essential parameter for absorbed dose calculation to patient and minimize the risk of external radiation exposure to staffs of nuclear medicine, family member and the public. These parameters are essential for management in thyroid cancer therapy, for both in-patients and out-patients. Additionally, our parameters could be a useful parameter to develop the guideline for occupational and public radiation protection.

Keywords: thyroid cancer, absorbed dose, I-131, bio-kinetic clearance, effective half-life

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Introduction

The medical use of radioiodine (^{131}I) is important in clinical applications for the diagnosis and treatment of human disease, especially in oncology[1]. Ninety percent of all therapies in nuclear medicine uses ^{131}I [2,3]. For the thyroid cancer, ^{131}I is commonly used in ablative or adjuvant therapy after surgery. The whole body ^{131}I bio-kinetic clearance is an essential parameter in the absorbed dose calculation and radiation protection in thyroid cancer management. However, so far the data based on gamma camera imaging are not available, especially serial imaging of whole body ^{131}I clearance (or effective half-life).

The uptake and effective retention half-time (T_{eff}) of ^{131}I in each organ and in the whole body are required to reliably calculate ^{131}I-cumulated activities (or residence times) and absorbed doses. The most widely used method of calculating absorbed dose for patients treated with unsealed sources has been developed by the Medical Internal Radiation Dose (MIRD) Committee of the American Society of Nuclear [4,5]. The equation for absorbed dose in the MIRD system is given as;

$$D_{rk} = \tilde{A}_h S(r_k \leftarrow r_h) \qquad (1)$$

where D_{rk} is absorbed dose to a target organ (μCi/hr or Gy/sec) and $\tilde{A}_h$ is the cumulated activity in the source organ (μCi-hr or MBq-sec). The factor S takes into account the fact that the absorbed dose in the target organ r_k is due not only to the activity of the considered radionuclide in that organ but also to the activities in other organs r_h of the body. The factor S is expressed as:

$$S(r_k \leftarrow r_h) = \frac{k \sum_i n_i E_i \phi_i (r_k \leftarrow r_h)}{m} \qquad (2)$$

where S (*rk* ← *rh)* is absorbed dose per unit activity (rad/μCi-hr or mGy/MBq.sec), k is the MIRD schema providing a proportionality constant that is 2.13 (rad-g/μCi-hr-MeV or Gy-kg/MBq-sec-MeV), n_i is the number of radiations with energy E emitted per nuclear transition, E is the energy per radiation (MeV), ($Ø_i$ is the fraction of energy absorbed in the target, and m is the mass of the target region (g or kg). The aim of this study was to determine internal absorbed dose to organs and whole body with MIRDOSE3.1 computer software by measuring retention activity in whole body, based on gamma camera imaging.

Materials and Methods

Between July 2010 and March 2011, 6 well-differentiated thyroid carcinoma patients having undergone total thyroidetectomy were prospectively enrolled in the study. All patients received oral and written information concerning ^{131}I treatment. Additionally, this study has received documentary proof of Ethical Clearance Committee on Human Rights related to researches involving human subjects from Faculty of Medicine, Ramathibodi Hospital, Mahidol University.

Patients were treated with 1.11GBq of ^{131}I capsule. Before whole body imaging, each patient was asked to urinate. Then, whole body imaging was performed in each individual patient with a gamma camera (Phillips' Forte with 3/8 inch of NaI(Tl) equipped with high energy general propose collimators) at the specific time point of 4, 24, 48, 72 and 144 hours, respectively. The energy window was centred at 364 keV ^{131}I photopeak with a width of 20%.

The whole body retention of ^{131}I was obtained by the ROI method, using the Pegasys 5.0 software for image processing and reconstruction. Then, T_{eff} was analyzed by the exponential curve plotting and converted to the residence times. The absorbed dose per unit of administered activity of organs and whole body were calculated by using the calculated residence times as input values to the software MIRDOSE3.1 with a 70 kg reference adult[6].

Results

From the combined action of physical decay and biological elimination, the mean±SD of an effective half-life (T_{eff}) obtained from the whole body activity was found to be 26.2±10.8 (13 to 36) hours. The mean±SD of the residence time (τ) was 38.0± 15.6 (19 to 52) hours (Table 1). The retained activity of ^{131}I at 4, 24, 48, 72 and 144 hours was 77.8±11.4, 44.4±13.9, 23.8±12.4, 13.3±9.1 and 2.7±2.6%, respectively (Figure 1).

The average absorbed doses to whole body (0.10±0.04 mGy/MBq) was calculated by using the MIRDOSE3.1 computer software (Table 2). The highest organ dose was uterus (0.11±0.05 mGy/MBq). The average effective dose was 0.11±0.04 mSv/MBq.

Discussion

The bio-kinetic clearance of ^{131}I was evaluated from in vivo study with gamma camera imaging of well-differentiated thyroid carcinoma patients having undergone total thyroidetectomy. T_{eff} value (26.2±10.8 hours) was generated with the time-activity curve of whole body counts. *In vivo* method with gamma camera imaging is a more accurate evaluation of Teff than external exposure-rate with portable survey meter[7]. However, important interference factors to

Evaluations of the T_{eff} are essential for absorbed dose calculation to patients and minimize the risk of external radiation exposure to staffs of nuclear medicine, family member and the public. The organs and whole body absorbed dose per unit of administered activity were estimated (Table 2). These results may be used to determine for normal tissue response to radioiodine therapy and cancer risk assessment[9]. On the other hand, we can use the Teff instead of the physical half-life (T_p) in generally equation of U.S. Nuclear Regulatory Commission for release of patients administered radioactive materials[10], which is the more appropriate parameter for representing the ^{131}I clearance in patient's body. Additionally, we will use the Teff to potential radiation doses received by others during these therapies and to perform the policies guideline for radiation protection.

Conclusions

The whole body retention/excretion of ^{131}I in all patients determined individually by using gamma camera imaging was more accurate than portable survey meter measurement. The results obtained here in show that knowledge of the ^{131}I bio-kinetic clearance in patient's body and absorbed doses in organs and whole body is valuable. The T_{eff} estimated from this study could be a useful parameter to develop guideline for radiation protection. However, for a greater impact of this technique, further investigation with more patients is required.

Table 1 Dosimetric parameters obtained from whole body ^{131}I clearance.

Patient no.	Age (year)	Effective half-life (hr)	Residence time (hr)
Pt.1	37	36	52
Pt.2	63	13	19
Pt.3	24	22	32
Pt.4	47	36	52
Pt.5	53	35	51
Pt.6	36	15	22
Mean±SD	43.3±13.9	26.2±10.8	38.0±15.6

Table 2 Absorbed doses per unit of administered activity (mGy/MBq).

Target organ	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Adrenal	1.48E-01	5.41E-02	9.11E-02	1.48E-01	1.45E-01	6.26E-02
Brain	1.24E-01	4.53E-02	7.63E-02	1.24E-01	1.22E-01	5.24E-02
Breasts	1.17E-01	4.27E-02	7.19E-02	1.17E-01	1.15E-01	4.94E-02
Gallbladder wall	1.53E-01	5.59E-02	9.42E-02	1.53E-01	1.50E-01	6.48E-02
LLI wall	1.51E-01	5.51E-02	9.29E-02	1.51E-01	1.48E-01	6.38E-02
Small intestine	1.53E-01	5.60E-02	9.43E-02	1.53E-01	1.50E-01	6.48E-02
Stomach	1.45E-01	5.31E-02	8.95E-02	1.45E-01	1.43E-01	6.15E-02
ULI wall	1.51E-01	5.51E-02	9.28E-02	1.51E-01	1.48E-01	6.38E-02
Heart wall	1.45E-01	5.29E-02	8.91E-02	1.45E-01	1.42E-01	6.13E-02
Kidneys	1.42E-01	5.21E-02	8.77E-02	1.42E-01	1.40E-01	6.03E-02
Liver	1.43E-01	5.21E-02	8.77E-02	1.43E-01	1.40E-01	6.03E-02
Lungs	1.34E-01	4.88E-02	8.22E-02	1.34E-01	1.31E-01	5.65E-02
Muscle	1.31E-01	4.80E-02	8.09E-02	1.31E-01	1.29E-01	5.56E-02
Ovaries	1.55E-01	5.65E-02	9.52E-02	1.55E-01	1.52E-01	5.55E-02
Pancreas	1.54E-01	5.61E-02	9.45E-02	1.54E-01	1.51E-01	6.50E-02
Red marrow	1.38E-01	5.05E-02	8.51E-02	1.38E-01	1.36E-01	5.85E-02
Bone surface	1.52E-01	5.56E-02	9.36E-02	1.52E-01	1.49E-01	6.43E-02
Skin	1.12E-01	4.10E-02	6.91E-02	1.12E-01	1.10E-01	4.75E-02
Spleen	1.43E-01	5.21E-02	8.77E-02	1.43E-01	1.40E-01	6.03E-02
Testes	1.31E-01	4.80E-02	8.08E-02	1.31E-01	1.29E-01	5.56E-02
Thymus	1.37E-01	5.00E-02	8.42E-02	1.37E-01	1.34E-01	5.79E-02
Thyroid	1.37E-01	5.00E-02	8.42E-02	1.37E-01	1.34E-01	5.79E-02
Urinary bladder	1.49E-01	5.45E-02	9.19E-02	1.49E-01	1.46E-01	6.32E-02
Uterus	1.56E-01	5.69E-02	9.59E-02	1.56E-01	1.53E-01	6.59E-02
Total body	1.32E-01	4.84E-02	8.15E-02	1.32E-01	1.30E-01	5.60E-02
Effective dose (mSv/MBq)	1.44E-01	5.26E-02	8.86E-02	1.44E-01	1.41E-01	6.09E-02

T_{eff} are the uptake values of remnant thyroid tissue and the presence of metastatic lesion[8].

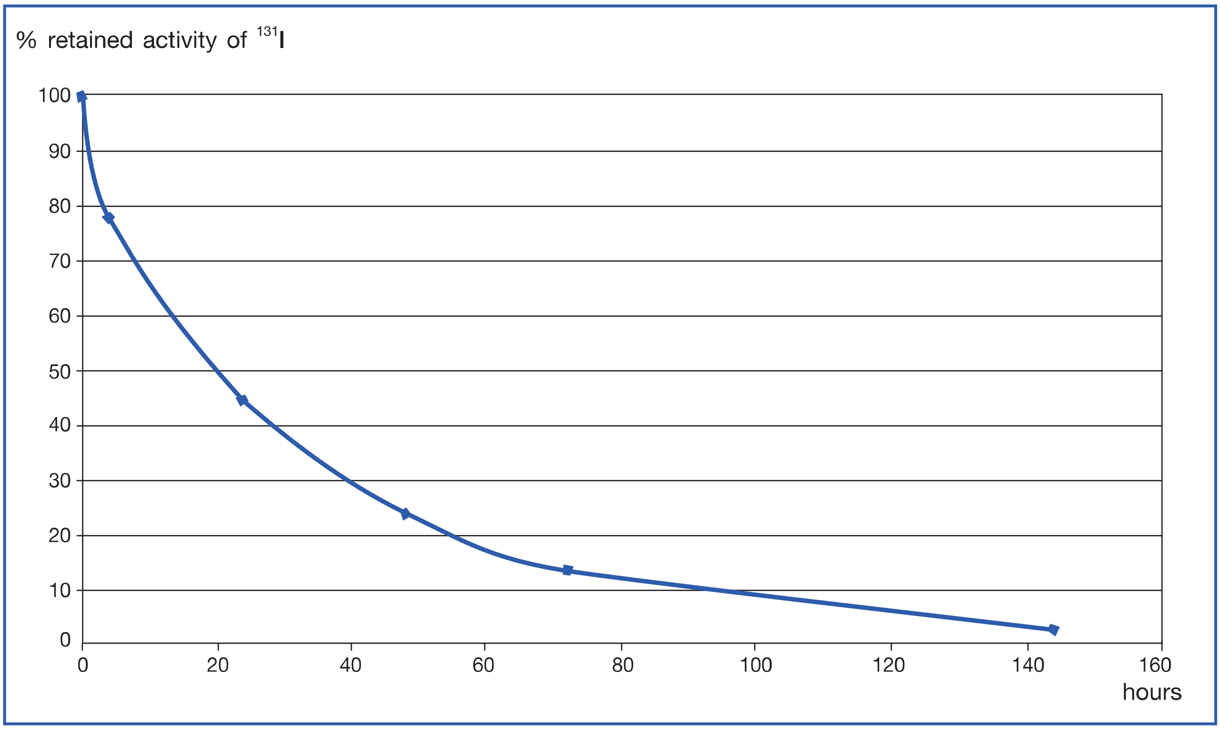

Figure 1 *The bio-kinetic clearance of radioiodine (^{131}I) in the well-differentiated thyroid carcinoma patients.*

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Original Articles/นิพนธ์ต้นฉบับ

การประเมินค่าพารามิเตอร์ในการคำนวณปริมาณรังสีจากการขับสารกัมมันตรังสีไอโอดีน-131 ออกจากร่างกายในการรักษาผู้ป่วยมะเร็งต่อมไทรอยด์

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Abstract

วัตถุประสงค์: เป็นการศึกษาการขับสารกัมมันตรังสีไอโอดีน-131 ออกจากร่างกายผู้ป่วยมะเร็งต่อมไทรอยด์ชนิด well-differentiated thyroid carcinoma และคำนวณปริมาณรังสีดูดกลืนที่ร่างกายผู้ป่วยด้วยโปรแกรม MIRDOSE3.1

วิธีการศึกษา: ผู้ป่วยมะเร็งต่อมไทรอยด์ชนิด well-differentiated thyroid carcinoma ที่ตรงตามเกณฑ์ในการศึกษาจะนำมานับวัดปริมาณรังสีในร่างกายตามเวลาที่กำหนดคือ 4, 24, 48, 72, และ 144 ชั่วโมง ตามลำดับ หลังจากผู้ป่วยได้รับสารกัมมันตรังสีไอโอดีน-131 แบบ low dose (1.11GBq) นำค่านับวัดรังสีที่ได้มาสร้างกราฟ exponential เพื่อนำมาคำนวณค่าครึ่งชีวิตยังผล, เวลาที่รังสีสะสมอยู่ในร่างกาย และค่ารังสีดูดกลืนที่อวัยวะต่างๆของร่างกาย

ผลการศึกษา: จากการศึกษาพบว่าค่าครึ่งชีวิตยังผลเฉลี่ยในร่างกายเป็น 26.2±10.8 ชั่วโมง และค่าเวลาเฉลี่ยที่รังสีสะสมอยู่ในร่างกายเป็น 38.0±15.6 ชั่วโมง นอกจากนี้แล้วพบว่าปริมาณสารกัมมันตรังสีไอโอดีน-131 สะสมในร่างกายที่ 4, 24, 48, 72 และ 144 ชั่วโมง มีค่าเป็น 77.8±11.4, 44.4±13.9, 23.8±12.4, 13.3±9.1 และ 2.7±2.6 เปอร์เซ็นต์ตามลำดับ ปริมาณรังสีดูดกลืนเฉลี่ยที่ร่างกายเป็น 0.10(0.04 mGy/MBq และพบปริมาณรังสีดูดกลืนสูงสุดที่ uterus มีค่าเฉลี่ยเป็น 0.11±0.05 mGy/MBq ค่าปริมาณรังสียังผลมีค่าเป็น 0.11±0.04 mSv/MBq

สรุปผล: ผลการศึกษาที่ได้เป็นข้อมูลเชิงพรรณนา โดยเฉพาะค่าครึ่งชีวิตยังผลที่นำมาใช้เป็นข้อมูลในการศึกษาปริมาณรังสีดูดกลืนในผู้ป่วย และใช้เป็นข้อมูลในการลดความเสี่ยงการได้รับรังสีของผู้ปฏิบัติงาน ญาติผู้ป่วย และการแผ่กระจายของสารรังสีสู่สิ่งแวดล้อมได้ อีกทั้งใช้เป็นข้อมูลในการปรับปรุง และพัฒนาในงานด้านการป้องกันอันตรายจากรังสีของหน่วยงานอีกด้วย

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