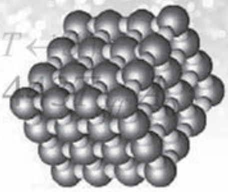
การเปรียบเทียบค่าปริมาณรังสีดูดกลืนของสารรังสีไอโอดีน-131 ในปอด จากการคำนวณด้วยวิธีการวัดจากภาพสแกนสองมิติ และโปรแกรมรังสีคณิต OLINDA

Comparison of calculated I-131 lung absorbed dose by quantitative 2 dimensional scan images and OLINDA dosimetry program



จินตนา อุ่นจันทร์[1*] มลฤดี เอกมหาชัย[2] นงลักษณ์ วิลาสเดชานนท์[2]

Jintana Ounchan[1*] Molrudee Ekmahachai[2] Nonglak Vilasdechanon[2]

[1*] นักศึกษาวิทยาศาสตรมหาบัณฑิต (ฟิสิกส์การแพทย์) ภาควิชารังสีวิทยา คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

[2] หน่วยเวชศาสตร์นิวเคลียร์ ภาควิชารังสีวิทยา คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

[1] graduate student. Department of Radiology, Faculty of Medicine, Chiang Mai University

[2] Nuclear Medicine Department of Radiology, Faculty of Medicine, Chiang Mai University

* ผู้รับผิดชอบบทความ

* Corresponding author

ABSTRACT

Introduction: The accuracy of radioiodine-131 absorbed dose to lungs was important for proper administered dose to the patient. In order to get a curative treatment as well as to control disease progression with the lowest radiation risk. This proposed study aimed to compare radioiodine-131 lung absorbed doses by manual calculation from quantitative two-dimensional scan images and OLINDA dosimetry program and to study the effect of lung mass on calculated absorbed dose.

Materials and Methods: Retrospective study of 10 well differentiated thyroid cancer with lung metastases patients who had first treatment of radioactive iodine-131 were studied. Calculation of radioactive absorbed dose in lungs by manual calculation from two-dimensional scan images and OLINDA dosimetry program did under MIRD principle. Two sets of adjusted S-value from SAF, lungs mass of Cristy-Eckerman-Stabin phantoms and Thai's lung mass were used for calculation by MIRD formula. The lung absorbed dose data from both calculation methods were analyzed by the percentage of differences, student pair t-test and correlation coefficients.

Results: No significant difference of lung absorbed dose calculated by manual calculation and OLINDA dosimetry program, p>0.05. An excellent correlation between manual calculation and OLINDA dosimetry program was found by using the S-value of Cristy–Eckerman–Stabin phantoms as well as by using the adjusted S-value with Thai's lung mass for absorbed dose calculation, r = 1.0. The percentage of difference between manual calculation and OLINDA dosimetry program by Cristy–Eckerman–Stabin S-value and adjusted S-value with Thai's lung mass was lesser than 0.5 and 0.3, respectively. Furthermore, a higher lung absorbed dose was found in adjusted S-value of Thai's lung mass than S-value of Cristy-Eckerman-Stabin phantom. The percentage of absorbed dose difference by these two S-value sets were between 20.4-38.3.

Conclusion: The absorbed doses in lungs calculated by these methods were not different when using the same S-value data set. Thus, both calculation methods could be compatible. In addition, changing of organ mass directly affected on S-value and organ absorbed dose that should be carefully consider in MIRD calculation. To define organ mass by a high-quality of medical images such as MRI, CT, US were recommended to improve accuracy and precision of absorbed dose calculation by these studied methods.

Keywords: *Lung absorbed dose, OLINDA dosimetry program, thyroid cancer, S-value, MIRD*

บทคัดย่อ

บทนำ ความถูกต้องในการคำนวณปริมาณรังสีดูดกลืนของสารรังสีไอโอดีน – 131 ในปอดมีความสำคัญในการกำหนดปริมาณรังสีที่เหมาะสมให้กับผู้ป่วย เพื่อรักษาผู้ป่วยให้หายจากโรคหรือสามารถควบคุมการดำเนินของโรคได้ โดยมีความเสี่ยงต่อรังสีน้อยที่สุด การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบค่าปริมาณรังสีดูดกลืนในปอดด้วยวิธีคำนวณด้วยมือจากภาพสแกนสองมิติและจากโปรแกรมรังสีคณิต OLINDA และศึกษาอิทธิพลของมวลปอดต่อการคำนวณค่าปริมาณรังสีดูดกลืน

วิธีการศึกษา เป็นการศึกษาแบบย้อนหลังในผู้ป่วยโรคมะเร็งต่อมไทรอยด์ที่มีการแพร่กระจายของเซลล์มะเร็งไปปอดจำนวน 10 รายที่เข้ารับการรักษาด้วยสารรังสีไอโอดีน-131เป็นครั้งแรก โดยใช้หลักการ เอ็ม ไอ อาร์ ดี คำนวณค่าปริมาณรังสีดูดกลืนในปอดด้วยวิธีคำนวณด้วยมือจากภาพสแกนสองมิติและการใช้โปรแกรมรังสีคณิต OLINDA และนำค่า S-value 2 ชุดที่ปรับปรุงจากข้อมูล SAF และมวลปอดของหุ่นจำลองคริสตี้-แอกเคอร์แมน-สตาบิน และจากมวลปอดของคนไทยมาใช้ในการคำนวณตามสูตรของเอ็ม ไอ อาร์ ดี การวิเคราะห์ข้อมูลค่าปริมาณรังสีดูดกลืนในปอดที่ได้จากการคำนวณทั้งสองวิธีใช้ค่าร้อยละความแตกต่าง student pair t-test และค่าสัมประสิทธิ์สหสัมพันธ์

ผลการศึกษา ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของปริมาณรังสีดูดกลืนที่ปอดจากการคำนวณด้วยมือและโปรแกรมรังสีคณิต OLINDA ด้วยค่า $p>0.05$ ปริมาณรังสีดูดกลืนในปอดที่คำนวณด้วยค่า S-value จากหุ่นจำลอง คริสตี้ – แอก เคอร์แมน - สตาบิน และที่คำนวณด้วยค่า S-value จากมวลปอดคนไทย มีความสัมพันธ์ดีเยี่ยมระหว่างวิธีคำนวณมือและคำนวณจากโปรแกรมรังสีคณิต OLINDA ด้วยค่าสัมประสิทธิ์สหสัมพันธ์เท่ากับ1.0 ค่าร้อยละความแตกต่างระหว่างวิธีคำนวณมือและโปรแกรมรังสีคณิต OLINDA จากการคำนวณด้วยค่า S-value จากหุ่นจำลอง คริสตี้ – แอกเคอร์แมน - สตาบิน และที่คำนวณด้วยค่า S-value จากมวลปอดคนไทย มีค่าน้อยกว่า 0.5 และ 0.3 ตามลำดับ และพบว่าค่าปริมาณรังสีดูดกลืนที่คำนวณจาก S-value มวลปอดคนไทยมีค่าสูงกว่าค่าปริมาณรังสีดูดกลืนที่คำนวณได้จาก S-value ของหุ่นจำลอง คริสตี้ – แอกเคอร์แมน - สตาบิน ด้วยค่าร้อยละความแตกต่างอยู่ระหว่าง 20.4 ถึง 38.3

สรุปผลการศึกษา ปริมาณรังสีดูดกลืนที่ปอดจากการคำนวณด้วยวิธีทั้งสองมีค่าไม่แตกต่างกันเมื่อใช้ S-value ชุดเดียวกัน ดังนั้นการคำนวณทั้งสองวิธีจึงใช้แทนกันได้ นอกจากนี้การเปลี่ยนแปลงมวลของอวัยวะมีอิทธิพลโดยตรงต่อค่า S-value และค่าปริมาณรังสีดูดกลืน จึงควรพิจารณาอย่างระมัดระวังในการนำไปใช้กับการคำนวณแบบ เอ็ม ไอ อาร์ดี และเสนอแนะให้หามวลของอวัยวะจากภาพการแพทย์คุณภาพสูงต่าง ๆ เช่น เอ็มอาร์ไอ ซีที อุลตราซาวน์ เพื่อปรับปรุงความถูกต้องแม่นยำของการคำนวณปริมาณรังสีดูดกลืนด้วยวิธีการคำนวณที่ใช้ในการศึกษานี้

คำรหัส: *ปริมาณรังสีดูดกลืนที่ปอด โปรแกรมรังสีคณิต OLINDA มะเร็งไทรอยด์ S-value MIRD*

Introduction

Lungs are the most frequent distant metastatic site in well differentiated cell thyroid cancer (WDT) that cause a complicated protocol for I-131 treatment.[1] The metastatic WDT cell is destroyed by within cell radiation of 191 keV beta emission but normal lung cell is also damaged by 364 keV gamma emission of I-131 decay. The observed lung complications are pneumonitis, lung fibrosis, and insufficient lung function which radiation dose to lungs has to be adjusted.[2] In order to optimize the efficacy of I-131 treatment with the less radiation side effects to lungs. The update treatment protocol for WDT with lungs metastases includes Medical Internal Radiation Dosimetry (MIRD) for radionuclide treatment planning[3] because the administered activity is related to radiation absorbed dose in lungs. Estimation of lungs absorbed dose is very sophisticate that why a standard procedure is needed. At present, a specific protocol for internal dosimetry by MIRD is accepted and widely applied for I-131 treatment planning.[4] Following the MIRD principle, an absorbed dose can calculate with manual method or computer program by using physical and biological data set of each radiopharmaceutical. Most of these data were obtained from experiments in reference man phantoms of Caucasian. If the internal dosimetry for I-131 WDT treatment is applied in different races then more studies of proper physical and biological data for specific absorbed dose calculation are needed. This study aimed to compare I-131 lung absorbed doses by manual calculation from quantitative two-dimensional scan images and OLINDA dosimetry program and to study the affect of lung mass on calculated absorbed dose for Thais.

Materials and Methods

10 WDT patients with lung metastases from Maharaj Nakorn Chiang Mai Hospital, Faculty of Medicine, Chiang Mai University were studied. All of them had the first treatment of radioactive iodine-131 and underwent whole body scan (WBS) after received iodine -131 treatment 5-8 days, WBS images were illustrated in Figure 1. Calculation of radioactive absorbed dose in lungs under MIRD principle were done by manual method and OLINDA dosimetry program. [5-7] Two sets of adjusted I-131 S-value derived by specific absorbed fraction (SAF)'[9,10] lungs mass of Cristy-Eckerman-Stabin phantoms[11] and Thais' lung mass were applied in MIRD formula.[12]

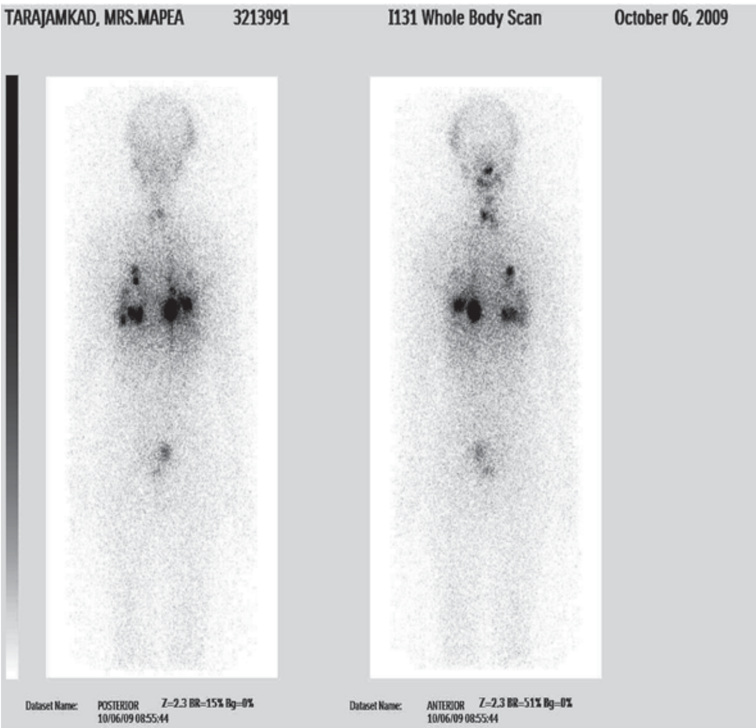


Figure 1 *The whole body scan images of well differentiated thyroid cancer with lung metastases patient after 5-8 days of I-131   5.5 GBq treatment*

Basic MIRD Formula

$$\overline{D}_{(T)} = \sum \tilde{A}_{(S)} \times S_{(T \leftarrow S)}$$

Where $\overline{D}_{(T)}$ is the mean absorbed dose to a target organ (Gy), $\tilde{A}_{(S)}$ is cumulated activity within the source organ (Bq-sec or Ci-hr) , $S_{(T \leftarrow s)}$ is the mean absorbed dose per unit cumulated activity (cGy/Ci-hr or Gy/Bq-s),

$$\tilde{A}_{(S)} = 1.443 T_{eff} \, A_o$$

Cumulated activity $\tilde{A}_{(S)}$

is cumulated activity within the source organ (Bq-sec or Ci-hr), T_{eff} is the effective half-life (hr or day) and A_0 is the administered activity (Bq or Ci) at time 0.

S value formula

$$S_{(T \leftarrow S)} = k \sum_i E_i y_i \, \Phi_{i \, (T \leftarrow S)}$$

where **y** is the number of radiations with energy **E** emitted form radionuclide per nuclear transition, **E** is the energy of the **i*** radiation (MeV), Φ_i is the specific absorbed fraction; SAF [8], is the constant of conversion unit :

$\kappa = 6.1 \times 10^{-4}$ for conversions unit of S-value is mGy/MBq sec

or $\kappa = 2.13$ for conversions unit of S-value is rad/μCi hr

and $$\Phi_{i \, (T \leftarrow S)} = \frac{\phi_{i \, (T \leftarrow S)}}{m_{(T)}}$$

when ϕ_i is the fraction of radiation energy emitted for the **i*** radiation in a source organ that is absorbed in the target organ ,also sometimes called absorbed fraction and $m_{(T)}$ is the mass of target region (g or kg)

Quantitative 2 Dimensional Scan images

The quantitative activity in region of interest (ROI) or source organ calculated by MIRD formula[7]:

$$A_j = \sqrt{\frac{I_A I_P}{e^{-\mu_e t}}} \frac{f_j}{C}$$

where A_j is activity in ROI of whole body scan images, I_A and I_P are the anterior and posterior counts in the ROI region, μ_e is the effective attenuation coefficient, t is the average patient thickness over the ROI, f_j is the source self-attenuation coefficient, and C is a source calibration factor (cps/Bq), obtained by counting a source of known activity in air.[5,13]

Lung Absorbed Dose Formula

$$\overline{D}_{Lung} = \left(\tilde{A}_{Lung} \times S_{(Lung \leftarrow Lung)}\right) + \left(\tilde{A}_{Thyroid} \times S_{(Lung \leftarrow Thyroid)}\right)$$

OLINDA /EXM Dosimetry program

OLINDA/EXM dosimetry program is an acronym standing for Organ Level Internal Dose Assessment/ Exponential Modeling which uses calculate internal radiation dose was designed as an update to MIRDOSE. Just with models of the Cristy–Eckerman–Stabin phantoms (adult male, adult female, children of various ages, and women at three stages of pregnancy) and to add several new individual organ models (prostate gland, peritoneal cavity, head/brain, multipart kidney, bone and marrow) . Many more nuclides were included, over 800 vs. around 240 available in the MIRDOSE codes are used dose conversion factor (DFs) or the S-value for all source organs and target organ of the each age and radionuclide type which user can adjust the mass of internal organ.[5]

The steps of internal dose calculation by OLINDA/ EXM dosimetry program were; select a radionuclide and reference phantom model, enter cumulated activity $\tilde{A}_{(S)}$ or percentage uptake in lungs and the effective half life (T_{eff}) of radionuclide in lung. The program will calculate and display the absorbed dose in lung and the effective dose of each patient as show in Table 1.

The lung absorbed dose by manual calculation from two-dimensional scan images and OLINDA dosimetry program were analyzed by percentage of differences, student pair t-test and correlation coefficients.

Table 1 Example of organ absorbed dose (mSv/MBq) of I-131 in adult female phantom calculated by OLINDA/EXM dosimetry program

Target Organ	Alpha	Beta	Photon	Total	EDE Cont.	ED Cont.
Adrenals	0.00E+00	0.00E+00	9.79E-03	9.79E-03	5.88E-04	4.90E-05
Brain	0.00E+00	0.00E+00	6.59E-04	6.59E-04	0.00E+00	3.29E-06
Breasts	0.00E+00	0.00E+00	8.78E-03	8.78E-03	1.32E-03	4.39E-04
Gallbladder Wall	0.00E+00	0.00E+00	3.16E-03	3.16E-03	0.00E+00	0.00E+00
LLI Wall	0.00E+00	0.00E+00	3.52E-04	3.52E-04	0.00E+00	4.23E-05
Small Intestine	0.00E+00	0.00E+00	8.65E-04	8.65E-04	0.00E+00	4.32E-06
Stomach Wall	0.00E+00	0.00E+00	5.24E-03	5.24E-03	0.00E+00	6.29E-04
ULI Wall	0.00E+00	0.00E+00	1.03E-03	1.03E-03	0.00E+00	5.17E-06
Heart Wall	0.00E+00	0.00E+00	1.79E-02	1.79E-02	1.08E-03	0.00E+00
Kidneys	0.00E+00	0.00E+00	3.25E-03	3.25E-03	0.00E+00	1.62E-05
Liver	0.00E+00	0.00E+00	8.59E-03	8.59E-03	5.15E-04	4.30E-04
Lungs	0.00E+00	4.38E-01	4.90E-02	4.87E-01	5.85E-02	5.85E-02
Muscle	0.00E+00	0.00E+00	4.46E-03	4.46E-03	0.00E+00	2.23E-05
Ovaries	0.00E+00	0.00E+00	3.87E-04	3.87E-04	9.68E-05	7.74E-05
Pancreas	0.00E+00	0.00E+00	7.38E-03	7.38E-03	4.43E-04	3.69E-05
Red Marrow	0.00E+00	0.00E+00	4.71E-03	4.71E-03	5.65E-04	5.65E-04
Osteogenic Cells	0.00E+00	0.00E+00	4.84E-03	4.84E-03	1.45E-04	4.84E-05
Skin	0.00E+00	0.00E+00	2.25E-03	2.25E-03	0.00E+00	2.25E-05
Spleen	0.00E+00	0.00E+00	7.05E-03	7.05E-03	0.00E+00	3.53E-05
Thymus	0.00E+00	0.00E+00	1.19E-02	1.19E-02	7.14E-04	5.95E-05
Thyroid	0.00E+00	2.33E+00	1.55E-01	2.49E+00	7.46E-02	1.24E-01
Urinary Bladder Wall	0.00E+00	0.00E+00	1.94E-04	1.94E-04	0.00E+00	9.72E-06
Uterus	0.00E+00	0.00E+00	3.63E-04	3.63E-04	0.00E+00	1.82E-06
Total Body	0.00E+00	6.86E-03	4.91E-03	1.18E-02	0.00E+00	0.00E+00
Effective Dose Equivalent (mSv/MBq)				1.39E-01		
Effective Dose (mSv/MBq)				1.85E-01		

Results

No significant difference of lung absorbed dose by manual calculation and OLINDA dosimetry program, $p>0.05$ (Table 2 and Table 3). An excellent correlation of absorbed doses between manual and OLINDA dosimetry program was found in both conditions of using the S-value of Cristy–Eckerman–Stabin phantoms (Figure 2) and the adjusted S-value with Thai's lung mass, $r = 1.0$ (Figure 3).

The percentage of difference between manual calculation and OLINDA dosimetry program by Cristy–Eckerman–Stabin S-value and adjusted S-value

Table 2 Percent differences of lung absorbed dose between manual calculation and OLINDA dosimetry program by using S-value of Cristy-Eckerman-Stabin phantom

Patients	Lung absorbed dose calculated by using S-value of Cristy–Eckerman–Stabin phantoms (mGy)		Difference (percentage)
	Manual	OLINDA	
1	1.2748×10^{4}	1.2765×10^{4}	0.133
2	3.1483×10^{3}	3.1524×10^{3}	0.130
3	8.2553×10^{2}	8.2510×10^{2}	-0.052
4	1.2812×10^{3}	1.2821×10^{3}	0.066
5	3.1554×10^{2}	3.1580×10^{2}	0.081
6	1.0684×10^{3}	1.0712×10^{3}	0.257
7	2.7010×10^{3}	2.7029×10^{3}	0.068
8	6.4087×10^{3}	6.4380×10^{3}	0.455
9	5.2832×10^{3}	5.2892×10^{3}	0.112
10	4.3657×10^{4}	4.3734×10^{4}	0.176

Table 3 Percent differences of lung absorbed dose between calculated manual and OLINDA dosimetry program by using S-value of Thais

Patients	Lung absorbed dose calculated by using S-value of Thai people (mGy)		Difference (percentage)
	Manual	OLINDA	
1	1.9538×10^{4}	1.9314×10^{4}	-0.116
2	4.0128×10^{3}	3.9590×10^{3}	-0.136
3	1.2652×10^{3}	1.2506×10^{3}	-0.117
4	1.9635×10^{3}	1.9370×10^{3}	-0.137
5	5.1141×10^{2}	4.9950×10^{2}	-0.238
6	1.7315×10^{3}	1.6872×10^{3}	-0.263
7	4.1396×10^{3}	4.0904×10^{3}	-0.120
8	9.8218×10^{3}	9.7125×10^{3}	-0.113
9	8.0969×10^{3}	7.9920×10^{3}	-0.131
10	6.6908×10^{4}	6.6045×10^{4}	-0.131

with Thais' lung mass was lesser than 0.5 and 0.3 respectively. Higher lung absorbed dose was found in adjusted S-value of Thais' lung mass than S-value of Cristy-Eckerman-Stabin phantom. The percentage of absorbed dose differences by these two S-value sets laid between 20.4 to 38.3 (Table 4 and Table 5).

Discussion

Since 1948, I-131 has been used for WDT treatment with satisfied clinical outcome in patient with low grade cancer staging. But a complex I-131 treatment was found in case of WDT with lungs metastases due to clinical optimization for treatment efficacy and the

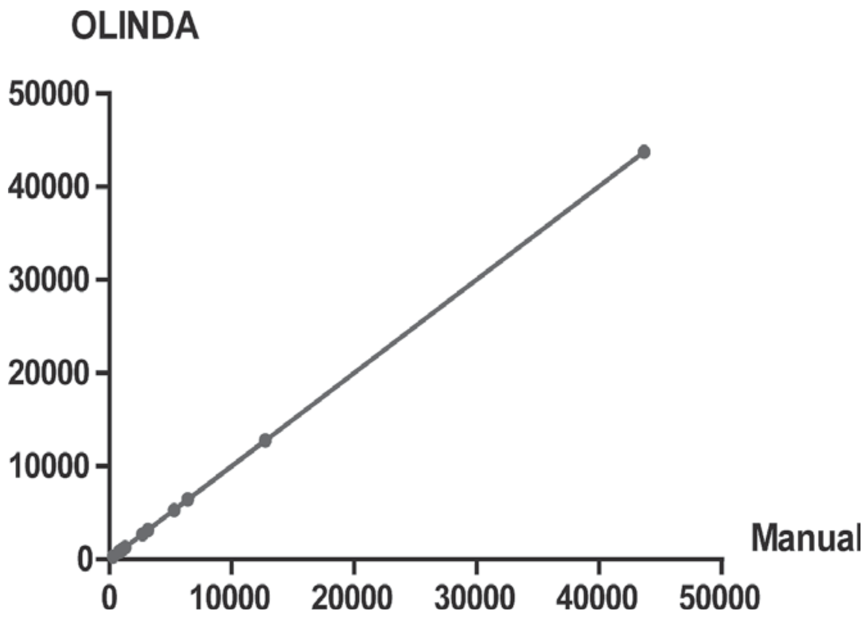


Figure 2 *An excellent correlation of lung absorbed dose between manual calculation and OLINDA dosimetry program by using S-value of Cristy–Eckerman–Stabin phantoms, r = 1.0*

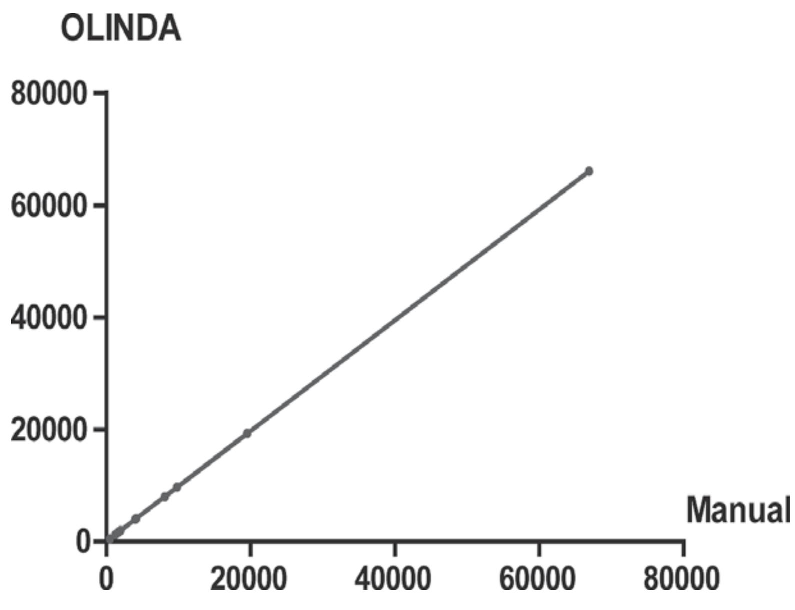


Figure 3 *An excellent correlation of lung absorbed dose between manual calculation and OLINDA dosimetry program by using S-value of Thais, r=1.0*

Table 4 Increased differences about 22–38 percents of lung absorbed dose by manual calculation method between using S-value of Cristy–Eckerman–Stabin phantoms and modified S-value of Thais

Patients	Lung absorbed dose calculated by manual (mGy)		Difference (percentage)
	S-value of Cristy–Eckerman–Stabin phantoms	S-value of Thai people	
1	1.2748×10^4	1.9538×10^4	34.75
2	3.1483×10^3	4.0128×10^3	21.54
3	8.2553×10^2	1.2652×10^3	34.75
4	1.2812×10^3	1.9635×10^3	34.75
5	3.1554×10^2	5.1141×10^2	38.30
6	1.0684×10^3	1.7315×10^3	38.30
7	2.7010×10^3	4.1396×10^3	34.75
8	6.4087×10^3	9.8218×10^3	34.75
9	5.2832×10^3	8.0969×10^3	34.75
10	4.3657×10^4	6.6908×10^4	34.75

Table 5 Increased difference about 20 – 37 percents of lung absorbed dose by OLINDA dosimetry program between using S-value of Cristy–Eckerman–Stabin phantoms and modified S-value of Thais

Patients	Lung absorbed dose calculated by OLINDA dosimerty program (mGy)		Difference (percentage)
	S-value of Cristy–Eckerman–Stabin phantoms	S-value of Thai people	
1	1.2765×10^4	1.9314×10^4	33.91
2	3.1524×10^3	3.9590×10^3	20.37
3	8.2510×10^2	1.2506×10^3	34.02
4	1.2821×10^3	1.9370×10^3	33.81
5	3.1580×10^2	4.9950×10^2	36.78
6	1.0712×10^3	1.6872×10^3	36.51
7	2.7029×10^3	4.0904×10^3	33.92
8	6.4380×10^3	9.7125×10^3	33.71
9	5.2892×10^3	7.9920×10^3	33.82
10	4.3734×10^4	6.6045×10^4	33.78

awareness of radiation risk to lung tissue.[13-15] The high gamma rays of 364 keV of I-131 decay will damage lung tissue and cause some serious complications such as lungs fibrosis, pneumonitis, lung function insufficiency. An internal organ absorbed dose measurement is now introduced as a tool for radionuclide treatment planning which benefit very much for advance WDT therapy with I-131. The MIRD techniques for internal absorbed dose measurement are widely applied both manual and computerized calculation methods. In this study found no significant difference of lungs doses between manual calculation and OLINDA program (p>0.05) because of both methods were derived from the same principle and database. But more random errors were observed in manual calculation than computer program due to many calculation steps. Then, to recheck the results by expert dosimetrist can minimize these errors.

According to MIRD formula, $\overline{D}_{(T)} = \Sigma\tilde{A}_{(S)} \times S_{(T\leftarrow S)}$ to define an $\tilde{A}_{(S)}$ in patient's lungs depended on individual effective half-life (T_{eff}) of I-131 in lungs. The serial time interval of lungs images by WBS was an essential performance for accurate activity measurement. At least 3 time intervals were recommended. The one point data of $\tilde{A}_{(S)}$ from this retrospective study may not equivalent for clinical decision but it is valuable for new implementation of internal radiation dosimetry. In addition, a finding of higher lung absorbed dose by adjusted S-value of Thais' lung mass than S-value of Cristy-Eckerman-Stabin with percentages of difference range 20.4-38.3 was nailed on the effect of organ mass to internal dose calculation. The improved organ mass measurement by high quality medical images such as computerized tomography (CT) images, magnetic resonance images (MRI), ultrasonography (US) etc., could increase accuracy of internal dosimetry.

Establishment of medical internal radiation dosimetry needs accurate quantitative equipment and qualified medical physicist. All instrument use in internal dosimetry should have continuous quality control and quality assurance program for accuracy and reliability results. A computer program for internal dosimetry should be utilized or developed in order to minimize random errors, less time consuming, support high workflow unit. Moreover, thinking of national reference man phantom for S-value database have to be plan especially in high competency laboratory.

Conclusion

The absorbed doses in lungs calculated by manual method and OLINDA program were not different when using the same S-value data set. Both calculation methods could be compatible for application in internal dosimetry. The individual measurement of organ mass by high-quality medical images such as MRI, CT, US were recommended to improve accuracy and precision of absorbed dose calculation. Carefully measurement of $\tilde{A}_{(S)}$ in region of interest and correct S-value selection were affected on absorbed dose validation.

Acknowledgement

We would like to sincere thank all stafs of the Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine, Chiang Mai University for their encouragement and assistance in this study.

References

1. Song H, He B, Prideaux A, Du Y, Frey E, Kasecamp W, Ladenson PW, Wahl RL, Sgouros G. Lung dosimetry for radioiodine treatment planning in the case of diffuse lung metastases. J Nucl Med 2006; 47(12): 1985-94.
2. Benua RS, Cicale NR, Sonenberg M. The relation of radioiodine dosimetry to results and complications in the treatment of metastatic thyroid cancer. AJR 1962; 87(1): 171–82.
3. Fisher DR. Internal dosimetry for systemic radiation therapy. Seminars in Radiation Oncology 2000; 10(2): 123-32.
4. Lassmann M, Hanscheid H, Chiesa C, Hindorf C, Flux G, Luster M. EANM dosimetry committee series on standard operational procedures for pre-therapeuitic dosimetry I: blood and bonr marrow dosimetry in differentiated thyroid cancer therapy. Eur J Nucl Med Mol Imaging 2008; 35: 1405-12.
5. Stabin MG. Documentation package of OLINDA 1.0. Department of radiology and Radiological Sciences, Vanderbilt University, 2009; 1-36.
6. Snyder WS, Ford MR, Warner GG. MIRD pamphlet no.5, revised: estimate of specific absorbed fraction for photon sources uniformly distributed in various organs of a heterogeneous phantom. Health Physics Division, Oak ridge National Laboratory, Oak ridge 1978; 1-70.
7. Siegel JA,Thomas SR, Stubbs JB, Stabin MG, Hays MT, Koral KF, Robertson JS, Howell RW, Wessels BW, Fisher DR, Weber DA , Brill AB. MIRD pamphlet no.16 : techniques for quantitative radiopharmaceutical biodistribution data acquisition and analysis for use in human radiation dose estimates. J Nucl Med 1999; 40 (2): 37s-61s.
8. Stabin MG. Uncertainties in internal dose calculations for radiopharmaceuticals. J Nucl Med 2008; 49(5): 853–60.
9. Cristy M. and Eckerman K. Specific absorbed fractions of energy at various ages from internal photon source. ORNL/TM-8381. Oak Ridge National Laboratory, Oak Ridge, 1987.
10. Stabin M, Watson E, Cristy M, Ryman J, Eckerman K, Davis J, Marshall D, Gehlen K. Mathematical model and specific absorbed fractions of photon energy in the nonpregmant adult female and at the end of each trimester of pregnancy. ORNL/TM-12907, Oak Ridge National Laboratory, Oak Ridge,1995.
11. Stabin MG and Siegel JA. Physical models and dose factors for use in internal dose assessment. Health Physics [Online] 2003 [cited 2009 March 10]; 85(3):294-310. Available from: http://www.doseinfo-radar.com/RADARphan.html.
12. Narongchai P, Narongchai S. Study of the normal internal organ weights in Thai population. J Med Assoc Thai. 2008; 91(5): 747-53.
13. Maxon HR, Englaro EE, Thomas SR, Hertzberg VS, Hinnefeld JD, Chen LS, Smith H, Cummungs D, Aden MD. Radioiodine–131 treatment for differentiated thyroid cancer: a quantitative radiation dosimetric approach: outcome and validation in 85 patients. J Nucl Med 1992; 33(6): 1132-6.
14. Klubo-Gwiezdzinska J, et al. Efficacy of dosimetric versus empiric prescribed activity of 131I for therapy of differentiated thyroid cancer. JCEM 2011: 96(5); 3217-25.
15. Verburg FA., et al. I-131 Activities as high as safely administrable (AHASA) for the treatment of children and adolescents with advanced differentiated thyroid cancer. JCEM 2011; 96(8): 1268-71.
16. Lassmann M., Reiners C., Luster M. Dosimetry and thyroid cancer: the individual dosage of radioiodine. Endocrine-Related Cancer 2010; 17: 161-72.