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Development of a software tool for an internal dosimetry using MIRD method

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Abstract. Currently, many software packages for the internal radiation dosimetry have been developed. Many of them do not provide sufficient tools to perform all of the necessary steps from nuclear medicine image analysis for dose calculation. For this reason, we developed a CALRADDOSE software that can be performed internal dosimetry using MIRD method within a single environment. MATLAB software version 2015a was used as development tool. The calculation process of this software proceeds from collecting time-activity data from image data followed by residence time calculation and absorbed dose calculation using MIRD method. To evaluate the accuracy of this software, we calculate residence times and absorbed doses of 5 Ga-67 studies and 5 I-131 MIBG studies and then compared the results with those obtained from OLINDA/EXM software. The results showed that the residence times and absorbed doses obtained from both software packages were not statistically significant differences. The CALRADDOSE software is a user-friendly, graphic user interface-based software for internal dosimetry. It provides fast and accurate results, which may be useful for a routine work.

1. Introduction

In nuclear medicine, radionuclides are used in variety of diagnostic and therapeutic procedures. Internal dosimetry is essential to evaluate the risk and benefit of any procedures. It is also used to optimize imaging techniques and develop new radiopharmaceuticals. Internal radiation dosimetry in nuclear medicine is usually performed using MIRD (Medical Internal Radiation Dose) method [1], which is based on measurement of the biokinetics data of serial image scans. There are three steps of calculation as follows: first, the time-activity data for each source organ is determined, then the residence time in each source organ is calculated and finally, the radiation absorbed dose in each target organ is determined using MIRD method. To manually perform internal dosimetry is time-consuming and errors can occur in each step leading to developing software tools to ease users.

There are many software packages available, however, many of them have limited functions. For example, OLINDA/EXM software [2] uses residence time to calculate absorbed dose per unit of administered activity. It also provides EXM tool to plot time-activity data and fit the data to multi-exponential function, which is then integrated to calculate residence time. Whereas, separate software such as ULMDOS [3] or SPRIND [4] is required to obtain the time-activity data that is used as input for OLINDA/EXM.

To include all three steps in one software tools, we have developed the ease-of-use, platform independent software named CALRADDOSE, which provides tools used for internal dose calculation using MIRD method in a single environment.

2. Materials and methods

2.1 Software development

Our software namely 'CALRADDOSE' was developed using MATLAB (MATrix LABoratory) program version 2015a. The development process covered the design of graphic user interfaces (GUIs), data structure, and calculation algorithms. The Graphic User Interface Development Environment (GUIDE) tool was used to create software GUIs. The dose calculation was performed using MIRD method. The calculation process in this software was divided into three major steps: time-activity data collection, residence time calculation, and dose calculation. Figure 1 showed a workflow of the software design including 'Image Processing UIs', 'Residence Time Calculation UI', and 'Dose Calculation UI', which provided functional units of the calculation process.

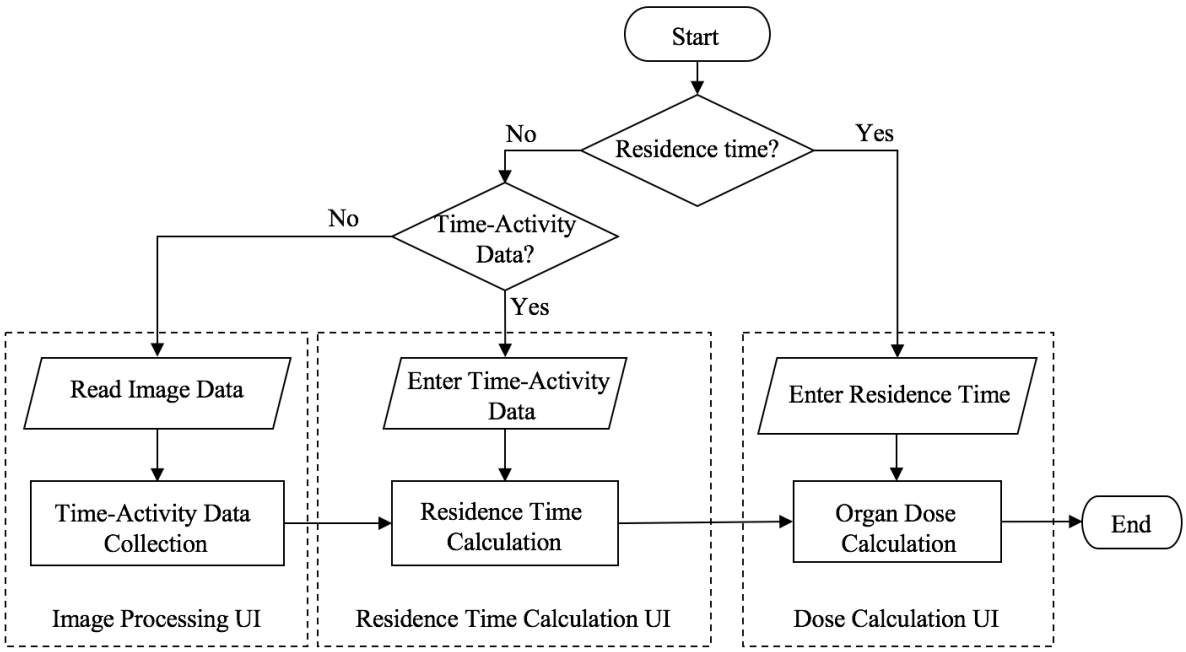

Figure 1. A flowchart of the calculation process of CALRADDOSE.

2.1.1 Time-activity data (TAD) collection. To collect time and activity from image data, the Image Processing UIs including 'Planar Image Processing UI' and 'SPECT Image Processing UI' were created to read DICOM file, draw ROI, obtain numbers of count and calculate count rate.

A simple screen shot of the 'Planar Image Processing UI' was presented in figure 2. Anterior and posterior whole-body images were read and displayed side-by-side. Study information including study description, study date-time, acquisition date-time, were automatically read from DICOM header. This UI provided a simple tool for drawing a region of interest (ROI) of source organ into image display. After an ROI was drawn on an anterior image, this ROI was copied to a posterior image, and also copied to series image at a time different. Counts from ROIs were background corrected [5] and averaged using geometrical mean [6], and finally, count rate was obtained.

For 'SPECT Image Processing UI', SPECT image data in transversal plane were read and used to generate images in coronal and sagittal plane. The user can determine the organ VOI by manual drawing ROIs combined with thresholding-based segmentation. Count rate was calculated by dividing total count in VOI with scanning time (frame time x numbers of frame).

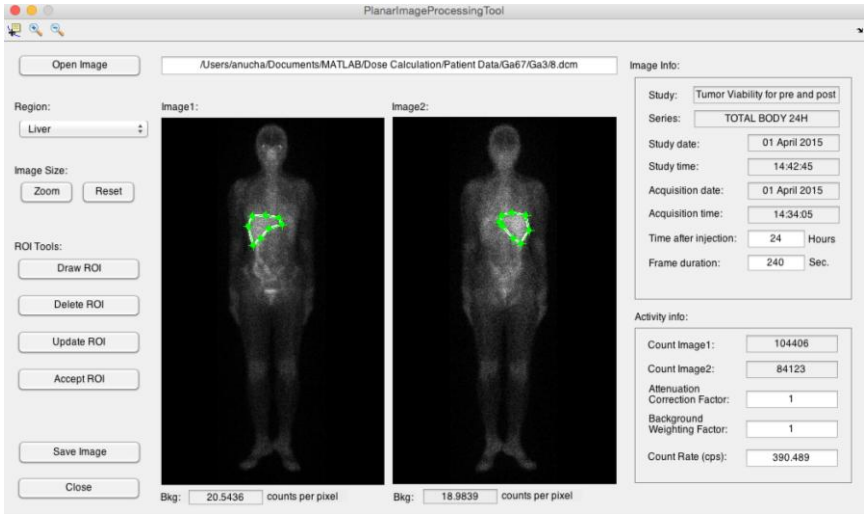

Figure 2. A simple screen shot of the 'Planar Image Processing UI' includes two planar images with liver ROIs.

2.1.2 Residence time calculation. The 'Residence Time Calculation UI' was created to calculate a residence time in source organ. In this UI, TADs of all source organ are plotted and fitted with either a single- or two-term exponential function. Curve fitting was performed using the Levenberg-Marquardt method [7, 8]. After the fitting was completed, count rate at each time point from zero to infinity was integrated and then divided by initial count rate of total body data to get residence time.

2.1.3 Dose calculation. The absorbed doses per unit administered activity in target organs were calculated using MIRD method. The general concept was to sum all the product of residence time for source organs (τ_h) and the S-values for the source-target organ $S(k \leftarrow h)$, which yielded the absorbed dose per unit administered activity as:

$$\frac{D_k}{A_0} = \sum_h \tau_h S(k \leftarrow h) \quad (1)$$

where D_k is absorbed dose to target organ k; A_0 is administered activity; h and k refer to source and target organ, respectively. All of these data used to calculate S-value were downloaded from RADAR website [9, 10] including: the radionuclide decay data from the Brookhaven National Laboratory's (BNL) National Nuclear Data Center, the specific absorbed fraction for various phantom [11, 12], and organ masses of Stabin phantoms [11] and Cristy and Eckerman phantoms [12, 13]. The software calculated S-value for each target organ by considering each emission in decay scheme. After calculation of S-value and residence time, the absorbed dose in target organ was calculated using equation (1). For photon emission, the absorbed dose was scaled with the cube root of organ mass for self-irradiation. Whereas alpha and beta emissions, the dose calculation needed to be linearly scaled with organ mass [2, 14].

2.2 Software evaluation

In this study, software evaluation was focused on the accuracy of residence time calculation and organ dose calculation by comparing with those from OLINDA/EXM. Planar images of five Ga-67 and five I-131 MIBG studies were used. The TAD were obtained from series of planar whole-body images at 24, 48 and 72 hours after injection for all the patients using 'Planar Image Processing UI'. The selected source organs were liver, spleen, and total body. These time-activity data were used to calculate residence time for all source organs and then organ doses with the CALRADDOSE and OLINDA/EXM. The differences of the results from both software were compared using a paired t-test with 95% confident interval (p-value<0.05).

3. Results and discussion

Table 1 shows residence times from 10 patients calculated from CALRADDOSE and OLINDA/EXM. The average percent difference was 0.76. A paired t-test was performed and there was no statistically significant difference in the residence time calculated by CALRADDOSE and OLINDA/EXM with p-value = 0.329 (>0.05). That meant the residence times obtained from both software were similar.

Table 2 shows organ doses from patient no.1 calculated from both software. The average percent difference was 2.26. The results showed that the organ dose calculated from both software also were not significant difference with p-value = 0.228 (>0.05). However, there were high percent differences due to difference calculation of S-value, which could be affected by many reasons. First, both software used

Table 1. A comparison of residence time from total body data calculated by CALRADDOSE and OLINDA/EXM.

Patient	Injected Nuclide	Calculated Residence Time (MBq-s/MBq)		Difference (%)
		CALRADDOSE	OLINDA/EXM	
1	Ga-67	94.49	94.00	0.52
2	Ga-67	82.67	83.10	0.52
3	Ga-67	81.22	81.10	0.15
4	Ga-67	92.01	92.30	0.31
5	Ga-67	78.43	79.40	1.23
6	I-131	26.49	26.50	0.05
7	I-131	40.19	40.10	0.22
8	I-131	41.74	41.80	0.14
9	I-131	64.11	64.00	0.17
10	I-131	63.64	64.00	0.56
Average				0.76

Table 2. A comparison of organ doses from patient no.1 calculated by CALRADDOSE and OLINDA.

Target	Calculated Dose per Administered Activity (mGy/MBq)		Difference (%)
	CALRADDOSE	OLINDA/EXM	
Adrenals	0.1261	0.1230	2.52
Brain	0.0785	0.0805	2.48
Breasts	0.0738	0.0745	0.94
Gall Bladder Wall	0.1479	0.1400	5.64
LLI Wall	0.1048	0.1070	2.06
Small Intestine	0.1051	0.1060	0.85
Stomach Wall	0.1104	0.1100	0.36
ULI Wall	0.1140	0.1140	0.00
Heart Wall	0.1127	0.1120	0.62
Kidneys	0.1126	0.1110	1.44
Liver	0.3021	0.2810	7.51
Lungs	0.1035	0.1030	0.49
Muscle	0.0870	0.0879	1.02
Ovaries	0.1075	0.1100	2.27
Pancreas	0.1333	0.1290	3.33
Red Marrow	0.0925	0.0878	5.35
Osteogenic Cells	0.1323	0.1360	2.72
Skin	0.0649	0.0659	1.52
Spleen	0.2480	0.2370	4.64
Thymus	0.0943	0.0958	1.57
Thyroid	0.0817	0.0836	2.27
Urinary Bladder	0.0997	0.1020	2.25
Uterus	0.1059	0.1080	1.94
Total Body	0.0963	0.0968	0.52
Average			2.26

different sources of radiation decay data, the OLINDA/EXM used the decay data that published by Stabin *et al*. [15] whereas the CALRADDOSE used that from the BNL's National Nuclear Data Center. Second, S-values in OLINDA/EXM were corrected when a source was in hollow organ (gall bladder, urinary bladder, GI tract) by estimating electron dose as the maximum dose at content/wall interface [14]. Third, the dose to source organs (liver, spleen) from CALRADDOSE was higher than that from OLINDA/EXM due to different methods for self-irradiation correction. Lastly, the dose to red marrow was high different because marrow model was not included in CALRADDOSE.

4. Conclusion

CALRADDOSE is a user-friendly, graphic user interface-based software. This software is imaging modality and analysis software vendor independent. It can be performed all steps of internal dosimetry within single environment lead to reducing calculation time and reducing possibility of error. CALRADDOSE also provides fast and accurate results which may be useful for a routine work.

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