Effect of Deviation in Image Quantification for Internal Dosimetry Assessment in Radionuclide Therapy

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ABSTRACT

There is a raising interest regarding internal dosimetry assessment for radionuclide therapy. One focus of interest lies on the importance of patient specific dosimetry for the efficacy of therapy, which needs a step of imaging quantification from gamma camera scans for a particular time interval. The quantification must be conducted according to Pamphlet No. 16 from Medical Internal Radiation Dosimetry Committee (MIRD) with a conjugate view method to determine the time-integrated activity coefficients (TIACs), which are necessary for absorbed dose prediction in the patients. The region of interest (ROI) in a gamma camera image reflects the accumulated activity of radionuclides in the respective organ. Hence, it is important to define the region of interest for target and source organs to find the amount of cumulated activity in each organ. The objective of this study is to observe the effect of deviation in the drawing process of organ ROI on the TIACs. Five patients with neuroendocrine tumors (NET) were intravenously injected with¹¹¹In-labelled DTPAOC (OctreoScan™) as bolus for (120 ± 48) MBq. Patients were scanned using a dual head gamma camera (ECAM; Siemens, Erlangen, Germany) for a series of whole-body scans. As a result, a pair of anterior and posterior image has been acquired at 0.6, 4, 24, 48 and 72 h post injection to observe the cumulated activities in particular organs. ROIs were defined using the ULMDOS software for treatment planning in internal radionuclide therapy. In this study, kidneys, liver and spleen were investigated. The process of ROI drawing for each patient has been repeated with decreased and increased ROIs and an approximate deviation of 5 %, 10 % and 15 % of the defined optimal ROI. Linear regression was used to quantify the dependence of the TIACs on the ROI size. The relation between the relative size of the ROI and the
corresponding relative change of the time-integrated activity coefficients can be approximated by a linear relationship. Linear regression yielded for the slope $s$ and the y-intercept $y_0$ of the organs the following values:

- Kidneys: $s = (0.61 \pm 0.05)$, $y_0 = (0.37 \pm 0.05)$,
- Liver: $s = (0.58 \pm 0.10)$, $y_0 = (0.44 \pm 0.10)$,
- Spleen: $s = (0.51 \pm 0.04)$, $y_0 = (0.49 \pm 0.04)$.

To conclude, the step of drawing ROIs is a crucial step in the process of calculation of time-integrated activity coefficients. Hence, the enlargement and reduction of a ROI will affect the obtained TIAC. In general, the relative error in the TIACs is in the same order of magnitude as the errors in the organ ROI drawing process.

**Keywords:** patient specific dosimetry, gamma camera, image quantification, ULMDOS software

**INTRODUCTION**

Radionuclide therapy has been acknowledged as a loco regional treatment for killing cancer cells in which radiation energy has been delivered selectively to diseased cells or tissues, while minimizing the damage on surrounding normal tissues. Moreover, radionuclide therapy has been proved as therapy with revolutionary approach, especially for the cancer type which is inoperable\(^1\).

With regard to internal dosimetry assessment for patients in the nuclear medicine department, the importance of patient specific dosimetry has been stressed for achieving the efficacy of therapy\(^2,4\). As initial step, an imaging quantification from gamma camera scans in a particular timing scale should be done as a treatment planning study prior the therapy\(^4\).

The latest studies have reported that performing patient specific dosimetry assessment prior radionuclide therapy will reduce the damage to the organ at risks and maximize the drug delivery to the target tissues\(^2, 3, 5, 6\). There are few ways to perform patient specific dosimetry using either a simple planar gamma camera, or advanced imaging equipments such as SPECT/CT or PET/CT, and a computational tool such as Monte Carlo code\(^7-10\).

Patient specific dosimetry is developed by a conventional internal dosimetry method. One of available and the most favorable is a method from Medical Internal Radiation Dosimetry (MIRD) Committee in United States Nuclear Medicine community, which has been reported in the MIRD pamphlet no. 16\(^9\). The MIRD 16 method suggests the use of a series of whole body scan from a gamma camera with anterior and posterior images. Calibration and attenuation correction must be considered as additional factors.
ULMDOS is a software for facilitating internal dosimetry studies for radionuclide therapy based on the MIRD pamphlet 16 method\textsuperscript{[11]}. The ULMDOS evaluates a pair of anterior and posterior images from gamma camera scans and will produce time-integrated activity coefficients (TIACs) as the output. These outputs are needed in further calculation steps, especially when software such as OLINDA/EXM\textsuperscript{[12]} will be used for predicting the organ doses.

In ULMDOS the delineation of source and target organ region of interest (ROI) is performed, which reflects the accumulated activity of radionuclides in the organs. Since in the determination of accumulated activity by using image quantification method, need a precise delineation of target organ, hence the objective of this study is to observe the effect of error in the drawing process of target organ ROI on the TIACs.

**MATERIAL AND METHODS**

To perform image quantification for patient specific dosimetry, patients need to be scanned in a series of gamma camera acquisitions. The acquired images have been subjected to investigate the response of radiopharmaceutical administration on either cancer cells or relevant organs. The responses which have been presented in the images can be quantified as cumulated activity of radiopharmaceutical by drawing the region of interest for relevant organs. Figure 1 shows the sample of display menu in ULMDOS which represent the number of cumulated activity in the organs.

In this study, five patients with neuron endocrine tumors (NETs) were intravenously injected with \textsuperscript{111}In-labelled DTPAOC (Octreoscan\textsuperscript{TM}) as bolus for (120 ± 48) MBq. Patients were scanned using a dual head gamma camera (ECAM; Siemens, Erlangen, Germany) for a series of whole body scans. As a result, a pair of anterior and posterior images has been acquired at 0.6, 4, 24, 48 and 72 h post injection to observe the cumulated activities in particular organs. ROIs were defined using ULMDOS software for treatment planning in internal radionuclide therapy. In this study, kidneys, liver and spleen have been investigated as these organs have been considered as organ at risk in peptide receptor radionuclide therapy (PRRT). The process of ROI drawing for each patient has been repeated with decreased and increased ROIs at ± 5 %, 10 % and 15 % of the defined true ROI based on the pixel number.
After ROIs have been adjusted in each scan, the fitting process could be started. An example of fitting process is displayed in Figure 2. From the PLOT&FIT menu, it can be seen how the accumulation and washout process occurred in the organs. The fit functions consist of the sum of exponential functions. The number of parameters can be reduced by constraining some prefactors of the exponentials or setting the biological half-life to infinity. Moreover, a fit function which is linked to the process can be chosen by investigating the trend of data. For example, “organ1” function has been chosen for the fitting model in kidneys. This is because the data of kidneys has a similar trend with three exponential functions.
RESULTS AND DISCUSSION

As the result of investigation, the effect of relative size of the ROI and the corresponding relative change of the time-integrated activity coefficients has shown a linear relationship, for example, with 5% ROI deviation, it has been produced approximately 5% error in TIACs. A linear regression with the slope $s$ and the $y$-intercept $y_0$ of the organs on the following values, such as: kidneys: $s = (0.61 \pm 0.05), y_0 = (0.37 \pm 0.05)$, liver: $s = (0.58 \pm 0.10), y_0 = (0.44 \pm 0.10)$, and spleen: $s = (0.51 \pm 0.04), y_0 = (0.49 \pm 0.04)$. These relationships are presented in Figures 3, 4, and 5 for kidneys, liver and spleen, respectively.
Figure 3. The relationship between relative size of the ROI and the corresponding relative change of the TIAC ($\tau$) for kidneys.

Figure 4. The relationship between relative size of the ROI and the corresponding relative change of the TIAC ($\tau$) for liver.
Figure 5. The relationship between relative size of the ROI and the corresponding relative change of the TIAC \( (\tau) \) for spleen.

From the plot analysis, when the ROIs have been set to be decreased and increased, the effect on TIACs will be either larger or smaller respectively. For example, 10\% smaller or larger error will produce the similar error at 5 \% error of TIAC in spleen, while in kidneys and liver, the relationship is on the contrary, for example the smaller ROI in kidneys produce larger error in TIAC, but the larger ROI in kidneys produces the smaller error of TIAC.

During the ROI drawing process, there were a few challenges in defining ROI for the livers in some patients since it seems that they have metastases in the liver. As a result a relationship which is less accurate can be seen in Figure 3. This is one of the particular problems in image quantification using planar images from gamma camera, for example a similar problem exists in the area where organs overlap, which can reduce the accuracy of ROI definition. To solve the problem, some correction need to be performed, for example the metastasis area needs to be subtracted from the total gross of ROI, but in this study, the correction has not been done, and the metastasis has been disregarded. It has been suggested\[^2\] that this correction will not be necessary for image quantification for PET images, since it represents a three dimensional volume. Moreover, a calibrated PET image can also be used to eliminate the effect of overlapping organs.
CONCLUSION
The step of drawing ROIs is a crucial step in the process of calculation of time-integrated activity coefficients. Hence, the enlargement and reduction of a ROI will affect the obtained time-integrated activity coefficient. In general, the relative error in the TIACs is in the same order of magnitude as the errors in the organ ROI drawing process.

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