Estimation of Organ Biodistribution of Activities in Human from External Measurement with TLD

V. 2. Estimation of Organ Biodistribution of Activities in Human from External Measurement with TLD

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Abstract

Biodistribution due to intravenous administration of F-18-fluorodeoxyglucose (FDG) in positron emission tomography (PET) studies was estimated from external measurement with thermo-luminescence dosimeters (TLDs) attached on the body surfaces of normal volunteers. The cumulated activities in nine source organs, brain, heart, lung, liver, kidney, pancreas, spleen, bladder and remainder of the body, were estimated by the unfolding method from the body surface dose measured with the TLDs. Cumulated activities thus obtained well agreed with those obtained with the direct measurements by PET. The TLD method will greatly contribute to internal dosimetry of patients because of its easy-handling.

Introduction

Internal dosimetry resulting from nuclear medicine is important in comparing the benefit of a procedure with its potential risk. The estimation of internal dose due to intake of radioisotopes has been established by the MIRD method. In the MIRD method, the doses absorbed in target organs are estimated from cumulated activities in source organs. The information on cumulated activities has been obtained for some specific organs necessary for nuclear medicine directly by PET, but is very scarce for other source organs in human. Organ biodistribution of cumulated activities usually has been measured in animals and extended to human, despite of the metabolic difference.

Here in this study, we developed a new method to estimate the biodistribution of radioactivities, which are injected into patient in nuclear medicine procedures from external exposure measurement with TLDs. In this method, a number of TLDs are attached on patient's body surface close to source organs to obtain the information on body surface doses. The organ biodistribution of radioactivities can be obtained from the surface doses by the inverse transform method coupled with the radiation transmission factor calculated with an aid of a mathematical phantom.

This new method has great advantages that cumulated activities in several organs can be obtained easily with a single procedure, and the measurements of body surface doses are

simultaneously done with the PET study, since TLDs are too small to interrupt other medical measurements. The measurements of body surface doses were done in clinical PET studies with F-18-FDG performed at the Cyclotron and Radioisotope Center (CYRIC) of Tohoku University.

Materials and Methods

In our TLD method, the absorbed dose on a body surface is given by

$$C_i = R_{i,1} X_1 + R_{i,2} X_2 + \cdots = \sum_j R_{i,j} X_j , \quad (1)$$

where C_i is the absorbed dose at i-th TLD position, X_j the integrated activity of j-th source organ during the TLD attachment on the body surface and R_{ij} the absorbed dose at i-th TLD position per unit cumulated activity of j-th source organ. This equation can be expressed as a matrix equation,

$$C = R \cdot X. \quad (2)$$

The C-vector can be obtained from the TLD measurements and the R-matrix can be calculated by using the MIRD mathematical phantom, so that one can obtain the X-vector by performing the inverse transform of the above matrix equation.

A pair of TLDs of $CaSO_4$(Tm) were attached at nine points on a body surface just above brain, thyroid, heart, left and right lungs, liver, left kidney, spleen and bladder which were regularly selected in the PET study. Figure 1 shows the TLD positions in the framework of MIRD phantom, together with their Cartesian coordinates and nearby source organs. Eight organs were selected as source organs, i.e., brain, heart, lungs, liver, kidneys, pancreas, spleen and bladder which are already known as organs which accumulate F-18-FDG by Mejia et al. [1] The remainder part of the body was treated as a single source organ in which radioactivity was uniformly distributed. Then in total, nine regions were considered as the source organs in this study. Nine values of TLD doses, C_i, determine nine values of organ activities, X_j, by unfolding Eq. (1).

Calculations of the R component, R_{ij}, are done by the VADMAP code [2] based on the point kernel method with the MIRD mathematical phantom composed of water. The lung is assumed to be composed of water whose density is 0.3. From the measured body-surface doses at nine points, C_i, and the calculated response of body-surface dose at each position per unit cumulated activities, R_{ij}, cumulated activities in nine source organs can be unfolded by the slightly modified SAND-II code [3] based on the successive iterative method. This unfolding is practiced under the constraint condition that the sum of cumulated activity in each source organ must be equal to the total accumulation of administered activity as follows,

$$X_{total} = X_1 + X_2 + X_3 + \ldots$$

$$= \int_0^t A_0 \exp(-\lambda t)\, dt \ , \qquad (3)$$

where A_0 is the injected activity, λ the decay constant of F-18 and t the measuring time period.

Results and Discussion

The TLD measurements of body-surface dose were done for 7 normal volunteers. Five volunteers were measured for 1 hour after administration of F-18-FDG and two patients were measured for 2 hours after that. The measured data of C_i were converted to the cumulated activities in source organs by the modified SAND-II unfolding code. As the TLD measurements could be done only during the course of clinical PET procedure, the estimation of the cumulated activities was also possible only for that period. The contribution of residual cumulated activities after the TLD measurement can be estimated, assuming that a biological clearance is negligible and only physical decay dominates.

Figure 2 shows the correlation of the present results of cumulated activities given by the TLD method and those by the direct PET measurements. (1) Generally speaking, good correlation can be seen between our TLD method and the PET reference values except for kidney and brain. The discrepancy on the brain activity may be due to inhomogeneous distribution of activity in the brain, and that on the kidney activity may come from a large difference of physique between the MIRD phantom and each individual, since the distance from the seventh TLD position to the kidney was largest among all as seen in Fig. 1.

It can be concluded that the new method to estimate the organ biodistribution in human from the surface dose measured with TLDs gives sufficiently good results considering experimental errors. This TLD method has great advantages that cumulated activities in numbers of human organs can be estimated very easily at once, and that the TLD measurements can be done simultaneously with medical study without interrupting it.

References

1) Mejia A. A. et al., J. Nucl. Med., 32(1991)699-706.
2) Yamaguchi Y., Togawa O. and Honma T., JAERI M(1987)87-186.
3) McElroy W. N. et al., AFWL-TR-67-41(1967).

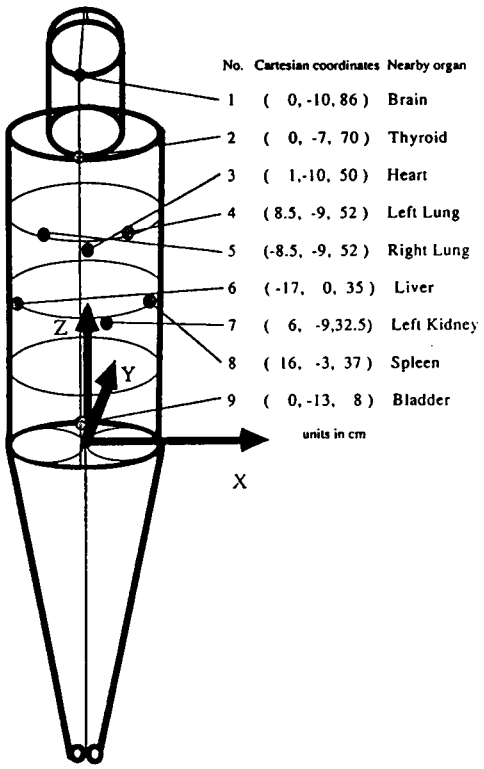

Fig. 1. Detection positions of body surface dose with TLDs which are adjusted to MIRD mathematical phantom. The figure also indicates their Cartesian coordinates and nearby source organs

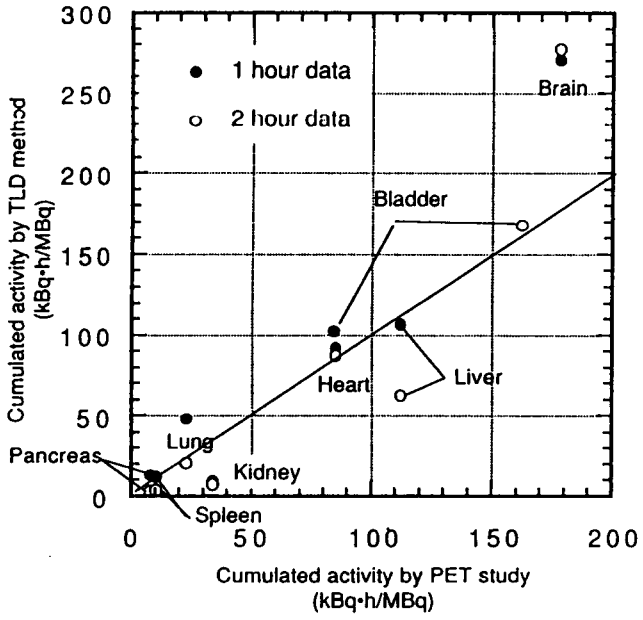

Fig. 2. Correlation between cumulated activities of source organs in kBq.h per MBq F-18-FDG injection estimated from the TLD method and those from the PET method as a reference.