V. 1. An External Approach for Organ Biodistribution and Dose Estimation due to Intake of Radiopharmaceuticals by IP and TLD

Deloar H. M., Yamadera A., Nakamura T., Fujiwara T., Itoh, M.
Cyclotron and Radioisotope Center, Tohoku University

Introduction

In the nuclear medicine procedure internal dose estimation due to intake of the radioisotope has been established by the MIRD committee of the Society of the Nuclear Medicine. Matsumoto et al. 2, have developed a new method to estimate the cumulated activities in source organs from external measurement with TLD (Thermo-Luminescent Dosimeter) during PET study, by coupling with the mathematical unfolding analysis.

In our present study the same method was applied to a simultaneous external measurement with IP (Imaging Plate) and TLD which were attached on the body surface close to the source organs. In diagnostic radiography the application of IP is increasing as a more sensitive image sensor than the conventional X-ray film. We tried to use IP having much higher sensitivity and larger sensitive zone than TLD for this internal dosimetry. But IP has highly increasing sensitivity with decreasing energy, while TLD has rather flat energy response, then we compared both results obtained by IP and TLD. Using these obtained results, the absorbed doses in the target organs were estimated with the MIRD method.

Material and Methods

IP (BAS-UR, Fuji Photo Film Co. Ltd.) and TLD of BeO (UD-170A, Matsushita Electric Co., Ltd) have been used for the experiment. During the PET study both IP and TLD were placed at nine positions together on the skin surface of the subject as shown in Figure 1. Nine positions were selected to be close to nine organs. 20 mCi of $^{11}$C labeled radiopharmaceutical (benzotropin) was injected intravenously for the PET study. During the experiment both IP and TLD were exposed by the internal radiation. In order to get the absorbed dose in mSv from the measured value of IP and TLD, the conversion factor of PSL(Photo-Stimulated Luminescence)/mm$^2$ to mSv and the TLD reader calibration factor must be known. These factors were obtained with the measurement of a 13mCi $^{18}$F point
source and water absorber. Since IP has non-uniform response, differently from TLD, the conversion factor PSL/(mm)$^2$ per mSv must change with photon energy.

In our present approach we have used the conversion factor of 836 mSv per PSL/mm$^2$ for 511 KeV gamma rays of $^{18}$F, without absorber, as the first approximation.

**Dose Calculation**

In the dose calculation by the MIRD method, the absorbed dose $D_i$ in i-th target organ is expressed by a sum of contributions from several source organs as follows;

$$D_i = \sum_j S_{ij} A_j,$$  \hspace{1cm} (1)

where $A_j$ is the cumulated activity in the j-th source organ. In this study the target organ is replaced by the IP and TLD position as

$$C_i = \sum_j R_{ij} X_j,$$  \hspace{1cm} (2)

where $C_i$ is the absorbed dose measured at the i-th IP and TLD position, $X_j$ is the integrated activity in the j-th source organ during IP and TLD attachment on the body surface and $R_{ij}$ absorbed dose at the i-th position per unit cumulated activity in j-th source organ. The $R$ value of IP and TLD for each position was calculated by the VADMAP simulation code$^3$ in which the MIRD mathematical phantom models the geometry of human organs. The cumulated activity of the source organ, $X_j$ was obtained from Eq. 2 using the SAND-II unfolding code$^4$ based on successive iteration method.

After IP and TLD measurement the contribution of residual cumulated activities was estimated by assuming only a physical decay without a biological clearance, and the cumulated activity of each source organ $A_j$ was finally estimated. The absorbed doses of the target organs only for gamma ray were calculated from Eq. (1) using the IDES code$^5$.

The effective dose equivalent can be estimated from the following equation

$$H_E = \sum_i w_i H_i = \sum_i w_i D_i$$  \hspace{1cm} (3)

where $w_i$ is the organ weighting factor given by ICRP 60, and $H_i$ is the organ dose equivalent.

**Result and Discussion**

Figures 2 and 3 show the absorbed dose C obtained at nine positions and the cumulated activities A for eight source organs excluding the remainder of the body, respectively. The figures clearly show that the results obtained by IP are higher than those by TLD, except brain. This difference mainly comes from the conversion factor, PSL/mm$^2$ per mSv, of IP used in this study. The present value was obtained for 511 KeV gamma rays, but
the exact conversion factor must be a larger value, since the gamma ray energy becomes lower on the body surface after penetration through a body and the IP sensitivity becomes higher for lower energy. The use of the proper conversion factor considering the energy dependence may give better agreement of cumulated activities obtained by IP with those by TLD. Figure 4 shows the absorbed doses of target organs obtained by IP and TLD. Both data give good agreement in general tendency, although the absolute values are larger for IP than for TLD. Pancreas, spleen, heart-wall, kidney and bladder give higher dose in this descending order. The effective dose equivalent estimated by IP is 1.75E-02(mSv/MBq) and by TLD is 1.45E-02(mSv/MBq). Generally speaking, the internal dose values given by IP and TLD indicate good agreement.

References


Fig. 1. Schematic diagram of the MIRD mathematical phantom and the positions of IP and TLD attachment on the body surface, together with the Cartesian coordinates.
Fig. 2. Absorbed doses at nine positions on the body surface obtained by IP and TLD.

Fig. 3. Cumulated activities of eight source organs estimated by IP and TLD.
Fig. 4. Absorbed doses for various target organs estimated by IP and TLD.