V. 4 Internal Dosimetry from Intakes of Radionuclides in Nuclear Medicine: A Preliminary Report

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Introduction

Nuclear Medicine procedures involve the use of radionuclides emitting ionizing radiation, and one of the more limiting factors in Nuclear Medicine is the absorbed dose because this always can carry a certain risk, even if the risk for a particular examination is small.¹) The radiation emitted by these radionuclides are absorbed by organs and tissues of the body, and the magnitude of the resulting absorbed dose depends on several factors which include the amount of radioactive material administered, its biokinetics and the decay scheme of the radionuclide. Of this three factors the second is the more difficult to determine, and the lack of radiopharmaceuticals biokinetics data has substantially limited the calculation of absorbed dose estimates from radiopharmaceuticals used in clinical nuclear medicine. For many radiopharmaceuticals the information concerning the biokinetics in total body and individual organ is mainly based on animal experiments since respective measurements in man have as yet hardly been performed. Some comparison of biokinetic data for radiopharmaceuticals for which comparatively complete biokinetic data from investigations in animals and man exist suggested that an extrapolation of cumulated retention from animal via body weight to man is barely possible.²) And hence, because there are difference in metabolism between human and animals, the presents available method is not valid in strict sense. Therefore measurements of biokinetic data and biological distribution of radiopharmaceuticals in human is necessary for a realistic calculation of absorbed dose in man.

Positron Emission Computerized Tomography (PET) constitute a potential tool for in vivo quantitation of the distribution of radiopharmaceuticals and determination of radionuclides concentration. An important attribute of PET is the ability to yield accurately the regional in vivo concentration of a radionuclide within an organ.³) This capability permits Positron Emission Tomography to be employed for: the quantitative uptake of radionuclides in region of interest, and the accurate determination for dosimetry purpose of the time course of a radiopharmaceutical through a specific organ.

Methods and Materials

In this study the estimation of absorbed dose for radiopharmaceuticals in
common use in human PET studies will be performed using for this purpose the data obtained from the PET scan of an organ under clinical study. This data is suitable for to get the activity retention function of that organ for the radiopharmaceutical utilized. The activity values are obtained from sequential PET scans of the region of interest (organ or tissue) during a fixed acquisition time. This data (number of counts) is decay-corrected to injection time. The activity values in μCi/g are calculated using a calibration factor between PET scanner, Curiometer and Well Counter. All the data already taken for normal volunteers is available for this study, and also blood activity data and the activity excreted in urine, saliva, tear, etc., that is utilized for evaluation of the total body excretion function. The organ volume will be estimated using CT images. The retention function obtained by this method are incorporate in a computer program code (PIEDEC) in the form of subprograms. The internal dose calculation will be done using this computer program code, which can calculate the total numbers of transformations in sources organs and the total body. The PIEDEC code has been developed for the application of the ICRP30 to the internal dose-equivalent evaluation. The program has been modifying and will include the transformations of SAF (specific absorbed fraction) values for Japanese physical, and also for different age.

Results and Discussion

At the present time we are analyzing the data already acquired for normal volunteers and obtaining new data for several organs and radiopharmaceuticals. Figures 1, 2, 3 and 4 show typicals time activity curves obtained for lung, brain, heart and blood respectively for 18F-FDG. The activity is expressed as percentage of injected activity per gram. In the case of brain and heart the curves were fitted by a fitting computer program to the function

$$A = \sum_{i=1}^{n} A_i (1 - e^{-k_i t})$$

for two components. The respective values are shown in Table 1.

The blood activity clearance curve was approximated by three components with half-live of 1.17 min, 5.5 min and 87 min, for the major, second and third component respectively. These values were very similar to that obtained by Phelp et al. (1978). Only the value of the second component was a little low. The major portion of the fast component probably result from the dilution of the injected FDG in the total blood pool and extraction by highly perfused tissues before equilibration is established, and the remaining clearance is due to continued metabolic extraction and also to clearance by the kidney. (These three components should not be taken as three compartments).

Table 2 shows the values of the time integral of activity for an administration of 1 μCi, and the radiation dose due only to the activity
accumulated in the organ. This values were obtained using the MIRD method. The formula used to calculate the dose in rads is

\[ D_i = S_{i+1} + \tilde{A}_i. \]

The \( S'^{9} \) values were calculated from specific absorbed fractions\(^{10} \), equilibrium dose constants\(^{11} \), and masses.\(^{10} \)

References

5) Iwai S., Private Communication.

<table>
<thead>
<tr>
<th>Organ</th>
<th>( A_1(%) )</th>
<th>( A_2(%) )</th>
<th>( k_1(\text{min}^{-1}) )</th>
<th>( k_2(\text{min}^{-1}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>0.73</td>
<td>0.39</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Brain</td>
<td>3.59</td>
<td>4.18</td>
<td>1.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Heart</td>
<td>0.87</td>
<td>0.69</td>
<td>2.34</td>
<td>0.05</td>
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</table>
Table 2. Radiation dose from target organ.

<table>
<thead>
<tr>
<th>Target Organ</th>
<th>Cumulated Activity* (μCi-hr)</th>
<th>Radiation Dose (mrad/mCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lungs</td>
<td>11.5</td>
<td>28.0</td>
</tr>
<tr>
<td>Brain</td>
<td>194.7</td>
<td>149.3</td>
</tr>
<tr>
<td>Heart Wall</td>
<td>38.7</td>
<td>36.2</td>
</tr>
</tbody>
</table>

* For injection of 1 mCi.

Fig. 1. Time activity curve for lung (18F-FDG).

Fig. 2. Time activity curve for brain (18F-FDG).
Fig. 3. Time activity curve for heart (18F-FDG).

Fig. 4. Activity clearance of 18F-FDG from blood.