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Assessment of Patient Dose by Positron Emission Tomography (PET) and Medical Internal Dose (MIRD) Methods

G. Yilmaz[a], A.B. Tugrul[a,*], M. Demir[b], D. Yasar[c] and B. Demir[d]

[a]Istanbul Technical University, Energy Institute, Nuclear Researches Division, ITU Ayazaga Campus, 34469, Sariyer, Istanbul, Turkey

[b]Istanbul University, Department of Nuclear Medicine at Istanbul University, Cerrahpasa Faculty of Medicine, Cerrahpasa Istanbul, Turkey

[c]Cekmece Nuclear Research and Training Center — Turkish Atomic Energy Authority, Cekmece, Istanbul, Turkey

[d]Physics Department of Science Faculty, Istanbul University, Vezneciler Istanbul, Turkey

Dynamic experiments cannot be observed easy on patients for determination of dosimetry in human PET studies dosimeter studies. In this study, it is aimed to estimate dose amount absorbed by some critical organs (e.g. bladder, lung, thyroid and ovary) by using a developed phantom. The phantom was improved as an original anthropomorphic whole body phantom which has been arranged with dynamic system. Therefore, organ absorbed doses by applying of fluorine-18-fluorodeoxyglucose in PET studies and was observed by using the phantom, while TLD dosimeters were used for determination of internal absorbed doses. In medical physics, the accuracy of absorbed dose resulting from radiopharmaceutical application was determined by the medical internal radiation dose method that depends theoretically on the cumulated activity of the source organs and their mass. The MIRD calculation was also used for the study and comparatively evaluated with the experimental results which were collected by using improved phantom.

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1. Introduction

PET is an important radioisotope imaging method for obtaining information by functional imaging technique that produces a three-dimensional image of functional processes in the body. PET is applied as the philosophy of radiotracer technique for medical diagnosis purposes and three-dimensional image of functional processes in the body can be obtained by this method [1]. Therefore, a short-lived radioactive tracer isotope is injected into the blood and it is chemically incorporated into a biologically active molecule. After waiting period while the active molecule becomes concentrated in tissues of interest, the patient is placed in the imaging scanner and image is obtained by using appropriate gamma cameras. F-18 fluorodeoxyglucose (FDG) is the most frequently used radiopharmaceutical material in PET imaging. During the scan a record of tissue concentration is made as the tracer decays and F-18 can affect the organs (e.g. bladder, lung, thyroid and ovary) [2]. The fluorine-18 can be excreted from the body through urination system [3].

F-18 is a most important positron emitter and electron–positron annihilations causes in two 511 keV gamma photons. Hence, it is possible to localize their source along a straight line of coincidence. This method has been based on coincidence detection of 511 keV energized annihilation photons.

Estimation of absorbed dose for humans in PET studies is an important dosimetric subject in the point of medical physics [4–6]. This study was aimed to assess the dosage in patients during PET applications, but it is hard directly to be observed from patients. Therefore, it was preferred using phanthoms with simulation of the patient to evaluate the absorbed doses [7–9].

2. Experimental

An original anthropomorphic phantom that could be arranged with dynamic system for the simulation of the bladder rejection was used in the experiments. Moreover,

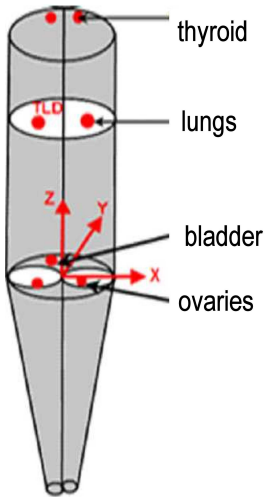

Fig. 1. TLD position in the phantom.

*corresponding author; e-mail: beril@itu.edu.tr

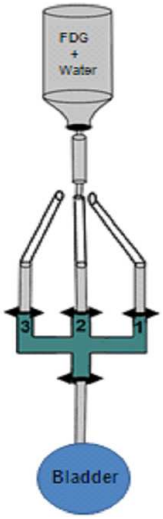

Fig. 2. Dynamic bladder system for three different cases in phantom.

discharge can be observed for three different discharging simulations as slow, medium and fast velocity (called as Model 1, Model 2, and Model 3). Therefore, three different cases could be observed in the experiments. Thermoluminescent dosimeters (TLDs) were placed in the phantom for determination of absorbed doses for bladder, lung, thyroid and ovary. Figure 1 shows the TLD position in the phantom and Fig. 2 shows the dynamic bladder system that was placed in the phantom.

T-100 powder for TLD dosimeters were used to measure the absorbed dose [10]. The used TLDs were prepared using Cs-137 calibration at the Turkish Atomic Energy Authority (TAEA) — Cekmece Nuclear Research and Training Centre (CNRTC) SSDL (Secondary Standard Dosimetry Laboratory).

3. MIRD method

In nuclear medicine, the accuracy of absorbed dose of an internally distributed radiopharmaceutical estimated by the MIRD method depends on the cumulative activity of the source organs and their mass [10–13]. Calculation of the dose results that were obtained through the performed experiments, was made via MIRD method as follows:

$$\bar{D}(r_k \leftarrow r_h) = \frac{1}{m_k} \sum_h \tilde{A}_h \sum_i \phi_i(r_k \leftarrow r_h) \Delta_i, \tag{1}$$

$$\bar{D}(r_k \leftarrow r_h) = \frac{\tilde{A}_h}{m_k} \sum_i \phi_i(r_k \leftarrow r_h) \Delta_i = \tilde{A}_h \sum_i \Phi_i(r_k \leftarrow r_h) \Delta_i, \tag{2}$$

where m_k is mass of target organ (g), $\tilde{A}_h$ — cumulative source organ activity (μCi-sa), r_k — target organ, r_h — source organ, Δ_i represents the total radiation energy emitted by the i-th radioisotope [5, 13, 14].

The definition of the S-value is

$$S(r_k \leftarrow r_h) = \sum_i \Phi_i(r_k \leftarrow r_h) \Delta_i.$$

The dose absorbed at the target organ is

$$\bar{D}(r_k \leftarrow r_h) = \tilde{A}_h \cdot S(r_k \leftarrow r_h),$$

$$\bar{D}(r_k \leftarrow r_h) = \sum_h \bar{D}(r_k \leftarrow r_h),$$

$$\bar{D}(r_k \leftarrow r_h) = \sum_i \tilde{A}_h S(r_k \leftarrow r_h),$$

where S is the absorbed dose per activity (rad/μCi-sa), $\bar{D}$ is the absorbed dose (rad). For calculations, the activity accumulated in the target organ $\tilde{A}_m$ is calculated as

$$\tilde{A}_m = 1.44 T_e A_0,$$

where T_e is effective half-life of the radioisotope, A_0 represents the initial activity that is 20 mCi in the experiments. The absorbed dose (rad) is $\bar{D}$ and can be calculated as follows:

$$\overline{D}_m = \tilde{A}_m \cdot S_{(m \leftarrow m)} + \tilde{A}_{ak} \cdot S_{(m \leftarrow ak)} + \tilde{A}_{ov} \cdot S_{(m \leftarrow ov)} + \tilde{A}_{tr} \cdot S_{(m \leftarrow tr)}.$$

In the study, accumulated doses for target organs (bladder, lung, ovary, and thyroid) were calculated in a similar way.

Apart from experimental studies, dose calculations were also conducted for the PET using the MIRD method. Dose calculation using the MIRD method can be carried out as excreted organs which are available in MIRD tables [7, 8].

4. Results and discussion

Experimental results by using phantom that were reached with the study and doses (for Model 1, Model 2 and Model 3) can be seen in Fig. 3 with comparison of MIRD calculation results.

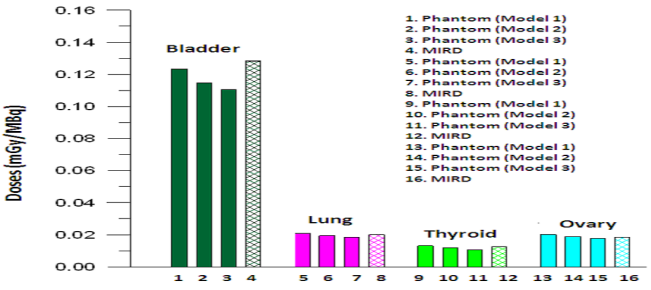

Fig. 3. Comparisons of experimental and MIRD results.

5. Conclusion

The results of experimental studies by using original anthropomorphic whole body phantom showed that the doses of the accumulated bladder are highest than the other organ doses. In the results of the experiments, Model 1 (slow velocity case) for all organs, doses are

greater than in the other cases. Inversely, Model 2 (fast velocity case) doses are smaller than the others. Therefore, decharge of the bladder is important and it can be said that working rate of metabolism in the body affected on cumulative doses. If the metabolism is slow, then the absorbed dose is higher than the others (Fig. 3). This means that patients should drink much water with diuretic pharmasotics.

The MIRD method was used to calculate the cumulative dose for four different organs and the results obtained were significantly close to experimental results. In other words, calculations reached by using the MIRD method were in compliance with experimental results.

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