

Determination and Comparison of Absorbed dose of Ovaries and Uterus in Heart Scan from TC-99 m, by Three Methods: TLD Measurement, MCNP Simulation and MIRD Calculation and Estimation of its Risks

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Abstract: Relation to high absorption fraction of Tc sestamibi by kidneys in heart scan and these organs are near to generation organs (Ovaries and uterus). Urinary system (kidneys and urinary bladder) are specified as sources organs. The main object of this study is to determine the absorbed dose in these critical organs. we have set amount of absorbed fraction radiopharmaceutical in position of kidneys and Urinary bladder in Rando phantom in form of elliptical surfaces, then absorbed dose to ovaries and uterus measured by TLD-100 that had set at position of these organs in Rando phantom. Results from ORNL phantom MIRD calculation TLD measurement and Rando phantom simulation (MCNP) are comprised. The absorbed dose to uterus and ovaries from urinary system for Rest are 0.139, 0.242 $\mu\text{Sv}/\text{MBq}$ and for Stress state are 0.105, 0.182 $\mu\text{Sv}/\text{MBq}$, respectively.

Keywords: Absorbed dose, MCNP, MIRD, rando phantom, Tc-99m, TLD

INTRODUCTION

In nuclear medicine applications, scintigraphic studies have been applied to the different organs such as liver, spleen, heart, kidneys, bone, lung, thyroid, lymph glands and etc UNSCEAR (1993). The absorbed dose levels for the critical organs are always high, during the therapeutic irradiation. Although the absorbed dose levels by critical organs during the scintigraphic application are lower than the therapeutic dose levels, their evaluation may be also considered important. Heart scan is the most common scan between all of scans in nuclear medicine. In heart scan, among various organs, kidneys and intestines adsorb the highest amount of radiopharmaceutical. Relation to high absorption fraction of Tc sestamibi by kidneys in heart scan and these organs are near to generation organs (Ovaries and uterus). These organs are near to the generation organs (ovaries and uterus); in research kidneys and urinary bladder (urinary system) are specified as sources organs. The female generation organs have been chosen as the critical organs, because they are the most sensitive organs for the genetic and somatic effects (Cember, 1992). The main object of this study is to determine the absorbed dose in these critical organs. Especially for the scintigraphic applications, those are important in nuclear medicine.

MATERIALS AND METHODS

Radiopharmaceutical: Although many different radionuclides were used in the past for the diagnostic purpose, now the mostly used radionuclides are TC-99m

and I-131. as a rule the dose per application is less for TC-99m which has a shorter half-life. So it is used preferably which explains why it is used in the majority of cases. In this study we also used TC-99m for this experimental study. Radiopharmaceuticals are radioactive pharmaceutical agents or drugs used for diagnostic or therapeutic procedures (Ricard, 1995). The use of technetium isotopes in both medicine and metallurgy has recently stimulated interest in the metabolic behavior of this element following the intake into body. TC-99m that decays by isomeric transition and has a half-life 6.02 h has found widespread use in biology and medicine both as a tracer and as a diagnostic tool in nuclear medicine (Ronald, 1995).

Rando-phantom: For this experiment a Rando-phantom is used, which is made natural male and female skeletons and tissue-equivalent materials (Ricard, 1995). The phantoms are transected at 2.5 cm intervals. An average female phantom corresponds to full body length of 163 cm and body weight 54 Kg soft tissue. The plastic used in the phantom has an effective atomic number of 7.3 and density of 0.985 g/cm³ (Golikov and Nikitin, 1989). The anthropomorphic phantom has some holes in these slices for placing of the dosimeters. It contains a representation of all organs. The phantom consists of 36 separated slices, each slice has holes drilled on 1.5×1.5 cm grid for holding dosimeters and unused holes are filled with tissue-equivalent plugs (Nariyama *et al.*, 1995).

Dosimeter: Very few detectors can be used to measure absorbed dose directly. In vivo dose measurements are

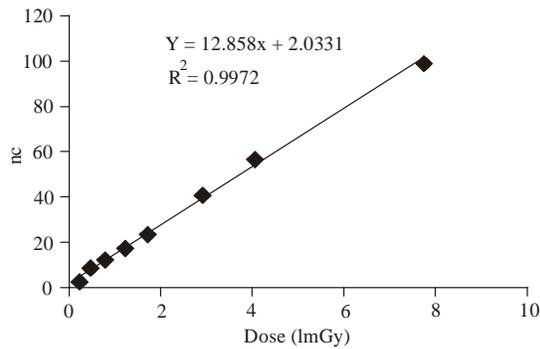


Fig. 1: Calibration plot of TLDs dosimeters

actually indirect processes. There are two general requirements for accurate dose measurements:

- The detector must respond reliably and reproducibly to the radiation field of interest (good sensitivity, stability) and background characteristics.
- The user must make a correct inference of the absorbed dose from the measured response.

The conditions of in vivo measurements lead to the further requirements of small physical size, high sensitivity, a response that is independent of photon energy, exposure geometry and the ability to function in vivo without endangering host (NCRP83, 1985). TLDs have proved to be a useful technique for a variety of purposes in radiation protection (Kinalay, 1980). It can detect a wide range of the radiation exposures. The phosphors used in this study were LiF (TLD-100), (3.1×3.1×0.9 mm) chips. All the chips were produced from the same batch. We chose TLD-100 because it is widely used in low-dose dosimetry, due to its high sensitivity and it is available for us.

Calibration: For calibration, TLDs-100 are annealed at temperature of 400°C for 1 h and then set at 105° C for 20 h to ensure that the saving energy in them is extracted. In interval between different stages such as processing, annealing and exposure, all of dosimeters putted in regions that safe for UV and temperature fewer than 30°C. Dosimetry performed by TLD reader system model of 4500 Harshaw. Calibration curve was plotted for various exposures using a standard phantom and a standard source of Cs-137. Relation to different photon energy of Cs-137 and Tc-99 m for TLD-100 we used a correction factor (Fig. 1).

Experimental procedure: The radiopharmaceutical injected to the patients for heart scan purposes. It is accumulated in kidneys and intestine. In this study kidneys and Urinary bladder were chosen as source organs the ovaries and uterus were defined as target

Table 1: The activity placing parameters for kidneys and urinary bladder

Organ simulation	Slice number of rando-phantom	Size of organ region for each slice (cm ²)	Activity rate (%)
Left kidney	21	2.04	6
	22	9.31	27
	23	11.78	34
	24	9.31	27
	25	2.04	6
Right kidney	22	2.04	6
	23	9.31	27
	24	11.78	34
	25	9.31	27
	26	2.04	6
Urinary bladder	31	53.83	68
	32	25.67	32

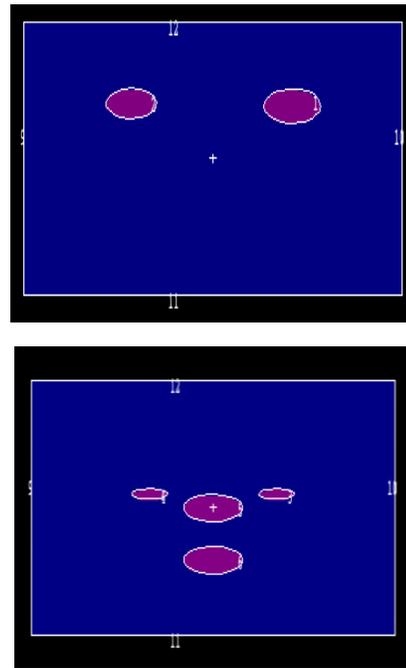


Fig. 2: Kidneys in left picture and ovaries, urinary bladder and uterus in right picture in a female rando-phantom simulated in MCNP4C

organs. The measurements were made with TLDs inside a female Rando-phantom. First, the size and the placement of source organs, were determined using the corresponding slice numbers given in the literature on the anthropomorphic phantom (Lanzl, 1973). Afterwards, the portion of source organs within each slice has been calculated. Detailed information is given in Table 1 corresponding radionuclide activities were absorbed in absorbent tissue paper that had cut in form of elliptical surfaces to simulate kidneys and Urinary bladder uniformly as possible and placed into plastic bags in order to prevent contamination Rando phantom. Finally they were placed among the slices of Rando-phantom. Each plastic bag with the active solution was placed between the slices, so that shapes and dimensions of the kidneys and Urinary bladder were simulated (Dogan and Tugrul,

2003). The detector TLDs (TLD-100) were placed in the target organs (ovaries and uterus) in Rando-phantom. Thirty seven TLDs had placed in ovaries and uterus and then, reading had performed by reader system model of 4500 Harshaw, The dose that have saved in TLDs were determined.

MCNP simulation: This code have an input file that, it consist of comment lines that called cards. These cards consist of cell, surface, data cards. In these cards, geometry, using materials, position and properties of neutron, electron or photon sources are defined (Briesmeister, 1993).

In this study we simulated Rando phantom by MCNP code. In this study we simulated kidneys, uterus, ovaries and urinary bladder attention to theirs size and theirs positions in Rando phantom that determined by direct measurement in Rando phantom (Fig. 2).

The calculation with mird method: The dose is calculated by using method that adopted by MIRD committee of the society of nuclear medicine as follow, the absorbed dose $D(r_k \leftarrow r_h)$ expressed in rads to a target organ (r_k) from a radionuclide distributed uniformly in a source organ (r_h) has been formulated by MIRD committee (Stabin, 1996). The MIRD formula has reduced the number of assumption necessary to perform dosimetry calculation over that required by the classic expression of dosimetry, MIRD formula presupposes that the source is uniformly distributed within a standard size organ, which is subject to much patient variation (UNSCEAR, 1982):

$$D(r_k \leftarrow r_h) = A_h \tau S(r_k \leftarrow r_h)$$

where, A_h (μci) is the cumulated activity in source organ, τ is residue time and where computer calculations of $S(r_k \leftarrow r_h)$ ($\text{rad } \mu\text{ci}^{-1} \text{h}^{-1}$) have been tabulated. The $S(r_k \leftarrow r_h)$ values are based upon the assumptions that radioactivity is uniformly distributed throughout the source organ. $S(r_k \leftarrow r_h)$ values of ovaries and uterus for source organ that kidneys, bladder are given in Table 2 and 3.

Absorbed dose values of ovaries and uterus were calculated for source organs which kidneys and urinary bladder for maximum activity (1110MBq) that used in Heart scans and effective half life. The results are given in Table 4 and 5.

RESULTS AND DISCUSSION

Although, it is essentially impossible to measure the radiation received by a particular patient, it is possible to calculate the absorbed dose for various organs of a standard man, this study was conducted in order to measure the absorbed dose, placing TLDs in a phantom in this experimental setup, both the source of activity and measuring TLDs were located in the phantom at regions corresponding to kidneys, urinary bladder, ovaries and uterus, Generally the study encountered in the literature only one of the two parties involved in the experiment (either radiation source, or the detector) is in contact with the phantom. Thus this study is both realistic and original from this point view. These measurements were performed for maximum activity injected to patient (1110MBq). The results are in agreement with each other and the difference between experimental and calculation methods are acceptable. The measured doses are generally higher than the calculated absorbed dose for ovaries. The reason for this is following: the experiment is realistic and covers all the environmental scattering effects, where no scattering calculation in MIRD method is performed consequently, in MCNP simulation, we ignored from ovarian fossa that have important scattering effect on TLD measurement. An original and realistic experimental arrangement is applied by using elliptical plane sources between the Rando- phantom slices and then non accuracy in distribution of activities in plane and non accuracy in determination position of ovaries in slice of Rando phantom and then the results are reliable, which can be shown the comparison of the MIRD calculations MCNP simulation, ORNL phantom simulation. Difference between theirs size causes difference results.

CONCLUSION

In this study, the evaluation of absorbed dose for the critical organ is made with an original setup and results for experimental and theoretical evaluated for nuclear

Table 2: S factor (rad/ $\mu\text{ci}\cdot\text{h}$) for Tc-99 m when source is kidneys

Method	Ovaries	Uterus
TLD measurement	7.130×10^{-7}	3.826×10^{-7}
MIRD method	7.56×10^{-7}	5.412×10^{-7}
MCNP simulation	6.24×10^{-7}	4.451×10^{-7}

Table 3: S factor (rad/ $\mu\text{ci}\cdot\text{h}$) for Tc-99m when source is urinary bladder

Method	Ovaries	Uterus
TLD measurement	2.38×10^{-5}	2.18×10^{-6}
MIRD method	2.471×10^{-5}	2.271×10^{-6}
MCNP simulation	2.479×10^{-5}	1.625×10^{-6}

Table 4: Absorbed dose (μSv) for 1110 MBq activity to ovaries from urinary system

Method	Rest	Stress
TLD measurement	268.90	202.50
MIRD method	275.00	209.00
MCNP simulation	249.92	192.01

Table 5: Absorbed dose (μSv) for 1110 MBq activity to uterus from urinary system

Method	Rest	Stress
TLD measurement	154.7	116.2
MIRD method	222.8	171.6
MCNP simulation	170.9	130.9

medicine applications were compared. In these original and realistic experimental arrangements the radioisotopes and TLDs were placed in the anthropomorphic phantom as, encountered in the scintigraphic applications of nuclear medicine. In generally other experiments, only one of them is in contact with the Rando-phantom directly. Cumulated dose of ovaries are about (0.471 mSv) for maximum activity (1110Mbq) for two stages from urinary system. The ovaries are sensitive organs doses as low as 1.5-6.4 Sv have been recorded as causing temporary sterility (Thomas and Walden, 2000). There is no radiation protection problem for the ovaries that is affected with maximum activity of our study.

REFERENCES

- Briesmeister, J., 1993. MCNP-A General Monte Carlo Code N-Particle Transport Code Version 2A. LA-12625-M (section 1). Documentation for CCC-200/MCNP 4A code Package.
- Cember, H., 1992, Introduction to Health Physics. 2nd Edn., Northwestern University, McGraw-Hill, INC, New York.
- Dogan, Y. and A.B. Tugrul, 2003. A comparison of TLD measurements to MIRD estimates of the dose to the testes from Tc-99m in the liver and spleen. *Radiat. Meas.*, 37: 113-118.
- Golikov, V.Y. and V.V. Nikitin, 1989. Estimation of the mean organ doses and the effective dose equivalent from rando phantom measurement. *Health Phys.*, 56(1): 111-115.
- Kinalay, M.C.A.F, 1980. Thermoluminescence Dosimetry. Medical Physics Handbooks, Adam Hilger Ltd., Bristol, Vol. 5.
- Lanzl, L.H., 1973. The Rando-Phantom and its Medical Applications. Department of Radiology, University of Chicago, Illinois, Chicago.
- Nariyama, N., S. Tanaka, Y. Nakane, Y. Namito, H. Hirayama, S. Ban and H. Akashima, 1995. Absorbed dose measurements and calculations in phantom for 1.5 to 50 Kev photons. *Health Phys.*, 68(2): 253-260.
- NCRP83, 1985. The experimental Basis for absorbed dose calculations in medical uses of radionuclids. NCRP Report No.83, National Council on Radiation Protection and Measurements, Bethesda, MD 20814 USA, pp: 109.
- Ricard, A.N., 1995. Radiopharmaceuticals, Principles and Practice of Nuclear Medicine. 2nd Edn., Mosby, St. Louis, pp: 94-117.
- Ronald, J.S., 1995. Biological Effects of Ionizing Radiation, Principles and Practice of Nuclear Medicine. 2nd Edn., pp: 118-129.
- Stabin, M.G., 1996. MIRDOSE, personal computer software for internal dose assessment in nuclear medicine. *J. Nucl. Med.*, 37: 538-546.
- Thomas, L. and J. Walden, 2000. Long Term and Low-Level Effects of Ionizing Radiation: Medical Consequences of Nuclear Warfare. Radiation Biochemistry Department, Armed Forces Radiobiology Research Institute Bethesda, Maryland, pp: 20814-5145.
- UNSCEAR, 1982. United Nations scientific committee on the effect of atomic radiation. Annex G Ionizing Radiation Source and Biological Effects UNSCEAR Report 1982.
- UNSCEAR, 1993. United Nations scientific committee on the effect of atomic radiation. Annex C Source and Effects of Ionizing Radiation UNSCEAR Report 1993.