Determination of Uterus Absorbed Dose by Patients following Myocardial Perfusion Scan using TLD and Conjugate View Methods

Shanei A.[1]*, Heydari F.[2], Moslehi M.[3]

[1]Associate Professor, Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
[2]MSc, Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
[3]Assistant Professor, Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Introduction: The determination of patient's absorbed dose is the first step of radiation protection which depends on the quantification of organ activity in nuclear medicine. The aim of the present study was to determine the absorbed dose by patient's uterus following myocardial perfusion scan with ^{99m}TC-sestamibi using Theroluminescnce dosimetry (TLD) and conjugate-view methods.

Material and Method: In this study, each patient was injected 15 to 20 mCi (based on their weight) of ^{99m}TC-sestamibi. Myocardial perfusion scan from twenty two patients (females) were acquired by gamma camera at 15, 60 and 90 minutes after ^{99m}TC-sestamibi injection. To determine the amount of activity in uterus, conjugate view method was applied on images. Then, MIRD equation was used to estimate absorbed dose in uterus of patients. Moreover, uterus absorbed dose was determined using TLD method. At the end, absorbed dose values obtained in conjugate view method were compared with the data obtained from TLD method.

Results: The average amount of uptake for ^{99m}TC-sestamibi by heart was calculated 3.077±0.067 percent of injected dose. The uterus activity at the intervals of 15, 60 and 90 minutes after injection of ^{99m}TC-sestamibi was 0.044±0.015, 0.031±0.014 and 0.026±0.013 mCi, repectively. The uterus absorbed dose per unit of injected activity (mGy/MBq × 10^{-4}) obtained 5.258±0.500 using TLD method.

Conclusion: The results of this study were in good agreement with similar studies. Dosimetry using TLD, in comparison with the conjugate view method, demonstrates more accurate results.

Keywords

Myocardial Perfusion Scan, Absorbed Dose, Conjugated-view Method, Thermoluminescence Dosimetry, Uterus

Introduction

The radiation dose estimation is the basis for the use of radiopharmaceuticals in nuclear medicine, and it is also the first step in protection against radiation. For example, in therapeutic applications of radiopharmaceuticals, it is necessary to assess the absorbed dose in the tumor and normal tissues to choose the most appropriate treatment protocol, maintaining doses to vital organs at safe levels [1].

It is important to state that the organ dose evaluation deeply depends

*Corresponding author:
A. Shanei
Associate Professor, Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
E-mail: shanei@med.mui.ac.ir

Received: 13 May 2016
Accepted: 27 August 2016

on the activity quantification of that organ [2, 3]. The standard method for the quantification of activity in an organ is the conjugate view method, in which generally one anterior and one posterior image are acquired, and region of interests (ROIs) are manually drawn over the organs of interest [4, 5]. However, the determination of activity using a conjugated-view method in scintigraphic imaging may be inaccurate [5] because the activity does not only spread in the organ, but also in its adjacent tissues and the blood stream [5]. This phenomenon leads to higher estimates of activity in the organ. In this case, several corrections need to be done [6, 7].

In MIRD method, the dose absorbed in the target organs are estimated as a function of activities accumulated in the source organ, and it provides a generally correct mathematical estimate dose [8].

Theroluminescnce dosimetry (TLD) is also an efficient method for assessing the dose of ionizing radiation [9]. It should be noted that TLD is used in many medical applications such as medical clinical radiation and personal and environmental monitoring of ionizing radiation [10]. Due to its many advantages such as high sensitivity, small physical size and tissue equivalent, TLD has led to interesting findings in medicine [11]. It also measures the doses of less than 1μGy (10). TLD has suitable characteristics to be used for research in nuclear medicine dosimetry [10, 12].

In myocardial perfusion scan which is the most common scan in nuclear medicine, the kidney and liver absorb the highest amount of radiopharmaceutical which must be measured accurately due to the placement of these organs in adjacent with the genital organs such as uterus [2].

The aim of the present study was to determine the absorbed dose by patients uterus following myocardial perfusion scan with ^{99m}Tc-sestamibi using TLD and conjugate- view methods.

Material and Methods

In this study, 22 female patients (30-65 year-old) were selected from among those who had attended the nuclear medicine department of Isfahan Chamran Hospital for myocardial perfusion imaging by ^{99m}Tc-mibi radiopharmaceutical. Injected dose to the patients was 15 to 20 mCi based on their weight. Samples were selected from patients who had not undergone hysterectomy or any uterus removal.

Patients were imaged with a dual-head gamma camera (Philips [ADAC], forte, Netherlands) equipped with low-energy collimators. A 20% energy window around the photopeak (140 keV) of ^{99m}Tc was used.

Images from the patients were acquired at 15, 60 and 90 minutes after ^{99m}Tc-MIBI injection.

Conjugate-view Method

To determine the activity in heart and uterus, conjugate view method was applied on images. Regions of interest (ROIs) were manually drawn on anterior and posterior images around all organs. A subtraction of surrounding activity was done by drawing ROI in the neighborhood of each organ. The same set of ROIs was used for all scans and the counts in each ROI were converted to activity using the conjugate-view method illustrated by the following equation [13]:

$$A = \sqrt{\frac{I_A \times I_P}{e^{-\mu_e t}}} \times \frac{f}{C}$$

In this equation, I_A and I_P represent the corrected count of anterior and posterior rate obtained using scintigraphy images, respectively (cpm), t is the thickness of the body at the position of the heart (cm), μ_e is the effective linear attenuation coefficient (0.141/cm for ^{99m}Tc) and f is a correction for the source region attenuation coefficient (μ_e) ans source thickness (t) obtained from following equation [13, 14]:

$$f = \frac{(\frac{\mu t}{2})}{\sinh(\frac{\mu t}{2})}$$

C is the system calibration factor (counting rate per unit activity). The system calibration factor used in this study (2773 cpm/MBq) was obtained by counting a known activity of ^{99m}Tc for a fixed period of time in air using the same camera, collimators and camera acquisition setting as for the scans [2].

To obtain the corrected count rate of I_A and I_P, it was first necessary to obtain the uncorrected count rate of the under study organs. Then, the rate of background counting, the origin of which is the activity of tissues and organs surrounding the organ under study, were removed. In the present work, Buijs method for calculating the heart activity as a percentage of the injected activity was used. In this method, the thickness of the organ and surrounding tissues is a significant factor for removal of the background count rate. The following equations show the Buijs method:

$$I_A = I_A' - I_{BGA} \times F$$

$$I_P = I_P' - I_{BGP} \times F$$

$$F = 1 - (\frac{t}{T})$$

I_A (I_P): the corrected count rate of organs in anterior (posterior) view

I'_A(I'_P): the uncorrected count rate of organs in anterior (posterior) view

T is the thickness of the body where the organ under study is located, and t is the thickness of the organ itself. These values were obtained by the gamma camera software based on the side images [15, 16]. It should be noted that IBGP and IBGA were found as equal to what we obtained outside the anatomical zone in ROI anterior and posterior views. It is noteworthy that uterus absorbs less radiopharmaceutical; thus it is impossible to obtain the uterus thickness through perfusion scanning. Therefore, the conventional method of background correction was used to this end.

Conventional method

In this method, the following equation is used to obtain the background countrate:

$$S_{source} \times \bar{I}_{ROI\ background}$$

$\bar{I}_{ROI\ background}$ is the average count rate per pixel in the uterus surrounding area where the background ROI was drawn.

S source is the area of the target zone (uterus) in pixel number for obtaining the background count rate. Using this method, ROI of the uterus surrounding zone was first drawn, and the area of the target zone as well as its contrast were obtained. Then, the background ROI was drawn around the organ such that it covers at least half of the surrounding area. Accordingly, the background count rate and its pixel numbers were obtained, and the value of count rate per pixel was calculated. Through the following equation, the corrected count rate was calculated for both anterior and posterior views.

$$I = I'_{ROI\ source} - \bar{I}_{ROI\ background} \times S_{source}$$

I is the corrected countrate of the organ and $I'_{ROI\ source}$ is the uncorrected count rate of the organ.

Based on the Buijs corrected method, the activity of heart was calculated during 60 minutes after radiopharmaceutical injection as a percentage of injection activity. Later, the activity of the uterus was calculated and next to obtain activity after injection of ^{99m}Tc-sestamibi, the activity graph by time was plotted using Excel software. Afterwards, the surface area under the curve of time activity was calculated which indicates the cumulative activity of the uterus in mCi/hr and then the absorbed dose in

the uterus was obtained through the following equqtion [17]:

$$D \approx A_0 \times \tau \times \frac{\Delta}{M}$$

Where, τ is the residence time of the radioactive substance by dividing the cumulative activity on the primary activity which is achieved in hours. Also Δ is the constant of the balance dose which, on the basis of ^{99m}Tc MIRD Committee report, is determined for the total radiation from ^{99m}Tc to be 0.0332 (gr. rad/μCi.hr) [18].

M is the mass of the organ under study which is estimated 79 gr based on the standard table CRP NO.106 [19].

TLD Method

The second part of this study is to determine the absorbed dose of uterus using TLD under heart perfusion scanning. To use TLD, calibration was firstly performed, of course after the primary annealing. The procedure of calibration was followed according to the device manual instruction, and the related equations were also used. Calibration factor changes to dose the amount read from the detector in terms of the corrected count. TLD calibration includs 2 types: individual and group. In this study, 2 TLD was used for each patient, located on the nearest place to the uterus. To locate the TLD on the patient's body, it was put inside a plastic cover and fixed with tape on the body. This operation was conducted after calibration and before imaging. TLDs remained on the patient's body for 24 hours, and were then put inside the TLD reader (SOLARO 2A) to be read for the final estimation. The average was taken among dosimeter values. According to the curve drawn by this device, the uterus absorbed dose was calculated using the related equation. This equation is given below:

Calculated dose = background radiation – (calibration factors × corrected count)

The background radiation happens when detectors also emit false signals in addition to the signal-generating radiations; the software is capable of measuring the background radiation for every group of detectors which should be declared in dose unit.

The quantitative data obtained from the calculation of the percentage of heart uptake and the dosimetry of the organ under study was analyzed by SPSS version 16.0 and T-test for comparing with standard values.

Results

The heart activity at 60 minutes after the injection of ^{99m}Tc-sestamibi obtained 0.510±0.128 mCi.

It should be noted that the injected dose to the patients was 16.864±1.552 mCi. Therfore, the average amount of uptake of ^{99m}Tc-sestamibi by heart was calculated 3.077±0.067 percent of injected dose to every individual subject of study.

The uterus activity at 15, 60 and 90 minutes after injection of ^{99m}Tc-sestamibi was obtained 0.044±0.015, 0.031±0.014 and 0.026±0.013 mCi, repectively.

Figure 1 shows the uterus activity versus time.

Our results showed a significant difference in the uterus activity values all times after the injection ($p=0<0.05$).

By calculating the area under figure 1, the accumulative activity was obtained. Then, by using MIRD formula, the average dose to the uterus was calculated as 0.0007± 0.0004 mGy/MBq.

In the second part of this study, the uterus dose was calculated using TLD method. The value of individual calibration factor was obtained for every dosimeter. Later, the exact value of a group calibration factor for the odd and even dosimeters was determined to be 5.2513×10^{-6} cGy and 7.3366×10^{-6} cGy, respectively. The amount of background radiation was consid-

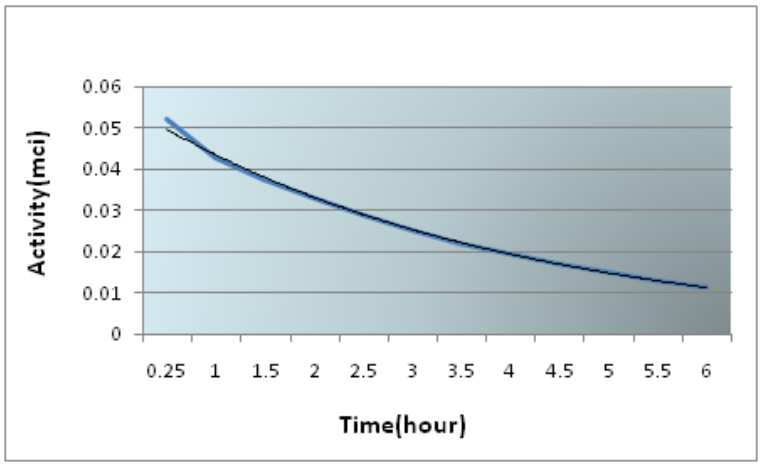

Figure 1: The uterus activity versus time

ered 0.015292 cGy for the odd dosimeters and 0.016290 cGy for the even ones. The dosimeter readings were obtained for every patient. The average of these readings was obtained as 7675.409±1745.94. Then, the uterus absorbed dose per unit of injected activity (mGy/MBq $\times 10^{-4}$) was obtained 5.258±0.500 using TLD method.

Discussion

The most common method used so far to calculate internal dose is suggested by MIRD Committee [20]. In a study conducted by Okadu et al, the heart uptake was determined in the rest test of the heart scan, the result of which does not show any significant difference from our study.

In 2012, Hilal applied a series of radiopharmaceuticals such as ^{99m}Tc-MIBI so as to check the up-taken dose of all organs in the imaging of bone, heart and where the internal dosimetry was calculated MIRDose software [21]. There appeared to be a considerable difference between Nadia's method of calculating the uterus absorbed dose and that of conjugated-view method. However, no significant difference was observed with TLD method (p=0.28).

Internal dosimetry data center in Central America is a center which perfomed the development of MIRDOSE software including the one, namelly MIRDOSE3 used in this study for calculating the absorbed dose [20].

In this study, we observed the absorbed dose of the uterus using MIRD and TLD methods and that revealed a considerable difference through the application of MIRDOSE3 software (p=0).

In another study performed by Stabin, two software MIRDOSE2 and MIRDOSE3 were compared with the results being an observation of significant difference between the dose estimated in this study and the one obtained through conjugated-view method and TLD (p=0) [22].

Also, in another study conducted by Sahebnasagh et al. in 2012, using three methods, the dose absorbed to the ovaries and uterus was measured in the heart scanning through radiopharmaceutical ^{99m}Tc injection and the uterus absorbed dose reported in the rest test was 0.0001mGy/MBq; significant difference was observed between the dose obtained through phantom and the one achieved in this study (p=0) [23].

Observed differences between the amount obtained as a result of simulation in reports and the one achieved through the conjugated-view method, one can conclude that the

prevailing strategies in the conjugated-view method are the most accurate ones provided that the organs are separate from one another, or not overlapping with the adjacent organs [13]. But due to the adjacency of the organs and the fact that the absorption is negligible in the uterus but significant in such neighboring organs as intestine, etc., it was very difficult to separate uterus and bladder.

Siegel et al. recognized error factors and limitations effective in determination of the organs activity including the inherent constraints of the device in the resolution of the energy and the lost data to be due to attenuation and scattering [13]. Among other factors in the creation of this difference, one can refer to the mass of organs [22]. It should be noted that while using TLD, none of these restrictions will exist. TLD is also a versatile tool for evaluating dose [9]. TLD 100 used in this study is equivalent to tissue and has a very high sensitivity [11]. It also fits into the phantom equivalent to tissue with no need for cables or any medical equipment [23] and its data loss in the room temperature is negligible [24]. In this study, the direct and easy placement of dosimeter near the organ under study as well as lack of attenuation of radiations in the air, and staying on the patient's body for 24 hours which is approximately equivalent to 4 halves of the radiopharmaceutical life span, would reduce the fallacy of the work.

Conclusion

In general, dosimetry using TLD, in comparison with the conjugated-view method, demonstrates more accurate results. The results of this study showed that methods used in the study for absorbed dose calculation is in good agreement with the data of MIRDose software, and it is possible to use the obtained method of the present study by a clinician.

In addition, findings may be useful to estimate the amount of activity which can be administered to the patients and also serve as a way of comparing the risk to the benefit value of these nuclear medical procedures with other modalities of diagnostic procedures.

Acknowledgment

This work was funded by Isfahan University of Medical Sciences, Isfahan. The authors would also like to thank the staff in nuclear medicine, Shahid-Chamran Hospital, Isfahan, Iran.

Conflict of Interest

None

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