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# Determination and Comparison of Breast Absorbed Dose in Myocardial Perfusion Scan Using Conjugated View and Thermo luminescence Methods

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***Abstract*—Introduction: Absorbed dose is an important part of considering the risk and predicting efficacy from nuclear medicine procedures. The accuracy of absorbed dose estimation depends on the activity quantification accuracies. The aim of this study is to determine the absorbed dose of breast using the two, TLD and MIRD methods, and finally the results were compared together.**

**Material and method: In this study myocardial perfusion scintigraphy on 22 99m TC-sestamibi injected females were performed at 15, 60 and 90 minutes after IV injection. The breast absorbed dose were calculated using 2 methods: 1) Thermoluminescence Dosimeter (TLD) and 2) the conjugated-view method by the Buij's background correction method and MIRD equation**

**Results: The results showed that the breast activity (mean±SD) in 15, 60 and 90 minutes after injection were 0.234±0.076, 0.17±0.053 and 0.134±0.053 mCi respectively. According to these finding, the mean absorbed dose of breast were estimated 0.0009745±0.0004 mGy/MBq using the conjugated-view method and 0.001789±0.00039052 mGy/MBq using TLDs. The mean hearth uptake percentage was obtained %3.065±0.327.**

**Conclusion: Summing up the results, it can be concluded thatthe TLD based dose monitoring method is more accurate in absorbed dose estimating than conjugated-view method.**

***Index terms -Absorbed Dose, Myocardial Perfusion Scan, Conjugated-view Method, TLD, 99mTC-sestamibi, Breast.***

## I. INTRODUCTION

Radiopharmaceuticals uses in nuclear medicine to provide diagnostic and therapeutic information about the organ of patients. The diagnostic applications include imaging of organs, tumors and also the physiological and Biochemical evaluation of organs [1]. It should be noted that nuclear Medicine imaging can play an important role in the diagnosis and determination or treat the variety of diseases such as different type of heart disease, cancers, gastrointestinal, neurological, endocrine disorders and also other abnormalities within the body [2]. However, the same as other medical methods, the risks and benefits of nuclear medicine imaging must be evaluated. The absorbed dose is an important part of considering the risk and predicting efficacy from these procedures [3].

The absorbed dose defines as the mean energy delivered to the unit mass of tissue and usually represents the probability of an injurious biological effect [4].Theoretical absorbed dose calculations for injected radiopharmaceutical have been carried out using different methods such as the Medical Internal Radiation Dose (MIRD) method, MIRDose software and thermoluminescent dosimeters(TLDs) which are usually used in nuclear medicine [5,6].

The generalized MIRD schematic was formulated to assist the calculation of absorbed dose from distributed radioactive sources [7]. It is essential to emphasis that the accuracy in the absorbed dose estimation of organs depends on the activity quantification accuracies in the MIRD method [8]. The conjugated-view method is commonly used for quantification of radioactivity. For this purpose, the conjugate-view projection pair which is classically anterior and posterior projections of the region of interest acquires, though any true l80 opposed set can be used for instance right and left lateral projections.Then the region of interests (ROIs) are drawn manually around the borders of organs of interest [9]. Activity determination using the conjugated-view method in scintigraphy imaging might be inaccurate due to the scattered radiation of adjacent organs and also activity of overlapping tissues [10]. This phenomenon causes over estimation of activity in the region of interest. To estimate accurate activity quantification out of measured count rate, some corrections needed [11].

Radiation dosimetry is essential in Medical Physics. In both cases of phantom and patient's dosimetry using TLD is the appropriate technique to measure the absorbed dose [12]. For example, the absorbed dose in breast, thyroid and testes can be easily determined by placing the TLDs on the patient'sskin [13]. TLD has many advantages such as close tissue equivalent, small detector size that make it appropriate

for medical applications. In medical imaging the risk assessment can be done even in low dose procedures because of the high sensitivity TLD materials (e.g. LiF:Mg,Cu,P and Al2O3:C) [14]. TLD-100 is the common dosimeter which belongs to lithium-fluoride family with magnesium impurities [15].

The aim of this study is to determine the absorbed dose of breast using the two, TLD and MIRD methods, and finally the calculated absorbed dose acquired by two methods were compared together and with the results of others using the computer simulations. It should be noted that in this study the Buijs' correction method was used for the myocard, and the hearth uptake percentage was obtained from the injected dose.

## II. Material and Methods

### *A. Patients*

In this study, we selected 22 adult female patients among those who had referred to the nuclear medicine department of Chamran hospital in Isfahan for Myocardial Perfusion Sintigraphy. The patients were in the age range of 30 to 65 years. The IntraVenues (IV) injection of Tecnesium – sestamibi (99m TC-sestamibi) was between 15 to 20 mCi for each patient according to their weight. Exclusion criteria for Myocardial Perfusion Scan (MPS) in the present study were the patients who underwent breast surgery, were pregnant or breast-feeding.

### *B. Study Design*

In this study, determination of organ absorbed dose have been done using two methods: 1) a quantitative distribution of '99mTC-sestamibi' have been calculated using the conjugated-view method and then the absorbed dose was calculated using MIRD equation and 2) Thermoluminescence Dosimeter (TLD).

The resting phase of myocardial perfusion scintigraphy on 22 females were performed at 15, 60 and 90 minutes after IV injection of 99m Tc-sestamibi using a Philips Gamma camera (Dual head, ADAC, forte, Netherland) and the parallel-hole, low-energy, high resolution collimator was mounted on it. The anterior, posterior and lateral projections were acquired in each scintigraphy for each patient.

A Symmetric energy window was centered at the 140 keV (photopeak Energy) and extending from 10% below to 10% above the photopeak energy (126-154 keV). The quality control tests for Gamma camera have been done by the expert technician.

The MPS was performed according to the clinical routine protocols. The imaging was carried out in a 180° counter clock wise circular orbit that began at 45° right anterior oblique projection and ended at 45° left posterior oblique projection (feet first supine)

### *C. Absorbed Dose Calculation*

*Conjugated-view method*

The quantitative radiopharmaceutical bio-distribution of heart and breast were calculated using the following equation that shows the conjugate view method.

$$A=\sqrt{\frac{I_A I_p}{e^{-\mu_e t}}}\times\frac{f}{c}$$ **Equation 1**

Where, IA and Ip are the background corrected count rates of anterior and posterior projections respectively (that will describe in the next section). $\mu_e$ is the effective linear attenuation coefficient and equal to 0.12 per cm for Technetium-99m based on the MIRD committee recommendation [16,17]. t is the body thickness along the collimator hole axis in each projection. It was obtained by the Gamma camera software and the lateral image. C is the Gamma Camera Calibration Factor which was measured by scanning a known Tc source (calibration source) in the air using the same Gamma camera setting as the patient setting [18,19]. Then ROI was drawn manually around the calibration source and the Calibration Factor determined by Equation 2 (counts per minute per mCi or cpm/mCi) [20,21].

$$CalibrationFactor\ (CF)=\frac{CalibrationSourcecountrate-backgroundcountrate}{CalibrationSourceactivity}$$ **Equation 2**

f shows the correction factor that depends on the region attenuation coefficient ($\mu_e$) and its thickness (t) according to the following equation.

$$f=\frac{(\frac{\mu t}{2})}{\sinh(\frac{\mu t}{2})}$$ **Equation 3**

f is always less than or equal to 1.

*Background correction using Buijs Method*

To obtain the corrected count rates out of scintigraphy projection raw data or uncorrected count rate, at first the ROI were drawn manually around the heartin anterior and posterior projections that were acquired at 15th,60th and 90th minute after the IV injection. The count rates in these ROI's represent the uncorrected Count rate (I'A and I'P respectively). Then the Buijs's background correction method used to measure the corrected count rate in both anterior and posterior ROI according to Equation 4 and Equation 5.

$IA=IA'-IBGA\times F$ **Equation 4**

$IP=IP'-IBGP\times F$ **Equation 5**

Where IA′ and IP′ are the organ's uncorrected count rates that were obtained from anterior and posterior ROI's that placed on an organ. IBGA and IBGP are the count rate in the anterior and posterior ROI's that placed on the background

and didn't have any overlap with the ROIs of the organ. F is defining as the fraction of background activity that is not from organ, using Equation 6:

$$F = 1 - \frac{t}{T}$$ **Equation 6**

Where t is the thickness of the source organ and T is the thickness of body at the placement of the organ's ROI. These values obtained using Gamma camera software and the lateral image, that is indicated in Figure 1[11,18].

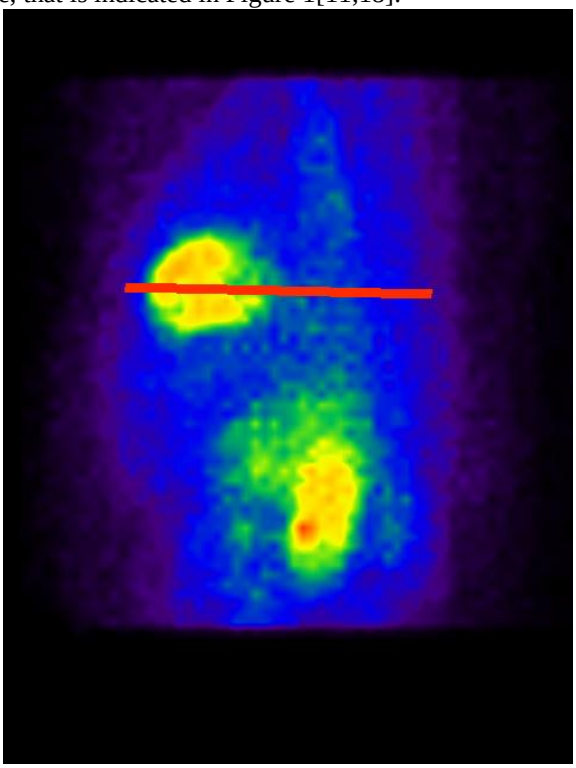

Figure 1: Thickness of Body at the Placement of the Organ's ROI in the Lateral Projection

*The Medical Internal Radiation Dose (MIRD) Method*

Finally the heart activity on 60th minute after radiopharmaceutical injection was calculated using Buijs's background correction method based on Equation 4 and Equation 5, as percentage of injected activity. The breast activity was also calculated based on Equation 1. After activity computation for breast on 15th, 60th and 90th minutes after radiopharmaceutical injection, the time-activity curve was drawn for each patient and fitted to exponential decay curve using curve fitting method. Calculating the area under the time-activity curve, determine the cumulative activity in mCi per hour. Then the breast absorbed dose was determining using MIRD method, according to the following equation: [17]

$$D \approx A_0 \times \tau \times \frac{\Delta}{M}$$ **Equation 7**

Where, D is the mean absorbed dose for breast. A0 is the administered activity (15 to 20 mCi). τ is the residence time and is defined as cumulative activity(Ã) over a time interval divided by the administered activity(τ=Ã/A0). Δ is the mean energy emitted per nuclear transition or the equilibrium dose constant which is 0.0332 (rad.g/μ Ci h) on the basis of the MIRD Dose Estimate Report No. 13 [22]. M is the breast mass and according to the latest ICRP1 report (ICRP 106) is considered 351 grams for each breast [23].

*Thermoluminescence Dosimeter (TLD)*

In the second part of the study, the breast-absorbed dose was calculated using Thermoluminescence Dosimeter (TLD). For this purpose, during the MPS, TLDs were placed on the right and left breast and both the individual and batch calibration of TLDs was performed before MPS started. The calibration factors used to convert count to dose. After the primary annealing, calibration steps were carried out according to a standard procedure of system manual. Then 4 TLDs (round TLD-100) were placed in the plastic bags that were fixed with tape on the predefined locations of each breast (2 on the right breast and 2 on the left breast). These TLDs were kept on the breasts of patients for 24 hours. The final answer obtained by calculating the mean of 4 TLDs absorbed dose. a Solaro2A TLD reader (NE Technology, England) was used to read the TLDs data. Area under the glow curve is directly proportional to the amount of radiation that was absorbed in the TLD. The breast absorbed dose calculated using the following equation:

**Absorbed dose= (corrected count×calibration factor) - background radiation** **Equation 8**

***D: Statistical analysis***

In this study the quantitative data obtained by calculating hearth uptake percentage and absorbed dose of organ were analyzed by SPSS16. In order to examine normality of data, Kolmogorov-Smirnov test was used and then the results of two methods for calculating absorbed dose were compared using t-test. A significance level of $P<0.05$ were used for data analysis and the results were presented as the mean±SD (Standard Deviation).

## *III.* RESULTS AND DISCUSSION

The calibration factor for gamma camera was equal to 2773 $(\frac{Cpm}{MBq})$ as seen from Equation2.

[1]The International Commission on Radiological Protection (**ICRP**)

The resting phase of MPS is done, 60 minutes after IV Injection. Myocardium count rate recorded using a manually drawn ROI over the whole myocardium on both anterior and posterior projections. It should be noted that the Buijs method of background correction was used for the calculation of the corrected count rate. Thus, using the relevant equation, the myocardium mean activity were 0.508 ± 0.123 mCi, since mean IV injected activity was 16.863 ± 1.552 mCi (60 minutes after IV Injection), the hearth uptake percentage was calculated and it was 3.065 ± 0.327.

Breast count rate recorded using a manually drawn ROI over the whole breast, in right and left lateral scintigraphy projections that was performed 15, 60 and 90 minutes after I.V injection. Then, according to the gamma camera calibration factor, the breast mean activities were obtained as shown in Table 1.

Table 1: Breast mean activity (mCi) in the resting phase of myocardial perfusion scintictigraphy that were performed 15, 60 and 90 minutes after I.V injection

| Time after injection | 15 min | 60 min | 90 min |
|---|---|---|---|
| Activity(mci) | 0.234±0.076 | 0.17±0.053 | 0.134±0.053 |

The time-activity curve was plotted in excel. According to the curve and proper caculation, the breast activity reduction was observed during one half-life of the Tc. Statistical analysis define the significance difference between the activities measured in the MPS that were performed 15, 60 and 90 minutes after IV injection(p= < 0.01).

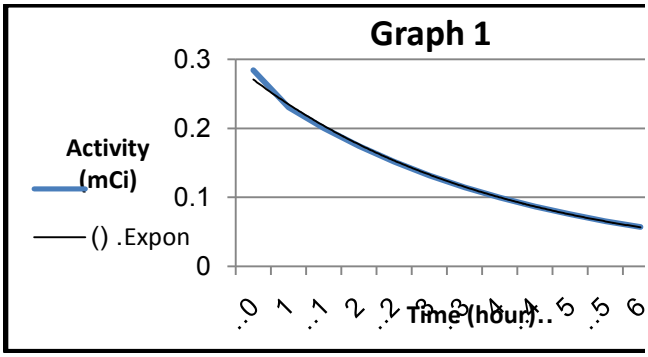


Figure 2: The Breast Activity Against Time During One Half-Life of $^{99m}$Tc (Time-Activity Curve)

The area under the time-activity curve (Figure 2) measured, as in each patient, to determine the cumulative activity and then the breast absorbed dose calculated using Equation 7. The mean absorbed dose of breast was 0.0009745 ± 0.0004 mGy/MBq using the conjugated-view method.

In the second part of the study, to account the differences in response, the individual calibration factor was estimated for each TLD.

After all, batch calibration were carried. The calibration factorS were 5.2513 × 10-6 and 7/3366 ×10-6 and the background radiations were 0.015292 and 0.016290 cGy for the odd-numbered and even-numbered TLDs respectively. by placing the TLDs on the patients body, the mean raw count was measured 11641.77±1745.94 for the right breast and 10314.08±1866.22 for the left breast. The records of each TLD reading were used to determine the mean absorbed dose. The derived mean absorbed doses were 0.000977±0.00019cGy and 0.000812±0.00021cGy for the right and left breast respectively. Total dose of right and left breasts was estimated as 0.001789±0.00039052cGy.

Finally, the absorbed doses obtained from the conjugated-view method and TLD compared using T-test, and the significant difference between means found (Figure 3). (P<0.01)

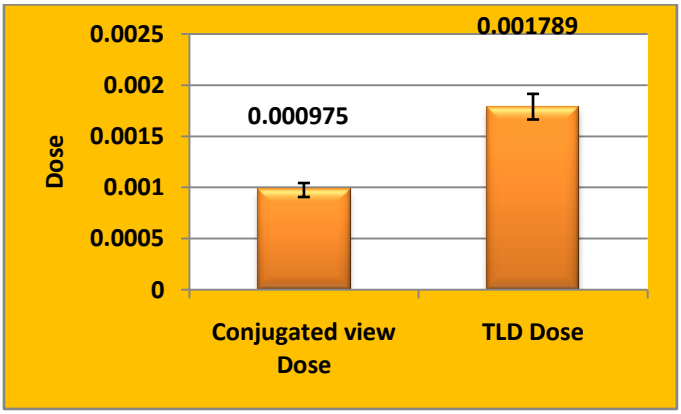


**Figure 3.** Comparison Between the Absorbed Dose Calculated Using the Conjugated-View Method and TLD

As mentioned above, TLD measurements showed the separate analyses in each breast, whereas such analysis is not possible for conjugated-view method. Our finding indicates a higher absorbed dose in the right breast compared with the left breast. As our understanding, the liver and gallbladder under the right breast might cause the higher absorbed dose in the right breast.

The results showed there is a significant difference between the absorbed dose measured by TLD and conjugate method. (P<0.01) The hearth uptake percentage in the rest phase of MPS herein is broadly consistent with the findings reported by Okada, and there is no significant difference between these two studies. (P=0.283>0.05) [24]. In a study conducted by Helal the absorbed dose from IV injection of 99mTc-MDP, 99mTc-MIBI radiopharmaceuticals in specific body organs measured during bone, myocardial and lung scintigraphies. She used the MIRDOSE code to calculate the breast absorbed dose. A significant difference was observed between the breast absorbed dose calculated in Helal's study and the conjugated-view method(P<0.01) and Thermoluminescence Dosimetry(P<0.01) in this study [25].

The organs' absorbed dose for different radiopharmaceuticals has been measured and published by the Radiation Internal Dose information Center (RIDIC)[26]. There is no significant difference between the breast absorbed dose estimated by RIDIC and TLD's dosimetry of this study (P=0.297>0.05) but significant difference exists between the RIDIC estimates and the conjugated-view method in this study. (P<0.01) The data obtained for absorbed dose in the Stabin's study that compared MIRDOSE Versions 2 and 3 are in good agreement with the TLD data of the present study. (P=0.473>0.05) but there is significant difference between the Stabin's results and the conjugated-view method in this study[27]. (P<0.01)

Vanzetto et all studied the dosimetry, safety and Biodistribution of 99m TC –NOET radiopharmaceutical in MPS. The breast absorbed dose in the rest phase of MPS was calculated by MIRDOSE code and significant difference observed between the results of Venzetto's study and TLD's dosimetry of the present study [28]. (P<0.01)

So the significance difference between absorbed dose estimated by the conjugated-view method in the present study and the results reported by some authors (presented above) was observed. The most likely explanation of this difference is the number of factors causing risks and uncertainties in dose obtained from these methods. These include intrinsic limitations of Gamma camera on energy resolution and effects of scattered radiation, attenuation. Also the internal dose estimatations are model based, and they aren't basis on individual subject measurements, therefore the mass of body organs with variations from the mass represented in the model encountered significant uncertainties [29].

Lack of accuracy in breast border definition on lateral projections affected the ROI's shape and therefore uncertainties in ROI's count rate and finally unreal absorbed dose estimation. Whereas none of these limitations exists when using the TLD method. The energy response of TLD 100 is equal to energy response of human tissue and it has high sensitivity even for low dose measurements. Therefore TLD 100 is a good candidate in dosimetry of ionizing radiation in medical imaging [30].

In this study TLDs were placed on the patient's breast surface, and the negligible attenuation of radiation in the air and also keeping TLDs on the patient's body surface for 24 hours(half-life of Tc-99m =6 hours) has been effective on lack of significant difference between the results of our work and the reference values.

The MIRDOSE software includes consideration of different physical decays of radiopharmaceuticals and their bio distribution in the body so the little difference between the absorbed doses obtained from the two methods in our study and those of the simulation software is expectable.

## IV. CONCLUSION

Reliable estimate of absorbed dose in the use of radiopharmaceuticals in nuclear medicine tests are important to evaluate their risks and benefits.

From the research that has been carried out, it is possible to conclude that the TLD based dose monitoring method is more accurate in absorbed dose estimating than conjugated-view method. According to the results of the present study and those of other studies, it is evident that TLD-100 provides a good spatial resolution, high sensitivity and good linearity of response so they are chosen as a good candidate for photon dosimetry.

Summing up the results, it can be concluded that using TLDs is simple, effective and playing an important role in calculating of the bio-distribution, cumulated activities and absorbed dose.

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