Estimation of Organ Absorbed Doses in Patients from 99mTc-diphosphonate Using the Data of MIRDose Software

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ABSTRACT

The purpose of this study was to compare estimation of radiation absorbed doses to patients following bone scans with technetium-99m-labeled methylene diphosphonate (MDP) with the estimates given in MIRDose software. In this study, each patient was injected 25 mCi of 99mTc-MDP. Whole-body images from thirty patients were acquired by gamma camera at 10, 60, 90, 180 minutes after 99mTc-MDP injection. To determine the amount of activity in each organ, conjugate view method was applied on images. MIRD equation was then used to estimate absorbed doses in different organs of patients. At the end, absorbed dose values obtained in this study were compared with the data of MIRDose software. The absorbed doses per unit of injected activity ($mGy/MBq \times 10^{-4}$) for liver, kidneys, bladder wall and spleen were 3.86 ± 1.1, 38.73 ± 4.7, 4.16 ± 1.8 and 3.91 ± 1.3, respectively. The results of this study may be useful to estimate the amount of activity that can be administered to the patient and also 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 by a clinician.

Key words: *Activity, bone scintigraphy, MIRDose software, organ dose*

INTRODUCTION

A bone scan or bone scintigraphy is a nuclear scanning test to find certain abnormalities in bone that are triggering the bone's attempts to heal. It is primarily used to help diagnose a number of conditions relating to bones, including: Cancer of the bone or cancers that have spread (metastasized) to the bone, locating some sources of bone inflammation (e.g., bone pain such as lower back pain due to a fracture), the diagnosis of fractures that may not be visible in traditional X-ray images, and the detection of damage to bones due to certain infections and other problems.[1,2]

Accurate dosimetry for representative groups of patients for each specific investigation is needed in order to optimize use of the various alternative radiodiagnostic techniques, and to estimate the collective radiation exposure and risk from nuclear medicine investigations.[3]

A computer program called MIRDose, has been developed and distributed by M.G. Stabin, Radiation Internal Dose Information Center, Oak Ridge Institute for Science and Education, Oak Ridge, USA. The program contains tables of the S factors for the common radionuclides; the user must provide the biokinetic data in the form of residence times for the source organs. The program then generates tables of organ doses per unit administered activity in the traditional and SI units (rad/mCi and mGy/MBq).[4,5]

Internal dose of different organs can be estimated by different methods such as Medical Internal Radiation Dosimetry (MIRD). 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.[6-8] The aim of the present study was to compare estimation of radiation absorbed doses to patients following bone scans with technetium-99m-labeled methylene diphosphonate (MDP) with the estimates given in MIRDose software (Version 3.0. 2).

MATERIALS AND METHODS

The study was performed on 30 adult patients (18 women and 12 men) with an average age of 38 ± 12 years referred to the nuclear medicine department of Seyed Al-shohada hospital in Isfahan, Iran for evaluation bone metastases. All patients signed a consent form after receiving detailed

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information about the aim of the study. Each patient was injected with 25 mCi of ^{99m}Tc-MDP. Patients were imaged with a dual-head gamma camera (Siemens GammaSonics, Hoffman Estates), equipped with low-energy collimators. A 20% energy window around the photopeak of ^{99m}Tc was used. Whole-body images from the thirty patients were acquired at 10, 60, 90, 180 minutes after ^{99m}Tc-MDP injection. Images of five min duration were acquired. To determine the activity, in different organs, conjugate view method was applied on total body images. Regions of interest (ROIs) were manually drawn on anterior and posterior images around all organs (liver, bladder wall, spleen and kidneys) on each time frame. A subtraction of surrounding activity was done by drawing ROI in 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 which illustrated by the following equation.[9-12]

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

In this equation, A is the organs activity in mCi, I_A and I_P are the anterior and posterior view background corrected counting rates, respectively, t is the body anterior–posterior thickness across each organ, this thickness were measured on the CT scanner (Brilliance; Philips). Also μ_e is the effective linear attenuation, f is equal to $(\mu_e t/2)/\sinh(\mu_e t/2)$ and represents a correction for the source region attenuation coefficient (μ_e) and source thickness (t) and C is the system calibration factor (counting rate per unit activity). The system calibration factor used in this study 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 settings. The mean uptake activity in different time periods (10, 60, 90, 180 min) after injection of ^{99m}Tc-MDP were also calculated for each organ and used in the time–activity curves. The time–activity curves used to calculate the cumulated activity in each organ was fitted by MATLAB software (Version. 7.5).

For obtained corrected counting rate, the counting rate measured in an adjacent ROI was subtracted from the counting rate in organs ROI, in according to the formula reported by Buijs *et al*., equation.[9]

$$I_A = I'_A - I_{BGA}$$
$$I_P = I'_P - I_{BGP}$$

Where I_A (I_P) is the background corrected counting rate in the anterior (posterior) organs ROI, I'_A (I'_P) is the measured counting rate in the anterior (posterior) organs ROI and I_{BGA} (I_{BGP}) is the counting rate in the anterior (posterior) background ROI.

Based on the MIRD schema, absorbed doses (D) were calculated for the liver, bladder wall, spleen and kidneys using follow formula:[12-14]

$$D = \tilde{A} \times S$$

where $\tilde{A}$ is the cumulated activity, "S" factor obtained from Yoriyaz and co-workers study.[15] The results of this study were compared with the data of MIRDose software[16] by performing *t*-test.

RESULTS

The absorbed doses per unit of injected activity (mGy/MBq $\times 10^{-4}$) for liver, kidneys, bladder wall and spleen were 3.86 ± 1.1, 38.73 ± 4.7, 4.16 ± 1.8 and 3.91 ± 1.3, respectively.

The results of *t*-test to compare the results of the data of MIRDose software and present study are shown in Table 1.

DISCUSSION

Radiation dose calculations for radiopharmaceuticals have been standardized by implementation and dissemination of tools like MIRDose software. The MIRDose software greatly facilitates the calculation of internal radiation dose estimates by the MIRD techniques. The program makes use of standard and most up-to-date models in internal dosimetry.[16]

The accurate absorbed dose calculations depends on the accuracy of the quantifications of organ activity.[17] The accuracy of the quantifications of organ activity from planar gamma camera images has been evaluated by several researchers.[17-20] They are demonstrated factors such as the effective attenuation coefficient (which could influence the estimation of activity by about ±10%), body thickness (±10%) and device sensitivity (±5%) which influences the accuracy of activity quantification. However, researchers noted that background activity was perhaps the most important factor, with differences in how background regions were defined contributing to as much as ±20% variation of the observed activity values from the known results. Another factor to consider in quantification of the activity based on planar scintigraphy is the effect of overlapping tissue. This applies particularly to kidneys and liver.[17-20]

Table 1 shows that the *P* values of compared the results of this study with the data of MIRDose software is more than 0.05 which means that there is no significant differences

Table 1: Results of *t*-test to compare the data of MIRDose software with the present study

Organ	*P* value
Liver	0.72±0.02>0.05±0.01
Bladder wall	0.12±0.06>0.05±0.02
Spleen	0.35±0.04>0.05±0.01
Kidneys	0.24±0.03>0.05±0.02

among these. According to the results here [Table 1], the *P* value of liver is higher than the rest which means is more in agreement with other studies.[17-19]

CONCLUSIONS

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. Also findings may be useful to estimate the amount of activity that 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 the other modalities of diagnostic procedures.

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