ESTIMATION OF ORGAN ABSORBED DOSES IN MICE FROM ^{99M}TC-MIBI USING MYOCARDIAL PERFUSION IMAGING

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Abstract. In nuclear medicine, the absorbed dose for target organs in myocardial perfusion imaging (MPI) has a critical role in assessment of radiation risk. Estimation of heart, liver and kidney absorbed doses of ^{99m}Tc-MIBI (Technetium sestamibi methoxyisobutyle isonutrile) in mice following myocardial perfusion imaging is important. In this study, the disintegration of administered radionuclides in heart, liver and kidney of mice was estimated. Diagnostic amounts of ^{99m}Tc-MIBI were counted by dose calibrator at different time intervals (10 min, 120 min and 240 min). Finally, organs' activity, residence time and absorbed dose were calculated. The results show that the absorbed doses for heart, liver and kidneys were 1.56, 0.53 and 0.51 mGy respectively and the residence times were 0.0568, 0.158 and 0.0938 hr correspondingly. In conclusion, this study may be useful to demonstrate the target organs (heart) in myocardial perfusion imaging compared to other organs and assessment the risk of radiation.

Key words: ^{99m}Tc-MIBI, MPI, absorbed dose, heart.

INTRODUCTION

Radionuclide myocardial perfusion imaging (MPI) using single photon emission computed tomography is a diagnostic imaging procedure for the detection of ischemia in patients with known or suspected coronary artery disease. ^{99m}Tc-MIBI is the radiopharmaceutical used for diagnostic procedures [11]. ^{99m}Tc-MIBI is distributed over the whole body and localized in mitochondrial rich organs like heart, liver, gall bladder and kidney [5]. On the other hand, ionizing radiation (IR) damages biological tissues and affects proliferating cell systems by exciting or ionizing their atoms and molecules as a function of both dose-rate and the total dose accumulated [6, 8]. Hence, lowering the radiation dose and maintaining or improving image quality should be considered. Accurate dosimetry for representative groups of patients for each specific investigation is needed in order

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to optimize use of the various alternative radio diagnostic techniques. In general, all MPI studies should be performed in appropriate patients using relatively short-lived radionuclides, and using all possible measures to minimize radiation exposure. Therefore, the benefits of the diagnostic information outweigh the risks of radiation exposure under such conditions [2, 3].

Different methods such as medical internal radiation dosimetry (MIRD) predicted the absorbed dose of different organs. In this method, the absorbed doses in the target organs are estimated as a function of accumulated activities in the source organs and mathematically calculated the predict dose [9, 10, 13].

The aim of the present study was to estimate the radiation absorbed doses in the organs (heart, liver and kidney) following whole body injection with ^{99m}Tc-MIBI

MATERIALS AND METHODS

BALB/c male mice (15 animals, 8–10 weeks old, 19.0–23.0 g weight), were obtained from Animal Reproduction and Artificial Insemination, Veterinary Research Division, National Research Center, Cairo, Egypt. They were housed in plastic cages holding autoclaved paddy covering as bedding and had access to standard mouse food and water ad lib. They were kept in a controlled humidity (50±5%) and temperature (25±3 °C) environment with 12 h light/dark cycle. All animal procedures and care were performed using guidelines for the Care and Use of Laboratory Animals [7]. All the mice were injected intravenously (i.v) with 5 mCi of ^{99m}Tc-MIBI and divided into three groups, each of 5 animals. First, second and third groups were sacrificed at 10, 120 and 240 min post-radiopharmaceutical administration respectively. Hearts, kidneys, and livers were removed, rinsed in saline, and weighed. Counts were determined using the dose calibrator Atomlab 200 Dose Calibrator (Biodex Medical Systems, Inc., USA). The measured activities were corrected for the decay factor.

The generic equation for calculating the absorbed dose rate in an object uniformly contaminated with radioactivity (for example an organ or tissue with radiopharmaceutical uptake) is [12]:

$$D = \frac{k\tilde{A}\sum_i n_i E_i \phi_i}{m} \quad (1)$$

which is a summation on all nuclear transitions i and were the other symbols are: D = absorbed dose in a target organ (rad or Gy), $\tilde{A}$ = cumulated activity (sum of all nuclear transitions that occurred) in a source organ (μCi×h or MBq×s), n = number of radiations with energy E emitted per nuclear transition, E = energy per radiation (MeV), ϕ = absorbed fraction (fraction of radiation energy absorbed in the target),

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m = mass of target region (g or kg), k = proportionality constant (rad×g/μCi×h× MeV or Gy×kg/MBq×s×MeV).

When the components of the various published internal dose calculation schemes are carefully studied, they can all be reduced to this single generic equation [12]:

$$D = \tilde{A} \cdot S = A_0 \cdot \tau \cdot S \quad (2)$$

were τ is the residence time (which equals $\tilde{A}/A_0$, the cumulated activity divided by the mice's administered activity A_0), and S is given by:

$$S = \frac{k \sum_i n_i E_i \phi_i}{m} \quad (3)$$

The mean activity at different time periods (10, 120, 240 min) after injection of ^{99m}Tc-MIBI were measured and calculated for each organ (heart, liver and kidney) and used in the time–activity curves. The time-activity curves are used to calculate the cumulated activity, residence time and radiation absorbed dose in each organ.

RESULTS AND DISCUSSION

Figure 1 shows the estimated activities (μCi) in the heart, liver, kidneys at 10 min, 120 min and 240 min post administration of 5 mCi of ^{99m}Tc-sestamibi respectively. The uptake of radiopharmaceutical was also calculated as a percentage of the injected dose (ID) per tissue gram according to [1] and equals 2.23%, 6.11% and 5.1% for heart, liver and kidney at 10 min post administration of ^{99m}Tc-MIBI respectively. Same authors reported that the uptake is dependent on the mitochondrial content of organs. The dose of radiation delivered to a target organ depends on the amount of activity present in the source organ and on the length of time for which the activity is present. The product of these two factors is the cumulative activity in the source organ.

Figure 2 shows the activity present in heart post administration with 5 mCi of ^{99m}Tc-MIBI as a function of time. After fitting the time / activity curve, we obtain:

$$y = 123.71 \cdot e^{-0.294x} \quad (4)$$

The integration of equation (4) from $0 \rightarrow \infty$ gives a cumulated activity of 284.45 μCi×h.

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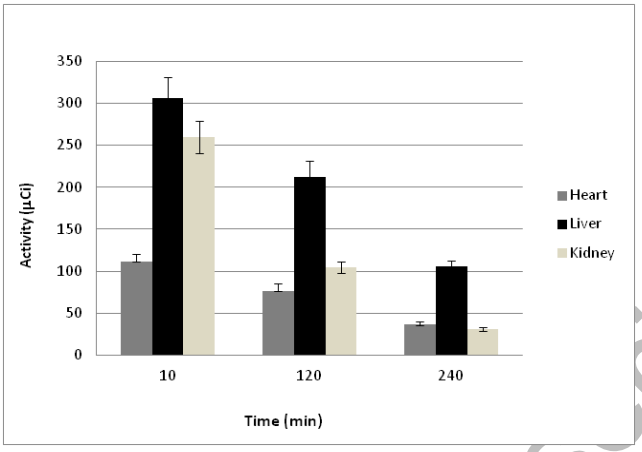

Fig. 1. Organs activity at 10 min, 120 min and 240 min post administration the mice with 5 mCi of ^{99m}Tc-MIBI.

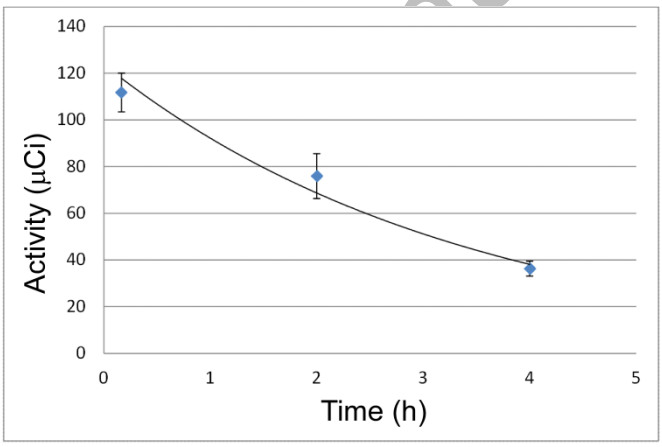

Fig. 2. Time/ activity curve for heart organ post administration the mice with 5 mCi of ^{99m}Tc-MIBI.

Figure 3 shows the activity of liver post administration with 5mCi of ^{99m}Tc-MIBI. After fitting the time/ activity curve, we obtain:

$$y = 336.81 \cdot e^{-0.28x} \quad (5)$$

The integration of equation (5) from $0 \rightarrow \infty$ gives a cumulated activity of 791.525 µCi×h.

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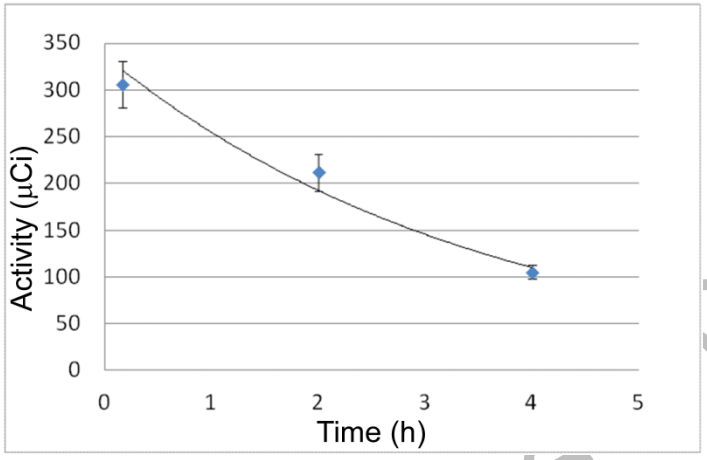

Fig. 3. Time/ activity curve for liver organ post administration the mice with 5 mCi of ^{99m}Tc-MIBI.

Figure 4 shows the activity of kidney post administration with 5 mCi of ^{99m}Tc-MIBI. After fitting the time/activity curve, we obtain:

$$y = 294.9 \cdot e^{-0.553x} \tag{6}$$

The integration of equation (6) from $0 \rightarrow \infty$ gives a cumulated activity of 469.3694 µCi×h.

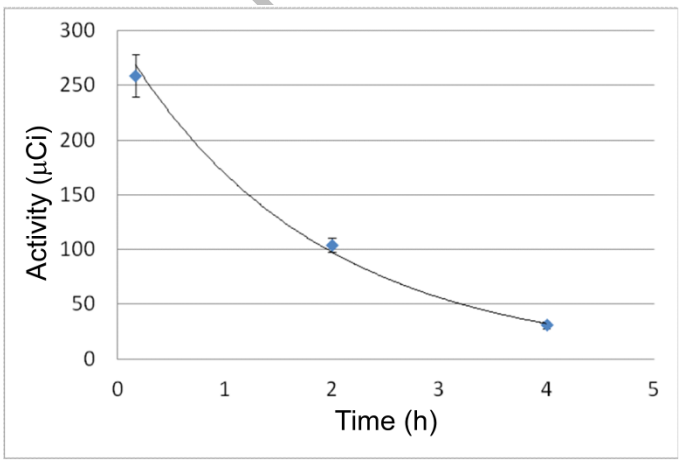

Fig. 4. Time/activity curve for kidney organ post administration the mice with 5 mCi of ^{99m}Tc-MIBI.

Absorbed dose is the fundamental radiation quantity that describes energy deposition by ionizing radiation in an absorbing medium. When dose and effects

are correctly assessed, the absorbed dose correlates well with biological effects such as adverse tissue reactions and tumor cell killing [4]. Table 1 shows the residence time, cumulated activity and the absorbed dose of the heart, liver and kidneys.

Table 1

Residence time, accumulated activity and absorbed dose measured on heart, liver and kidneys post administration of 5 mCi ^{99m}Tc-MIBI

Observed parameter	Heart	Liver	Kidneys
Residence time (h)	0.05689	0.158	0.093872
Cumulated activity (mCi×h)	284.45	791.525	469.36
Absorbed dose (mGy)	1.56	0.53	0.53

The most important effects of these variations were changes in accumulation in the heart and elimination from non-target tissues, such as the liver, and kidney. These results, in combination with the low residence time and high absorbed dose in heart, could be used as improved heart perfusion tracers for collecting high-quality scintigraphic images.

CONCLUSION

In this study the distribution of ^{99m}Tc-MIBI in mice heart, liver and kidney was investigated. The heart showed the highest uptake and the methods used in the calculation for absorbed dose are worthy to demonstrate which are the preferred target organs (heart) in myocardial perfusion imaging MPI compared to other organs.

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