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ESTIMATION OF INTERNAL EXPOSURE TO ^{99}Mo IN NUCLEAR MEDICINE PATIENTS

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Abstract – ^{99m}Tc is the most widely used radionuclide in nuclear medicine. It is obtained by elution of ^{99}Mo-^{99m}Tc generators. Depending on the quality of the generator and its integrity, ^{99}Mo may be extracted from the column during the elution process, becoming a radionuclidic impurity in the ^{99m}Tc eluate. This fact would impart an unnecessary dose to the patients submitted to diagnostic procedures. The aim of this work is to evaluate ^{99}Mo incorporation and internal effective doses in nuclear medicine patients through bioassay techniques, providing information on the metabolism of molybdenum in humans. A methodology based on in vivo and in vitro measurements was developed. In vivo measurements were performed with a NaI detector installed in the IRD WBC. Urine samples were analysed with a HPGe at the IRD bioassay laboratory. Patients showed detectable activities of ^{99}Mo in whole body and urine. Results were interpreted with AIDE software. Estimated incorporation was compared to predicted values based on ICRP model. Effective doses were in the order of micro sieverts. Results suggest the need to implement a routine quality control program of radionuclidic impurity of ^{99}Mo in ^{99m}Tc eluates to be conducted by radiopharmacy laboratories of nuclear medicine centers.

Key words: Molybdenum, tecnecium, nuclear medicine, internal dosimetry.

INTRODUCTION

The isotope ^{99}Mo, during its decay process, emits high-energy beta particles and gamma rays. These emissions, besides degrading the image quality of the examined organ, unnecessarily increase the radiation dose received by the patient. The dose coefficient due to ^{99}Mo incorporation is about 50 times higher than the corresponding value of ^{99m}Tc (3). This means that the risk of later effects due to ^{99}Mo incorporation, especially cancer, is 50 times higher than for ^{99m}Tc, per unit of activity.

The field of Nuclear Medicine has developed enormously in the last 10 years with the use of a large variety of new radioisotopes. However, technetium-99m (^{99m}Tc) continues to be the most used, representing nearly 80% of the image diagnostics all over the world.

Abbreviations: AIDE, Activity and Internal Dose Estimates; **ANVISA,** Brazilian Sanitary Agency; **CNEN,** Brazilian Nuclear Energy Commission; **HPGe,** High purity germanium; **IRD,** Institute for Radioprotection and Dosimetry; **WBC,** Whole Body Counter

One of the parameters used to state the quality of ^{99m}Tc eluates is the radionuclidic purity, MBT (molybdenum breakthrough) defined as the ratio between ^{99}Mo and ^{99m}Tc in eluates. The comparison between the radionuclidic impurity limits adopted by the American and European control agencies shows meaningful differences. European Pharmacopeia establishes that solutions to be given to patients should not present activity concentration higher than 1kBq of ^{99}Mo / 1MBq of ^{99m}Tc. American regulation does not allow this figure to be higher than 0.15 kBq of ^{99}Mo / 1MBq of ^{99m}Tc, and it establishes the obligation to carry out the control of this parameter routinely by the Nuclear Medicine Service (5). The US limit is the same recommended by the International Atomic Energy Agency (IAEA). Brazilian Regulatory Bodies (CNEN and ANVISA) do not establish neither limits nor quality control of these parameters.

Data related to injection, the main incorporation pathway used in Nuclear Medicine, are still rare and incomplete. Therefore, studies based on Nuclear Medicine patients can provide useful information to enhance the biokinetic model of ^{99}Mo in the human body, since it is possible to calculate incorporation and estimate

the committed effective dose delivered to the patient due to the presence of the radionuclinic impurity through the detection of ^{99}Mo activity in human body and biological samples.

MATERIAL AND METHODS

In vivo Measurements

In vivo measurements were performed in IRD whole body counter using a NaI(Tl) 8''x 4'' scintillation detector. The detector is located inside a shielded room with internal dimensions of 2.5 x 2.5 x 2.65 meters. The shielding is made of steel walls internally covered with lead, cadmium and zinc. Such detection system has been designed to detect and quantify low activities of radionuclides emitting photons in the energy range from 10 to 3000 keV deposited in organs and tissues of the human body (6).

The patients who agreed to voluntier in this project were monitored in the IRD whole body counter 4 to 8 days following bone scintilography procedure with ^{99m}Tc MDP. After changing clothes to a clean uniform, the volunteer had his height and weight registered and was conducted to the monitoring room to be monitored for 30 minutes.

In order to determine the background count rate in the region of interest on the in vivo measurement spectrum to calculate the ^{99}Mo activity in each patient, 40 spectra from the IRD WBC database of individuals not exposed to molybdenum were selected. Considering the average counting of the background on male and female spectra, the minimum detectable activities for the measurement of ^{99}Mo in the whole body geometry for 30 minutes counting time were 408 Bq for men and 402 Bq for women.

In Vitro Measurements

In vitro analysis was based on the collection of 24-hour urine samples from the patients who were involved in the study. The analysis was performed at the IRD Bioassay Laboratory, through gamma spectrometry using a HPGe detection system. The activities of urine samples were normalized for Bq.L^{-1}.

Methodology for Internal Dose Calculation

The interpretation of bioassay data was based on the activity of ^{99}Mo injected in the patient (intake), the activity in the whole body and in urine samples.

The software AIDE (Activity and Internal Dose Estimates) used in this work for dose calculation is based on the analytic resolution of auto-values and auto-vectors (1). This program is used to calculate activities in several parts of the body, and to estimate the committed effective dose due to the intake of radionuclides, using the bioassay data available.

In order to estimate an intake, the measurement value of the activity in the body or excreta, M, is divided by the retention or excretion fraction m(t) of the radionuclide in the body in time t after the intake:

$$Intake = M / m(t) \qquad (1)$$

The ICRP and IAEA publications (3,4) provide general values of m(t) for a variety of radionuclides in tissues and excreta. The committed effective dose is calculated by multiplying the Intake by the dose coefficient (e_{50}):

$$E(50) = I \, . \, e(_{50}) \qquad (2)$$

where E_{50} = Committed effective equivalent dose;
I = Intake (Bq);
e_{50} = Dose coefficient (Sv/Bq).

RESULTS

Table 1 shows the results of MBT determinations in samples of eluates administered to the patients who participated in this study.

Table 1. MBT values at the moment of the injection

Eluate	MBT
1	**1.033 x 10^{-2}**
2	**5.887 x 10^{-3}**
3	**6.461 x 10^{-4}**
4	**1.411 x 10^{-3}**
5	**1.411 x 10^{-3}**

All the eluates presented MBT values below the limit suggested by IAEA. This shows the good quality of the ^{99}Mo/^{99m}Tc generators used in the two NMS where the analysis were carried out.

Based on ^{99m}Tc activity incorporated and the MBT value, it is posible to calculate the intake of ^{99}Mo by each patient. Table 2 shows the values of ^{99m}Tc and ^{99}Mo intake. These values have been considered as real intakes, to be compared to the estimated intake based on in vivo and in vitro measurements.

Table2. ^{99m}Tc and ^{99}Mo Incorporated Activities

Patient	**^{99m}Tc (Bq) Intake**	^{99}Mo (Bq) Intake
1	**1.110 x 10^{9}**	1.147 x 10^{4}
2	**9.620 x 10^{8}**	5.665 x 10^{3}
3	**9.250 x 10^{8}**	5.976 x 10^{2}
4	**9.250 x 10^{8}**	1.305 x 10^{2}
5	**9.250 x 10^{8}**	1.305 x 10^{2}

Table 3 compares the committed effective doses calculated from the real value (based on the ^{99}Mo measurement in the eluates) and the estimated values from the in vivo and in vitro measurements.

The committed effective doses of the patients varied between 0.03 and 2.6 μSv using the real intake values as a basis, i.e, determined from the eluate measurement. Considering the dose limit of 1mSv per year for the public, it is concluded that the levels of ^{99}Mo detected on the eluates administred to the patients represent a small contribution to the dose limit of public. Such value is also insignificant if compared to the dose of 4.2 mSv, due to the administration of 20mCi of ^{99m}Tc for a bone cintilography.

The radiation dose received by an organ or tissue depends on the physical and biological half lifes of the radionuclide incorporated. The combination of these parameters results in the effective half-life, which is the time in which the activity in the organ or tissue becomes half of its initial value. From the measurement of the activities in the whole body of the patients, the effective half-life of ^{99}Mo was estimated, using the radioactive decay formula. The average values of effective half-life was 2.34 ± 0.44 days.

Table3. Comparison between effective doses calculated from eluate and bioassay measurements

Patient	Dose estimation (μSv)		
	Eluate	*In Vivo*	*In Vitro*
1	2.627	7.537	10.63
2	1.297	1.607	7.129
3	0.134	0.738	2.591
4	0.030	0.4266	3.295
5	0.030	0.6474	2.179

When an element, radioactive or not, is introduced in a living organism, it suffers its own metabolization and excretion. Biological half live is the time required for half of the ingested element to be eliminated from the organism through natural ways. Biological half-life was calculated using 2.75 days physical half-life and effective half-lives calculates through in vivo model and measurements.

Biological half-life calculated through the model (60.3 days) is 3.8 times longer than value calculated through in vivo monitoring (15.7 days). This means that, according to ICRP model, ^{99}Mo is retained in the human body much time than observed in the experimental data obtained in this study. These data are in agreement with the values of about 20 days, suggested by Giussani et al (2).

DISCUSSION

The minimum detectable activities for in vivo monitoring of ^{99}Mo in the whole body geometry in 30 minutes of counting were 408 Bq for men and 402 Bq for women. This sensitivity allows the detection and quantification of ^{99}Mo in levels suitable for studies related to incorporation of ^{99}Mo in patients submitted to diagnostics with ^{99m}Tc.

All the eluates collected and analysed present MBT values below the levels suggested by IAEA. This shows the conformity of the generators used in both Nuclear Medicine Services where the present study was carried out. However, considering the small sampling, routine procedures of eluate quality control in the Nuclear Medicine Services should be implemented in a routine basis, in order to guarantee that the patients are not submitted to unnecessary doses due to the presence of ^{99}Mo as eluate radionuclidic impurity.

Average real ^{99}Mo intake by the patients, determined through the measurement of the eluates collected in the Nuclear Medicine Services was 3599 Bq, which represents an effective dose of 0.82 μSv. Such dose does not represent a significant contribution on the dose limit for the public.

Other articles in this theme issue include references (7-14).

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