Development of a Method to Assess the Radiation Dose due to Internal Exposure to Short-lived Radioactive Materials

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INTRODUCTION

Work with radioactive materials requires monitoring of the employees' exposure to ionizing radiation. Employees may be exposed to radiation from internal and/or external exposure. Control of external exposure is mostly conducted through personal radiation dosimeters provided to employees. Control of internal exposure can be performed by measuring the concentration of radioactive substances excreted in urine or through whole-body counting in which the entire body or target organs are scanned with a sensitive detector system \cite{1}. According to the regulations in Israel an employee that may be internally exposed must undergo an exposure control at least once every three months. The idea lying behind the control of internal exposure by urine testing is that if radioactive material has penetrated into the employee body, it can be detected even if the test is performed once every three months. A model was fitted for each element describing its dispersion in the body and its excretion therefrom \cite{2}. By means of this model, one can estimate the activity that entered the body and calculate the resulting radiation dose to which the worker was exposed. There is a problem to implement this method when it comes to short-lived radioactive materials, for which it is very likely that the material that penetrated into the body has decayed and cannot be detected by testing once every three months. As a result, workers with short-lived radioactive materials are presently not monitored for internal exposure, in contradiction to the requirements of the Safety at Work Regulations. The purpose of the study is to develop an alternative method to assess the amount of radioactive material absorbed in the body and the resulting radiation dose due to internal exposure of workers to short-lived radioactive materials.

METHODS

Two methods for monitoring two radionuclides that enter the body were investigated in the study.

\textbf{\textsuperscript{99m}Tc}

The method is based on introducing a known activity of \textsuperscript{99m}Tc in various organs inside a phantom (liver, stomach and other organs in the abdomen), and measuring the dose rate in front of the stomach area. The bio-kinetic model of \textsuperscript{99m}Tc determines its distribution among the different body organs.

The first step is to determine the activity that if introduced daily into the body will cause a dose of 1 mSv per year (the dose limit to members of the public), taking into account the physical and biological decay (“activity threshold”).

The second step is to measure the dose rate corresponding to the activity threshold in front of the stomach of the phantom. This dose rate is used as a decision value above which employees are sent to a urine test or a whole-body counter test. In addition, the behavior of the dose rate as a function of the activity was examined, in order to ensure that this behavior is linear.

\textbf{\textsuperscript{131}I}

The method is based on measuring the count rate produced by a known activity of \textsuperscript{131}I inside a capsule by means of an uptake counting instrument.
The same two-step procedure as for $^{99m}$Tc is used for $^{131}$I with two differences: the measurement is carried out in front of the thyroid and a count rate is measured in cpm (counts per minute).

**RESULTS**

$^{99m}$Tc

To determine the threshold value above which the employee should be sent to a urine test, a few radiation detectors were tested, functioning according to different principles (Geiger-Mueller (GM) counter, proportional counter and plastic scintillator). Measurement results were obtained in units of cps (GM counter and proportional counter) or μSv/h (plastic scintillator).

a. The results obtained with the radiation detectors 1 and 2 (a GM counter and a proportional counter, respectively) show that the coefficients of variation for these radiation monitors are quite low (0.22 and 0.13, respectively) and the results are therefore highly reliable. In addition, there is a very good correlation between the activity introduced in the phantom and the count rate ($R^2 = 0.9856$ and $R^2 = 0.9615$, respectively). However, for radiation detectors that measure the count rate (cps), the size of the detector and its principle of operation have a strong influence on the results. Therefore, since it cannot be guaranteed that all employers possess a specific radiation detector, an instrument that measures the count rate is not suitable as a screening tool for radiotoxicology monitoring.

b. The results obtained with the radiation detectors 3 and 4 (plastic scintillators) show that the coefficients of variation for these instruments are low (0 and 0.43, respectively). In addition, there is a very good correlation between the activity introduced into the phantom and the radiation dose rate (μSv/h) ($R^2 = 0.972$ and $R^2 = 0.9298$, respectively). Therefore, both monitors are suitable as screening tools for radiotoxicology monitoring. The radiation dose rate that was defined as the threshold value above which a urine test should be conducted is 0.1 μSv/h above the background level.

c. In spite of the recommendations in paragraphs (a) and (b) above, since the RAM GENE 1 GM device (Rotem Ltd.) is a relatively cheap instrument, workplaces involved in working with $^{99m}$Tc that do not possess a plastic scintillator could use a RAM GENE 1 detector. The threshold value above which a urine test should be conducted is in this case 2 cps above the background radiation level.

$^{131}$I

The results of the experiments conducted show that the coefficient of variation is very low (0.15). In addition, a very good correlation exists between the activity of $^{131}$I in the thyroid and the count rate (cpm) ($R^2 = 0.9987$). Therefore, a Model CAPTUS 2000 (Capintec Inc.) can be used as a screening tool for radiotoxicology monitoring. It was found that the measurement period should last at least two minutes. The threshold value above which a urine test should be performed is 20 cpm.

**CONCLUSIONS AND RECOMMENDATIONS**

The following conclusions and recommendations can be drawn from the present study:

1. Workers with $^{99m}$Tc should be checked at the end of each working day with a radiation detector of the plastic scintillator type positioned in front of the stomach. If the reading is higher than 0.1μSv/h, a urine sample should be immediately sent to a radiotoxicology laboratory. Every reading lower than this value should be considered as negligible. A GM detector can also be used for this purpose, but because of the strong influence of the detector size, the use of a uniform device should be recommended. Economic considerations being taken into account, the most suitable device is the RAM GENE 1. The threshold value is in this case 2 cps above the background level.

2. Workers with $^{131}$I should be checked at the end of each working week with an uptake device. The threshold value above which a urine sample should be sent to a radiotoxicology laboratory is 20 cpm (above the background level).
REFERENCES