

Estimation of Internal Radiation Dose to Nuclear Medicine Workers at Siriraj Hospital

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Abstract— Every type of work performed in a nuclear medicine department will make a contribution to both external and internal exposure of the worker. The purpose of this study is to evaluate the potential risks of internal contamination to staff members during nuclear medicine practices and to conclude about the requirement of a routine internal monitoring. Following the method describes in the ICRP Publication 78 and the IAEA Safety Standard Series No. RS-G-1.2, in vivo thyroid bioassays using NaI(Tl) thyroid probe were performed to determine the intake estimates on 7 groups of nuclear medicine personnel working with I-131 and Tc-99m, based on working conditions and amount of radionuclides being handled. Frequency of measurements was between 7 and 14 days. These include (1) physicians and physicists, (2) radiochemists (3) technologists, (4) nurses and assistant nurses, (5) imaging room assistants, (6) hot lab workers and (7) hospital ward housekeepers/cleaners. Among all workers, the intake estimates of I-131 in the thyroid ranged from 0 to 76.7 kBq and of the technetium-99m from 0 to 35.4 MBq. The mean committed effective dose equivalent (CEDE) from both I-131 and Tc-99m were 0.63, 1.44 0.53, 0.57, 0.73, 0.98, and 1.36, mSv, for group 1 through group 7 respectively. However, the highest mean CEDE of 1.44 (max. 1.75) and 1.36 (max. 2.11) mSv observed in groups of radiochemists and hospital ward housekeepers were within the permissible level. Our results showed that CEDE for internal exposure in this study were less than investigate level of 5 mSv according to the ICRP Publication 78 and the IAEA Basic Safety Standards. However, the mean CEDE for radiochemists and hospital ward housekeepers were considered in exceed of the limits of recording level (1 mSv). The increasing use of I-131 and Tc-99m in nuclear medicine poses significant risks of internal exposure to the staff. This study suggests that a routine monitoring program for internal exposures should be implemented for most nuclear medicine workers in order to demonstrate that individual doses are kept as low as possible.

Keywords— Internal dose, committed effective dose equivalent, nuclear medicine workers

I. INTRODUCTION

The increase in the number of diagnostic nuclear medicine procedures has resulted in an increase in cumulative exposure to workers. In the year 2000, UNSCEAR estimated that, worldwide, approximately 32 million diagnostic nuclear medicine procedures are performed each year [1]. Every type of work performed in a nuclear medicine facility will make a contribution to the exposure of the worker. Physicians and nurses engaged in the intravenous injection of radiopharmaceuticals, technologists performing nuclear medicine examinations, radiochemists preparing radiopharmaceuticals for diagnostic imaging and therapeutic applications, as well as other

workers involved in the handling of radioactive sources need to be monitored for the radiation doses received. Due to the unsealed nature of the radioactive sources used in these activities, the potential risks are of both external and internal exposure. The most frequently used radioactive sources in nuclear medicine practices is I-131 and Tc-99m. I-131 is highly volatile and radiotoxic [2], Tc-99m in the aerosolized form exhaled from the patients in ventilation study can be inhaled by the nuclear medicine staff and be hazardous if internally deposited. According to the requirements recommended in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (IAEA Safety Series No. 115) [3], individual dose monitoring shall be undertaken for workers who are normally exposed to radiation in controlled areas.

This study is aimed to evaluate the potential risks of internal contamination of I-131 and Tc-99m to staff members during nuclear medicine practices on routine individual monitoring basis following a methodology proposed by the International Atomic Energy Agency (IAEA Safety Standards Series RS-G-1.2) [4] and ICRP Publication 78 [5]. An in vivo thyroid bioassay is used to assess occupational exposure due to intakes of I-131 and Tc-99m in a group of workers involved in handling large quantities of I-131 and Tc-99m radiopharmaceuticals or likely to receive an intake of radioactive material. These include nuclear medicine physicians, radiochemists, physicists, technologists, nurses and assistant nurses, and other ancillary workers.

II. MATERIALS AND METHODS

A. Instruments and calibration sources

1. Thyroid uptake system, Microprocessor-controlled 1024 channel Multi-Channel Analyzer with 2"×2" NaI(Tl) detector, flat field collimator IAEA standard and a personal computer interface, Model Biodex Medical Systems, Atomlab 950 PC.
2. Dose calibrator, Model CAPINTEC/CRC-15R, Serial No. 152-455, CAPINTEC, Inc. New Jersey 07445 USA.
3. IAEA Standard Thyroid phantom by ORTEC
4. Certified I-131 (1.19 μ Ci) and Tc-99m (1.16 μ Ci) sources, obtained from the Office of Atom for peace.

B. Determination of counting efficiency

Counting efficiency of I-131 and Tc-99m was determined using certified sources obtained from the Office

of Atom for Peace, Ministry of Science and Technology. The counting efficiency of I-131 and Tc-99m was 0.001471 and 0.000744 count per second/Bq respectively.

C. Calculating minimum detectable activity (MDA)

The smallest amounts of sample activities for the measurements of I-131 and Tc-99m in neck phantom with a counting time of 4000 seconds were investigated by using the following equation [4]:

$$MDA_{\mu Ci} = \frac{\frac{2.71}{T_s} + 3.27 \sqrt{\frac{R_b}{T_b} + \frac{R_b}{T_s}}}{(E) \times \left(2.22 \times 10^6 \frac{dpm}{\mu Ci} \right)}$$

T_s = sample counting time
 T_b = background counting time
 R_b = background counting rate
 R_s = sample counting rate
 E = counting efficiency

The minimum detectable activity (MDA) for I-131 and Tc-99m was 231.5 Bq and 122.7 Bq respectively.

D. Counting windows for simultaneously measurements of I-131 and Tc-99m

The dual isotope counting technique was applied to reduce monitoring time. I-131 was counted simultaneously with Tc-99m in separate counting windows, which were not overlapping. The spillover from the I-131 to the Tc-99m window was corrected [6]. The counting window for I-131 was set between 330 keV and 410 keV and between 119 keV and 162 keV for Tc-99m.

E. Categorization of workers

Thirty five nuclear medicine workers were categorized into 7 groups based on working conditions and amount of radionuclides being handled. These include 2 nuclear medicine physicians and physicists, 7 technologists, 7 nurses and assistant nurses, 2 radiochemists, 6 imaging room assistants, 4 hot lab assistants and 7 hospital ward housekeepers/cleaners. Based on risk associated with everyday activities of which contamination is likely to occur. The monitoring time interval was set at 12, 1, 8, 8, 4, 2 and 1 weeks for group 1 through 7 respectively. The thyroid activities of both I-131 and Tc-99m was measured simultaneously for 10 minutes and another 10 minutes for background subtraction. The protocol was approved by the Siriraj Ethics Committee for Human Experiment and a written informed consent was obtained from each subject.

III. RESULTS

The intake estimates on 7 groups of 35 nuclear medicine workers involved in handling I-131 and Tc-99m was presented in Table 1. Almost all workers presented positive

results of the thyroid uptake. Uptake values at or below the minimum detectable activity (MDA) were assigned the value zero to represent undetectable measurements. The mean intake estimates for group 1 through 7 ranged from 0 to 76.7 kBq for I-131 and 0 to 35.4 MBq for Tc-99m. The mean \pm SD of the intake estimates for all groups were 25.40 ± 15.46 kBq for I-131 and 13.24 ± 4.0 MBq for Tc-99m. The corresponding CEDE was 0.51 ± 0.31 mSv for I-131 and 0.38 ± 0.12 mSv for Tc-99m as shown in Table 2. A combination of dose estimates of I-131 and Tc-99m was shown in Figure 1. The overall CEDE of group 1 through 7 ranged from 0.53 to 1.44 mSv. Mean \pm SD for all groups was 0.89 ± 0.38 mSv (Table 2). Overall CEDE results above the recording level of 1 mSv was observed in two groups of workers, radiochemists (1.44 mSv) and hospital ward housekeepers/cleaners (1.36 mSv).

Table 1 Intake estimates of I-131 (kBq) and Tc-99m (MBq) in nuclear medicine workers.

Categorization	I-131 (kBq)			Tc-99m (MBq)		
	min	max	mean	min	max	mean
Physicians and physicists	0 ^a	35.8	17.9	0 ^a	18.9	9.4
Radiochemists	44.5	62.0	53.3	8.4	17.5	13.0
Technologists	0 ^a	39.3	14.8	0 ^a	21.6	8.0
Nurses and assistant nurses	0 ^a	28.0	10.3	0 ^a	31.6	12.7
Imaging room assistants	0 ^a	40.8	16.7	0 ^a	33.7	13.6
Hot lab workers	16.2	35.1	25.9	8.2	26.8	16.0
Housekeepers /cleaners	12.4	76.7	39.0	5.0	35.4	20.0
Mean \pm SD	25.40 \pm 15.46			13.24 \pm 4.0		

^a Intake values below MDA of both I-131 and Tc-99m was assigned the value undetectable measurements (0 Bq).

Table 2 Dose estimates (mSv) of I-131 and Tc-99m in nuclear medicine workers.

Categorization	I-131 CEDE (mSv)			Tc-99m CEDE (mSv)		
	min	max	mean	min	max	mean
Physicians and physicists	0	0.71	0.36	0	0.55	0.27
Radiochemists	0.89	1.24 ^a	1.07	0.24	0.51	0.38
Technologists	0	0.79	0.30	0	0.63	0.23
Nurses and assistant nurses	0	0.56	0.21	0	0.62	0.37
Imaging room assistants	0	0.82	0.33	0	0.98	0.39
Hot lab workers	0.32	0.7	0.52	0.24	0.78	0.46
Housekeepers /cleaners	0.25	1.53 ^a	0.78	0.14	1.03 ^a	0.58
Mean \pm SD	0.51 \pm 0.31			0.38 \pm 0.12		
Overall CEDE (I-131 + Tc-99m)	0.89 \pm 0.38			0.89 \pm 0.38		

^a CEDE exceed the recording level of 1 mSv

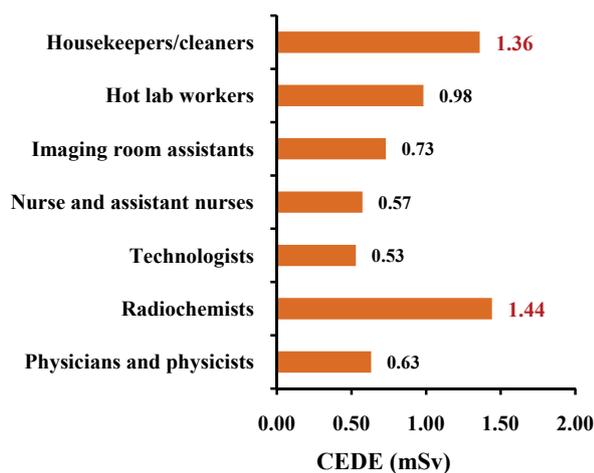


Fig. 1 Dose estimates (CEDE) (I-131 + Tc-99m) performed in nuclear medicine workers by vivo thyroid bioassay.

IV. DISCUSSION

Standards for protection against radiation established radiation dose limits for occupationally exposed adults [3, 7- 10]. These limits apply to the sum of the dose received from external exposure and the dose from internally deposited radioactive materials. The total effective dose equivalent of an individual is determined by combining the external and internal dose equivalent values. Radiation doses due to internally deposited radionuclides are calculated based on the intake which is the amount of radioactive material taken into the body by inhalation, absorption through the skin, injection, ingestion, or through wounds. Once the intake measurements is determined, it can be used to calculate the intake of a radionuclide, which, when multiplied by the appropriate dose coefficient, leads to an estimate of committed effective dose.

In this study, the results showed that the internal dose estimates from the intakes of I-131 and Tc-99m to nuclear medicine staff were well within permissible levels. Mean value (0.89 ± 0.38 mSv) of committed effective dose associated (CEDE) to the thyroid measurements performed were below the recording level of 1 mSv. However, the dose estimated exceeding this level but below the investigation level of 5 mSv was observed in a group of radiopharmacists and hospital ward housekeepers/cleaners.

V. CONCLUSIONS

This study suggests that categorization of workers is needed and a routine monitoring for internal dose estimation should be performed in most of the workers. The periodicity of monitoring should depend on the likelihood that the individual could receive an intake of radioactive material exceeding a predetermined level.

ACKNOWLEDGMENTS

The research was partially supported by a grant from the Faculty of Medicine Siriraj Hospital.

We are grateful to the Office of Atom for Peace for providing technical assistance and scientific documents and to all physicians, technologists, nurses and physicists and other ancillary workers for their contribution to this work.

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