Finger Doses for Staff Handling Radiopharmaceuticals in Nuclear Medicine

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Radiation doses to the fingers of occupational workers handling ^{99m}Tc-labeled compounds and ^{131}I for diagnostic and therapeutic procedures in nuclear medicine were measured by thermoluminescence dosimetry. **Methods:** The doses were measured at the base of the ring finger and the index finger of both hands in 2 groups of workers. Group 1 (7 workers) handled ^{99m}Tc-labeled radiopharmaceuticals, and group 2 (6 workers) handled ^{131}I for diagnosis and therapy. Radiation doses to the fingertips of 3 workers also were measured. Two were from group 1, and 1 was from group 2. **Results:** The doses to the base of the fingers for the radiopharmacy staff and physicians from group 1 were observed to be 17 ± 7.5 (mean ± SD) and 13.4 ± 6.5 μSv/GBq, respectively. Similarly, the dose to the base of the fingers for the 3 physicians in group 2 was estimated to be 82.0 ± 13.8 μSv/GBq. Finger doses for the technologists in both groups could not be calculated per unit of activity because they did not handle the radiopharmaceuticals directly. Their doses were reported in millisieverts that accumulated in 1 wk. The doses to the fingertips of the radiopharmacy worker and the physician in group 1 were 74.3 ± 19.8 and 53.5 ± 21.9 μSv/GBq, respectively. The dose to the fingertips of the physician in group 2 was 469.9 ± 267 μSv/GBq. **Conclusion:** The radiation doses to the fingers of nuclear medicine staff at our center were measured. The maximum expected annual dose to the extremities appeared to be less than the annual limit (500 mSv/y), except for a physician who handled large quantities of ^{131}I for treatment. Because all of these workers are on rotation and do not constantly handle radioactivity throughout the year, the doses to the base of the fingers or the fingertips should not exceed the prescribed annual limit of 500 mSv.

Key Words: finger radiation dose; TLD; average radiation dose

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The most commonly used radionuclides in nuclear medicine are ^{99m}Tc and ^{131}I. Their applications have been continuously increasing for diagnostic and therapeutic procedures in most of the nuclear medicine facilities in India. Although such an increase is a positive trend for the benefit of patients, the associated risk of radiation exposure of staff needs to be properly evaluated. Generally, occupational workers are routinely monitored for their effective whole-body doses by use of chest badges and doses to extremities by use of wrist badges in most of the nuclear medicine centers in India. The equivalent doses to the fingers, which are closest to the radioactive sources during handling, are rarely measured. The measurement of radiation doses to the fingers of staff involved in handling large quantities of radioactivity not only indicates the level of radiation safety standards maintained at a given center but also can act as a guide for safe work practice.

Thermoluminescence dosimetry disks are normally used to measure radiation doses to the fingers of staff involved in handling radioactivity (*1,2*). The present study was undertaken to estimate the radiation doses to the base of the ring finger and the index finger of both hands of staff handling large quantities of ^{99m}Tc and ^{131}I for diagnostic and therapeutic purposes. In some workers, doses to the fingertips also were measured.

MATERIALS AND METHODS

Thermoluminescence dosimeters (TLD; Renentech Inc.) consisting of disks measuring 4.5 mm (diameter) by 0.9 mm (thickness) were used in this study for measuring finger doses for staff handling ^{99m}Tc-labeled compounds and ^{131}I for diagnosis and therapy of patients with thyrotoxicosis and differentiated thyroid cancer. TLD have been reported to be suitable for such studies (*3,4*). As the response of the TLD used in this study is known to have energy dependence, separate dose–response relationships were established for γ-radiation from ^{99m}Tc and ^{131}I before the TLD were used for finger dose estimation. Only TLD for which the sensitivity variations were less than ±10% were used in this study.

The TLD were inserted in a plastic ring holder that could be adjusted for any finger size. The occupational workers wore them at the base of the index finger and the ring finger of both hands. In 3 workers, doses to the fingertips also were measured. The workers wearing these TLD were advised to wear rubber gloves over them to avoid any possible radioactive contamination. The TLD were kept in a low-background-radiation area when not in use.

Two groups of workers were evaluated. Group 1 consisted of 2 workers from the radiopharmacy, 2 physicians, and 3 technologists. These workers handled ^{99m}Tc-labeled compounds, and

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their finger doses were estimated. The radiopharmacy staff was involved in the elution of ^{99m}Tc (from the ^{99}Mo-^{99m}Tc generator) and the preparation of ^{99m}Tc-labeled compounds for diagnostic procedures. The nuclear medicine physicians were involved in loading of the individual doses of ^{99m}Tc-labeled radiopharmaceuticals into syringes and in intravenous administration to patients for γ-camera imaging. The nuclear medicine technologists were involved in positioning and imaging of the patients and occasionally in assisting physicians in dose administrations. Doses to the fingertips of a radiopharmacy worker and a physician involved in handling ^{99m}Tc-labeled compounds also were measured.

Group 2 consisted of 3 nuclear medicine physicians and 3 technologists. The physicians handled therapeutic quantities of ^{131}I for the treatment of patients with differentiated thyroid cancer and thyrotoxicosis. Two technologists were involved in routine monitoring of the patients in an isolation ward, and the third technologist was involved in imaging of the patients before and after radioiodine therapy. However, the technologists did not handle the radioactivity directly. Doses to the tips of the ring and index fingers of a physician also were measured.

While wearing the ring dosimeters, none of the workers used a syringe shield while handling radioactivity. The use of a syringe shield is recommended from a radiation safety standpoint but is not mandatory in India. Some workers use them, and some do not. A control ring was kept in a low-background-radiation area for measuring the background response of the TLD. The staff used the ring dosimeters for 1 wk and returned them for measurements. Some of them were issued another batch of ring dosimeters for the next week if they had to perform identical work. The process was repeated for 4 wk for some of the workers. Thus, we could measure the finger doses for workers for a period ranging from 1 to 4 wk. Doses to the fingertips were measured for the ring and index fingers of both hands for only 1 wk.

Exposed TLD were read with a RADOS TLD reader (RADOS Technology Oy). The doses were expressed in microsieverts or millisieverts by use of the dose–response (calibration) curves for ^{99m}Tc and ^{131}I γ-rays (*5*).

RESULTS

Irradiated TLD disks with different doses of γ-photons from ^{99m}Tc and ^{131}I were placed in the TLD reader to obtain their response in relation to radiation dose. The average response (counts) of 3 TLD inside each holder was obtained and corrected for background. The method used for the calibration procedure is described elsewhere (*5*). The radiation weighting factor for the γ-photons from both ^{131}I and ^{99m}Tc was taken as 1.

Table 1 shows the radiation doses to the fingers of the group 1 workers. As expected, the radiation doses to the fingers of the radiopharmacy staff and the physicians involved in intravenous administration were observed to be higher than those for the technologists. The dose to the right index finger of a physician (RW4) could not be measured for technical reasons. The technologist designated as RW6 worked in the radiopharmacy laboratory in addition to his routine duties in γ-camera imaging during the period of this study; this schedule led to finger doses higher than those for the other 2 technologists.

Table 2 shows the finger doses for group 2 workers. Three physicians prepared and administered therapeutic doses of radioiodine to patients with thyroid cancer and thyrotoxicosis, 2 technologists were involved in the routine monitoring of patients, and the third technologist was involved in imaging of the patients before and after radioiodine therapy. The dose to the right index finger of a physician (RW9) could not be measured for technical reasons.

TABLE 1
Finger Doses for Group 1 Workers Involved in Handling ^{99m}Tc-Labeled Compounds

Workers	Activity handled/wk (GBq)	Hand	Dose (mSv) accumulated in 1 wk: Index finger base	Dose (mSv) accumulated in 1 wk: Ring finger base	Mean ± SD finger dose (mSv) accumulated in 1 wk for both hands
Radiopharmacy laboratory					
RW1	97.1	Right	2.2	0.8	1.2 ± 0.6
		Left	0.9	1.0	
RW2	35.1	Right	0.6	0.5	0.6 ± 0.1
		Left	0.8	0.7	
Physicians					
RW3	83.3	Right	1.5	1.8	1.4 ± 0.4
		Left	0.9	1.3	
RW4	24.1	Right		0.4	0.3 ± 0.1
		Left	0.3	0.3	
Technologists					
RW5		Right	0.1	0.1	0.1 ± 0.1
		Left	0.1	0.2	
RW6	36.6 (in radiopharmacy)	Right	0.6	0.8	0.8 ± 0.1
		Left	0.8	0.9	
RW7		Right	0.2	0.2	0.2 ± 0.1
		Left	0.2	0.1	

TABLE 2
Finger Doses for Group 2 Workers Involved in Handling ^{131}I

Workers	Activity handled/wk (GBq)	Hand	Dose (mSv) accumulated in 1 wk: Index finger base	Dose (mSv) accumulated in 1 wk: Ring finger base	Mean ± SD finger dose (mSv) accumulated in 1 wk for both hands
Physicians					
RW8	22.2	Right	1.8	1.8	1.9 ± 0.2
		Left	1.7	2.1	
RW9	22.6	Right		1.4	1.5 ± 0.7
		Left	1.7	1.4	
RW10	21.6	Right	2.3	2.1	2.0 ± 0.3
		Left	1.7	1.9	
Technologists					
RW11		Right	0.3	0.4	0.3 ± 0.1
		Left	0.3	0.3	
RW12		Right	0.2	0.2	0.2 ± 0.0
		Left	0.2	0.2	
RW13		Right	0.1	0.1	0.1 ± 0.0
		Left	0.1	0.1	

The doses to the tips of the index and ring fingers of both hands of 3 workers (2 from group 1 and 1 from group 2) are shown in Table 3. The maximum dose was observed for the fingertips of a physician in group 2 who handled a large quantity of radioiodine for therapy.

The dose range and the mean dose to the base and tips of the fingers of workers in group 1 are shown in Table 4. With this level of exposure (average) in handling ^{99m}Tc-labeled compounds, exposure would not be expected to exceed the prescribed annual limit of 500 mSv for any worker, particularly when duties change periodically from one area to another. All of the areas of work examined in this study had the highest potential for exposure of fingers of the occupational staff.

The dose range and the mean dose to the base and tips of the fingers of a worker in group 2 also are shown in Table 4. With this level of exposure (average) in handling ^{131}I, exposure could exceed the annual limit of 500 mSv if the worker continued to perform the same work throughout the year. However, in our facility, each physician is involved in therapeutic ^{131}I procedures for a period not exceeding 6 mo under the supervision of a consultant. The finger doses per unit of activity for technologists are not shown in Table 4 because technologists do not handle ^{131}I directly.

DISCUSSION

Staff preparing and administering radiopharmaceuticals in nuclear medicine, whether for diagnostic imaging or for therapeutic application, may receive significant radiation doses to their hands, particularly the fingers. Ring dosimeters are useful for measuring doses at either the base or the tip of the fingers of staff handling large quantities of radiopharmaceuticals in nuclear medicine. Finger doses can serve as a guide to suggest any needed modification in work practice to minimize radiation doses to the extremities. For all of the workers in this study, doses to the base of the index and ring fingers that accumulated in 1 wk suggested that exposure was not likely to exceed the annual limit of 500 mSv in our facility. However, the same may not be true for fingertips. Fingertips are closer to the radiation sources in most situations during handling of radioactivity.

TABLE 3
Doses to Tips of Index and Ring Fingers of Both Hands of 3 Occupational Workers

Workers	Activity handled/wk (GBq)	Hand	Dose (mSv) accumulated in 1 wk: Tip of index finger	Dose (mSv) accumulated in 1 wk: Tip of ring finger	Mean ± SD finger dose (mSv) accumulated in 1 wk for both hands
Radiopharmacy laboratory					
RW1	87.2 (^{99m}Tc)	Right	8.7	5.1	6.5 ± 1.7
		Left	7.0	5.1	
Physicians					
RW4	34.6 (^{99m}Tc)	Right	1.4	1.2	1.9 ± 0.6
		Left	2.9	1.9	
RW10	21.6 (^{131}I)	Right	18.4	9.7	10.2 ± 5.8
		Left	7.0	5.5	

TABLE 4
Dose Range and Mean Doses to Fingers of Workers Involved in Handling Radiopharmaceuticals

Group	Radiopharmaceuticals handled	Workers	Dose range (μSv/GBq)		Mean ± SD finger dose (μSv/GBq)	
			Base of fingers	Fingertips	Base of fingers	Fingertips
1	^{99m}Tc-Labeled compounds	Radiopharmacy staff	8.2–28.5	58.5–99.8	17.0 ± 7.5	74.3 ± 19.8
		Physicians	10.8–21.6	34.7–83.8	13.4 ± 6.5	53.5 ± 21.9
2	^{131}I	Physicians	61.9–106.5	254.6–851.8	82.0 ± 13.8	469.9 ± 267.0

In 1 worker in this study, the average dose to the fingertips of 10.2 mSv that accumulated in 1 wk suggested that the annual dose for the worker could reach or even exceed the annual limit of 500 mSv if the worker continued to perform the same type of work throughout the year. The physicians in this study handled therapeutic ^{131}I for a period of 6 mo over a span of 3 y. In this study, we selected the workers and the type of work with the highest potential for exposure of the extremities, particularly the fingers. However, the chance of exceeding the prescribed annual limit for these workers was remote in our practice. Further, doses to the fingertips of physicians were evaluated during the initial period of posting, when physicians generally perform procedures slowly to avoid spillage and contamination.

The annual equivalent doses to fingertips have been reported to potentially exceed the annual limit of 500 mSv (*6,7*). To control exposure to the fingers, syringe shields made of lead or tungsten are normally used. A dose rate of 1.35–1.62 mGy/h/MBq was reported when activity was contained in disposable syringes shielded by lead glass (*8*). The syringe shield is one of the devices used to minimize radiation doses to fingers during injections, whereas the use of specialized syringe calibrators reduces the doses to fingers during dose measurements with calibrators (*9,10*). The use of syringe shields can reduce finger doses by 75%–85%, and doses received from individual injections vary from 1 to 150 μGy, depending on the degree of difficulty experienced during injection (*11*). Finger doses can be reduced by use of a short-tubing butterfly cannula inserted into the vein of patients before radiopharmaceutical administration (*12*).

The highest finger dose reported at a radiopharmacy and dispensary in 1 wk has been reported to be 6.8 mSv, which corresponds to an annual dose of 330 mSv (*13*). At the same center, weekly and annual doses during the administration of injections were recorded to be 4.6 and 220 mSv, respectively. In the present study, the highest finger dose that accumulated in 1 wk for a physician injecting ^{99m}Tc-labeled compounds was observed to be 1.4 ± 0.4 mSv. The radiopharmacy worker who handled the maximum activity of ^{99m}Tc during the period of this study showed a finger dose of 1.2 ± 0.6 mSv that accumulated in 1 wk. If these workers continued to perform the same procedures throughout the year, their finger doses probably would not exceed 65 mSv (maximum, 80 mSv) in 1 y.

The radiation dose to fingertips has been reported to be 0.18 mSv/10 GBq with ^{99m}Tc-labeled compounds (*14*). In the present study, the maximum dose to the fingertips of a physician involved in radiopharmaceutical injections was recorded to be 0.8 mSv/10 GBq with ^{99m}Tc-labeled compounds (with a mean ± SD of 0.5 ± 0.2 mSv/10 GBq). This dose could lead to an annual dose of 90–325 mSv if this physician continued to perform the same procedure throughout the year.

In this study, relatively higher finger doses were observed for physicians handling ^{131}I for therapeutic procedures. Doses to the fingertips also were found to be higher in a physician involved in the preparation and administration of ^{131}I for therapy. The 1-wk accumulated dose to the fingertips of a physician handling ^{131}I was found to be 10.2 ± 5.8 mSv; this dose could lead to an annual dose exceeding the 500-mSv annual limit if the physician continued to perform the same work with radioiodine throughout the year. At our center, each physician performs this work for a period not exceeding 6 mo. This situation is applicable to all of the physicians, as they are on rotation, except for the consultant in charge of ^{131}I treatment, who supervises all of the treatments throughout the year. We measured the fingertip dose for a physician who was in the initial stage of this posting, when physicians handle ^{131}I slowly to avoid any spillage and contamination. In our practice, exposure is not likely to exceed the annual limit of 500 mSv for any physician under normal prevailing work circumstances.

CONCLUSION

Radiation doses per unit of activity (μSv/GBq) to the base of the index and ring fingers of radiopharmacy staff were observed to be nearly the same as those for physicians involved in injections of ^{99m}Tc-labeled compounds. However, the total dose to the fingertips of a radiopharmacy worker was observed to be 1.4 times higher than that for a physician. The mean finger dose per unit of activity (μSv/GBq) for physicians handling ^{131}I was found to be 4.7 times higher than that for physicians involved in injecting ^{99m}Tc-labeled compounds. The dose to the fingertips of a physician handling ^{131}I was measured to be 469.9 ± 267 μSv/GBq. If the physician continued to work with ^{131}I throughout the year, the dose to the fingertips might reach or even exceed the annual limit of 500 mSv for the extremities.

The main reason for this elevated dose is thought to be the initial stage of posting, when physicians perform procedures slowly to avoid spillage and contamination. Thus, staff handling ^{131}I could benefit from practice with dummy sources that would allow them to become familiar with procedures and optimize their handling techniques. Such practices also could improve radiation safety awareness and minimize the potential for contamination. With adequate radiation safety standards and good work practice, there is a good chance that exposure will not exceed the annual limit of 500 mSv for the extremities.

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