Exposure to Fingers While Handling a Solvent Extraction-Type Technetium-99m Generator

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Technetium-99m-labeled compounds are routinely used for various diagnostic procedures in nuclear medicine. In India, most of the nuclear medicine centers use ^{99m}Tc obtained from a solvent extraction-type generator.* As a result of the long procedure involved in the separation of ^{99m}Tc from ^{99m}Mo in this type of generator compared to the elution of ^{99m}Tc from a column-type generator, the likelihood of exposure to fingers of technicians is high. The measurement of radiation exposure was done on 16 workers at seven major nuclear medicine centers in India. The maximum exposure to any of the fingers per MBq of ^{99m}Tc extracted was found to vary from 1.46×10^{-9} to 22.38×10^{-9} C-kg^{-1}. With the existing work load, the exposures to the fingers were found to be within the permissible limits.

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The use of technetium-99m- (^{99m}Tc) labeled compounds for various diagnostic procedures in nuclear medicine has been increasing at most of the nuclear medicine centers. The radionuclide can be made readily available at the respective place of work and possesses several advantages over other radionuclides. Technetium-99m is a daughter product of molybdenum-99 (^{99}Mo) which is obtained as a fission product from uranium-235 or by neutron irradiation of stable ^{98}Mo in a reactor. The fission ^{99}Mo is available with relatively high specific activity compared to ^{99m}Mo obtained by the ^{98}Mo (n,γ) ^{99}Mo reaction. The most common method of separation of ^{99m}Tc is by elution with physiologic saline from an alumina column to which the ^{99}Mo is complexed. This type of ^{99}Mo-^{99m}Tc generator requires ^{99}Mo of high specific activity. Another way of obtaining ^{99m}Tc is by the solvent extraction method in which methyl ethyl ketone (MEK) is used as a solvent for extracting ^{99m}Tc. In India, at most of the centers, ^{99m}Tc is obtained by the latter method, from the ^{99}Mo-^{99m}Tc generator (*1*).* The ^{99}Mo used in these generators is a (n,γ) product from ^{98}Mo and is supplied by the Bhabha Atomic Research Center at weekly intervals to the respective institutions. The solvent extraction procedure of obtaining ^{99m}Tc involves many stages compared to the elution of ^{99m}Tc from the column-type generator. These operations result in a considerable amount of radiation exposure to the technician, particularly to the fingers, since the extraction procedure involves the transfer of ^{99m}Tc activity, ranging from ~50 mCi (1,850 MBq) to 400 mCi (14,800 MBq) from one container to another, two to three times during the whole procedure. Some of the main stages at which the radiation worker is likely to be exposed to radiation are (a) while transfering ^{99}Mo from the supply vial into the generator through a PVC tube; (b) collection of aqueous phase containing ^{99}Mo for next extraction; (c) collection of organic phase containing ^{99m}Tc; (d) filtering the organic phase through an alumina column; (e) evaporation of MEK; and (f) preparation of sodium pertechnetate from the precipitate obtained in Stage (e). These operations may give rise to a significant amount of exposure to fingers during extraction of ^{99m}Tc. There is relatively less information available about the finger doses received during extraction of ^{99m}Tc from a solvent extraction-type generator. Most published papers describe the column-type generator.

Exposure to fingers while injecting ^{99m}Tc radiopharmaceuticals has been measured and published (*2–6*). This exposure depends very much on the technique of holding the active syringe, syringe type, whether or not syringe is shielded, and time taken per injection.

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The effect of these factors on the exposure to fingers has been explained previously elsewhere and, hence, is not dealt with in this paper.

In India, there are about 30 institutions routinely extracting ^{99m}Tc at their respective centers. A countrywide program has been undertaken to carry out measurement of exposure to fingers at all these nuclear medicine centers. Here we have analyzed our observations made at seven major centers in this country.

MATERIALS AND METHODS

Thermoluminescent dosimeters (TLDs) and LiF TLD-100 extruded rods (1 mm diam × 6 mm height),† were used for the measurement of radiation exposure. After annealing, the individual rods were sealed in small polythene covers to avoid any possible contamination during use. Before the start of extraction procedure, the TLDs were fixed onto the fingers of both the hands, at the middle position by adhesive bandage tape as shown in Fig. 1. Surgical hand gloves were worn over the dosimeters. The dosimeters were removed after the extraction of ^{99m}Tc and the preparation of ^{99m}Tc radiopharmaceuticals was completed. This procedure was repeated two to three times, ensuring that the same dosimeters were used in identical positions so that the dosimeter fixed to a particular finger recorded the exposure received by that finger only during the extractions. Total amount of ^{99m}Tc extracted by each worker was recorded. During the extraction, the hands of the workers were frequently checked for contamination, and whenever considerable amount of contamination was observed, the workers were asked to change the gloves.

The exposed dosimeters were read in a TLD counting unit where a minimum exposure of $2.58 \times 10^{-6} \pm 16\%$ (σ)C-kg^{-1}(10 mR) can be read using TLD-100 extruded rods. This unit was designed and made in our laboratory (*7*).

TL dosimeters were calibrated for TL counts compared with exposure, exposing the dosimeters to gamma rays from radium-226 (^{226}Ra). Hence, all our results are expressed in units of exposure (C-kg^{-1}). In order to get the dose equivalent, the results are to be multiplied by a factor of 37.2, which will give the dose equivalent to soft tissue in Sievert (1C/kg = 37.2 Gy or 37.2 Sv for gamma rays in soft tissue calculated using 0.96 rad/R). The energy dependence of LiF between gamma energies of ^{99m}Tc and Cobalt-60 (^{60}Co) was studied by Liu et al. (*8*). They observed that the TL response per R for ^{99m}Tc gamma rays was greater than that for ^{60}Co gamma rays by a factor of 1.084, i.e., an increase of about 8%. Since the energy response of ^{226}Ra is nearly the same as that of ^{60}Co, no correction for energy dependence has been applied as it can be safely assumed to be less than 10%.

RESULTS AND DISCUSSION

The exposures received by fingers of individual workers during extraction of ^{99m}Tc is shown in the form of histograms (Fig. 2) for 16 radiation workers, for both right and left hand fingers. Readings of a few fingers were lost due to breakage of TLD-rods while handling, and could not be shown in the histograms. It is observed that the maximum exposure per MBq extracted to any of the fingers, indicated by the maximum height of histogram, for either hand of each worker varies from 1.46×10^{-9} to 22.38×10^{-9} C-kg^{-1}/MBq (0.21-3.21 mR/mCi). The mean value for these 16 workers is 7.81×10^{-9} C-kg^{-1}/MBq (1.12 mR/mCi) extracted. There is a remarkable difference in the exposure to fingers per unit activity extracted among the workers. The large variation in the values of maximum exposure per MBq is mainly due to two reasons. First, some of the workers were not using any remote handling devices while handling large activities of ^{99m}Tc or ^{99}Mo, particularly when transfering large activity from one container to another. During this process, the finger closest to the activity would receive the highest exposure with varying amounts of exposures to other fingers, depending upon their closeness to the activity. Second, chances of contamination on the glove are very high when radioactivity is handled without the help of tools. It was observed that some of the workers were holding the stopcock of the generator by hand while collecting ^{99m}Tc or ^{99}Mo. This type of exercise will invariably lead to contamination of gloved fingers and consequent exposure. Left hand, middle finger of Worker No. 9 is an example of high exposure as a result of contamination. It is interesting

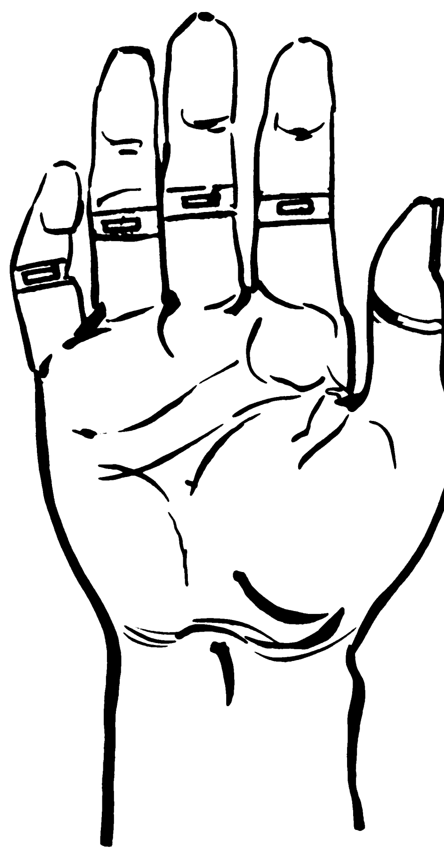

FIGURE 1
TL dosimeters (LiF extruded rods) fixed to middle portion of fingers

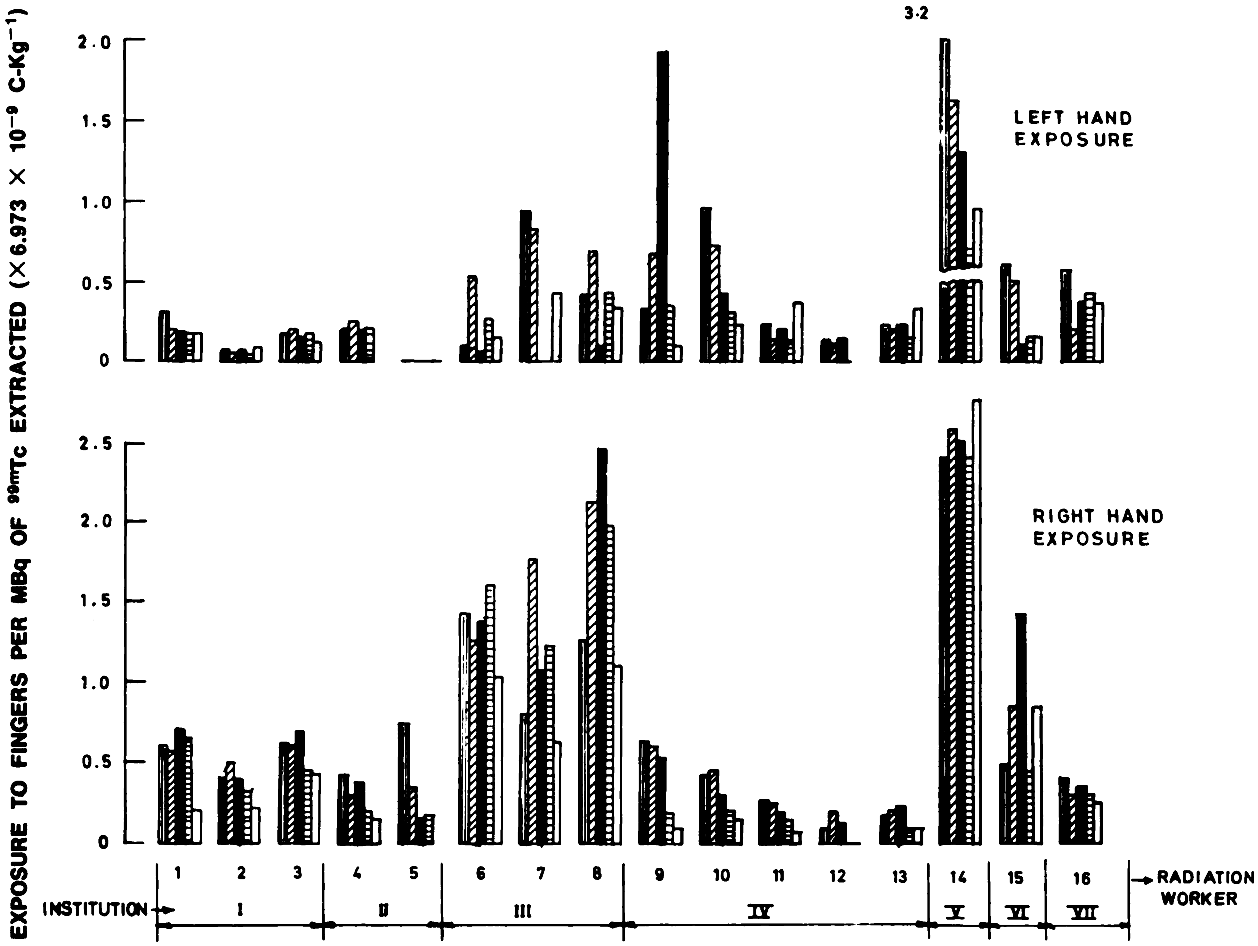

FIGURE 2
Exposure to fingers during extraction of ^{99m}Tc (▥) Thumb; (▨) Index finger; (■) Middle finger; (▤) Ring finger; (□) Little finger

to see that within the same institution the exposures to the fingers of different workers follow nearly the same trend, indicating that within that institution the work practice is nearly the same. Further, right hand fingers, which are mostly used in the operations, indicate larger exposures compared to left hand.

The average activity of ^{99m}Tc extracted per institution works out to be about 675 mCi/wk (25 GBq/wk) or ~35 Ci (1,300 GBq) annually. From the mean exposure value per MBq extracted mentioned above (i.e., 7.81×10^{-9} Ckg^{-1}/MBq), the annual exposure to the fingers per institution is $\sim 1.015 \times 10^{-2}$ $C\text{-}kg^{-1}$ or equivalent to a dose equivalent of 37.8 rem (378 mSv) which is to be shared by the number of workers doing extraction. From the details collected from the seven institutions surveyed by us, the average number of workers doing extraction per institution works out to be 2.57. From these figures it may be seen that, on an average, the dose equivalent to fingers during extraction of ^{99m}Tc does not exceed the annual limit of 50 rem (0.5 Sv) (*9*).

Table 1 gives the details of institutions where finger dose measurements have been carried out. From the average values of exposure per MBq extracted, the total activity extracted and number of workers involved, it may be seen that the exposures are within International Commission of Radiological Protection limits. However, if the work load is increased, keeping the number of workers the same, the exposure may reach or exceed the maximum permissible limits. For example, at institution No. V, the present work load is only 3.7 GBq of ^{99m}Tc/wk and is likely to be increased. As the exposure to fingers of the only worker available at this place is relatively very high, there is every likelihood of the worker exceeding the permissible limits, if the work load increased to even half of the average work load per institution. Necessary advice has been given to the institution authorities to take care of the situation.

In some of the institutions, e.g., institution No. III, the same radiation worker does the extraction as well as injection of the radioactivity. In such a case, the actual exposure to the fingers of these workers is greater than the exposure given in Table 1.

In conclusion, it may be said that the exposure to personnel from the solvent extraction procedure of ex-

TABLE 1
Exposures to Fingers During Extraction of ^{99m}Tc

Institution no.	No. of radiation workers doing extraction	Average activity of ^{99m}Tc extracted per week (GBq)	No. of extractions done per week	Values of maximum exposure per MBq extracted and finger exposed of individual workers ($C\text{-}kg^{-1}/MBq$)	Mean value of maximum exposures per MBq extracted ($C\text{-}kg^{-1}/MBq$)	Remarks
I	3	29.6 (800 mCi)	5–6	4.93×10^{-9} (Rt. middle) 3.47×10^{-9} (Rt. index) 4.84×10^{-9} (Rt. middle)	4.413×10^{-9} (0.632 mR/mCi)	In addition to extraction these workers help the doctors while injecting radioactivity, by drawing activity into the syringe, etc.
II	2	16.65 (450 mCi)	6	2.98×10^{-9} (Rt. thumb) 5.16×10^{-9} (Rt. thumb)	4.07×10^{-9} (0.584 mR/mCi)	These workers are helped by wardboys during extraction in transferring radioactivity from one container to another.
III	3	16.65 (450 mCi)	6	11.23×10^{-9} (Rt. ring) 12.42×10^{-9} (Rt. index) 17.04×10^{-9} (Rt. middle)	13.56×10^{-9} (1.945 mR/mCi)	These workers inject radiopharmaceuticals also in addition to routine extraction of ^{99m}Tc. Exposures from injections are not included in these readings.
IV	5	66.6 (1,800 mCi)	5–6	13.43×10^{-9} (Lt. middle) 6.66×10^{-9} (Lt. thumb) 2.09×10^{-9} (Lt. little) 1.46×10^{-9} (Rt. index) 2.29×10^{-9} (Lt. little)	5.186×10^{-9} (0.744 mR/mCi)	
V	1	3.70 (100 mCi)	3	22.38×10^{-9} (Lt. thumb)	22.38×10^{-9} (3.21 mR/mCi)	Exposure to fingers was measured during two extractions only.
VI	2	9.25 (250 mCi)	5	9.97×10^{-9} (Rt. middle)	9.97×10^{-9} (1.43 mR/mCi)	Measurements done on one radiation worker only. Both radiation workers are medical doctors and do both extraction and injection of radioactivity.
VII	2	31.45 (850 mCi)	6	2.859×10^{-9} (Rt. thumb)	2.859×10^{-9} (0.41 mR/mCi)	Measurements done on one radiation worker only.

tracting ^{99m}Tc in routine use in this country, is within permissible limits. However, the potential for exceeding the limits in some of the institutions exists. Adequate training and better work practices should definitely aid the reduction of exposure to fingers of radiation workers. Appropriate advice, wherever required, has been given to the respective institution.

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FOOTNOTES

* Bhabha Atomic Research Center, Bombay, India.
† Harshaw Chemical Company.

REFERENCES

1. Mani RS, Narasimhan DVS: Development of kits for short-lived generator-produced radioisotopes. In *Radio-pharmaceuticals and Labelled Compounds*, Vol. 1, IAEA, Vienna, 1973, pp 135–148
2. Neil CM: The question of radiation exposure to the hands from handling Tc-99m. *J Nucl Med* 10:732–734, 1969
3. Clayton RS, White JE, Brieden M, et al: Skin exposure from handling syringes containing radioactive isotopes. *Am J Roentgenol* 105, 897–899, 1969
4. Anderson DW, Richter CW, Ficken VJ, et al: Use of thermoluminescent dosimeters for measurement of dose to the hands of nuclear medicine technicians. *J Nucl Med* 13, 627–629, 1972
5. Takaku Y, Kida T: Radiation dose to the skin and bone of fingers from handling radioisotopes in a syringe. *Health Phys* 22:295–297, 1972
6. Lis GA, Zubi SM, Brahmavar SM: Finger tip and whole body exposure to nuclear medicine personnel. *J Nucl Med Technol* 9:91–98, 1981
7. Kannan S, Ramanathan G: A photon counting system for TLD measurements of very low exposure. *Proceedings of a National Seminar on Radiation Protection*, Bombay, BARC, Dec. 21–24, 1976
8. Liu NH, Gillium JD, Anderson DW: Response of LiF thermoluminescent dosimeters to Tc-99m gamma rays. *Health Phys* 38, 359–363, 1980
9. *Recommendations of International Commission on Radiological Protection. Publication No. 26*, International Commission on Radiological Protection, Pergamon Press, 1977