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USE OF THERMOLUMINESCENT DOSIMETERS FOR MEASUREMENT OF DOSE TO THE HANDS OF NUCLEAR MEDICINE TECHNICIANS

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In the last several years the total activity of radioisotopes injected into patients for diagnostic studies has increased steadily at the University of Oklahoma Health Sciences Center. At present it is in excess of 0.3 Ci/week, mainly due to ^{99m}Tc. The technicians who routinely elute the technetium generator, and prepare, calibrate, and inject the scanning agents perform many operations with containers filled with radioactive material. Because of this, the radiation dose to their hands is of concern.

The National Council on Radiation Protection and Measurements (NCRP) has recommended 75 rems as the maximum permissible dose equivalent to the hands in any one year. If received at an average rate, this is about 1.5 rems/week. A footnote comment in NCRP Report No. 39 is of interest: ". . . reasonable efforts should be made to keep exposure of hands and forearms within the general limits for skin." (The value for unlimited areas of the skin is only 15 rems/year.) The value of 75 rems is further described in the report as an interim concession (*1*).

A study by Neil (*2*) on radiation exposure to the hands of technicians showed a maximum dose equivalent rate of 10 rems/Ci/min for the index finger and thumb and smaller values for other parts of the hand. For Neil's measurement, "A standard hypodermic syringe containing 10 mCi of ^{99m}Tc as pertechnetate was held in a usual working condition for a timed 5 minute interval." Because technicians perform many operations with containers of radioactive material requiring many different hand positions it was decided to investigate the situation more thoroughly.

The following is a report of measurements of the dose equivalent for the fingers of nuclear medicine technicians due to the elution, preparation, calibration, and injection of ^{99m}Tc under actual working conditions.

METHOD

During the study the technicians wore bands of tape containing thermoluminescent dosimeters (TLD) around their fingers between the joints. The TLD devices were arranged around the bands so the dose measured would be directly indicative of the average superficial dose to the middle of the finger. In the first series of measurements the dosimeters were disks made of lithium borate in a Teflon matrix, 10 mm in diameter and 0.4 mm thick. In the second study lithium fluoride rectangular rods, 6 mm long and 1 mm thick, were used because of their increased sensitivity. The properties of lithium borate and lithium fluoride which make them useful for dosimetry have been discussed extensively (*3*).

The TLD bands were worn from 2 weeks to a month before they were collected. During this time periodic checks were made to verify that the technicians were wearing the bands regularly. Four exposure intervals were involved in the first study and two in the second study. The total elapsed time from the start of the first study to the completion of the second study was about 6 months. During the first study the bands were worn on various fingers so that the finger receiving the largest dose could be determined. The right-hand index finger was indicated (right-handed technicians) so all bands were worn on this finger during the second study.

During all the time periods additional dosimeter bands were left in the nuclear medicine area in places well removed from radioactive material. These dosimeters measured the general background dose which was subtracted from the dose on the finger bands.

The thermoluminescent response per rad was calibrated for each exposure interval using a known dose of ^{60}Co radiation and dosimeters chosen at random from the general batch. Calibration with ^{60}Co radiation was used because a source with well-established absolute output was available. The difference between

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TABLE 1. RESULTS OF DOSE EQUIVALENT MEASUREMENTS

Study No.	Trial	Finger	mrem/ Ci injected	mrem/ Ci eluted
1: Dose equivalent from injection, elution, calibration, and preparation	LB1	R1	2,130 ± 240	
	LB2	L1	1,000 ± 130	
	LB3	R1	2,020 ± 170	
	LB4	R2	1,400 ± 400	
2-A: Dose equivalent from injection	LF1	R1	1,470 ± 90	
	LF2	R1	1,660 ± 130	
B: Dose equivalent from elution, calibration, and preparation	LF1	R1		215 ± 11
	LF2	R1		221 ± 15

the thermoluminescent response per rad for 1.25 MeV (^{60}Co) radiation and 140 keV (^{99m}Tc) radiation is less than 10% for the dosimeters used (*4*). In all cases the quality factor of one was used to convert rads to rems (*5*).

For each exposure interval the total activity injected was obtained from the injection log book. The dose equivalent received was correlated with the activity injected.

The technetium generator used during the study was an Abbott Pertgen 7721 (200 mCi) which was shielded. Laboratory procedure was such that the bottle containing the ^{99m}Tc eluate was never held directly in the hand during preparation and calibration. It was kept in a ¼-in. lead shield or transferred by 8-in. tongs (except during calibration which will be discussed later). Prior to injection the standard syringes were filled from the shielded bottle of ^{99m}Tc scanning agent. During the injection the right-hand index finger and thumb were used to grip the barrel of the syringe which was not shielded. The average time elapsed during the injection procedure was 14 sec for our technicians.

RESULTS AND DISCUSSION

The data are summarized in Table 1 with standard deviations indicated in the usual manner. From the results of the first study, it is evident that the index finger of the right hand (right-handed technicians) received more dose equivalent than other fingers. The second study yielded the result that the superficial dose equivalent for the middle of this finger is about 1.6 rem/Ci injected. One should note that the dose involved in elution of the technetium generator, ion chamber calibration, and preparation of scanning agents was included in Study 1 and was excluded in Study 2-A. In view of this the agreement is reasonably good.

The TLD study by Neil (*2*) mentioned above showed a maximum dose equivalent rate of 10 rem/Ci/min to the index finger. As mentioned previously our results are not directly comparable to these since ours were taken under actual working conditions. Nevertheless it is interesting to note that by dividing our value of 1.6 rem/Ci by the 14-sec average injection time we obtain about 7 rem/Ci/min.

From the data shown in the table under Study 2-B, it is evident that the dose equivalent from elution of the generator, ion chamber calibration, and preparation of the scanning agents was quite small per curie eluted. However, the total activity eluted is often considerably in excess of the activity injected into patients. Thus the absolute dose equivalent due to these operations may be more substantial.

The dose equivalent due to injection is easily understood since unshielded syringes were used during these operations. Although smaller, the dose equivalent due to elution, calibration, and preparation is more difficult to explain since shields and tongs were generally used. A likely major cause was exposure during transfer of the technetium bottle between the shield and the ion chamber for calibration. The plastic tube used to hold the bottle in the chamber was held in the right hand while the bottle was inserted. The resulting exposure can easily be eliminated by use of tongs during calibration.

It is certain that the dose equivalent received will vary considerably with technician dexterity and experience, as well as with laboratory safety practices. Thus each nuclear medicine facility would be well advised to make their own measurements. Nevertheless, several observations of general interest can be made from this study:

1. The dose equivalent to the hands of an experienced technician is likely to be less than the 1.5 rems/week maximum if he handles only a few hundred millicuries of ^{99m}Tc per week and uses appropriate handling techniques. Our measured values indicate maximum dose equivalent to any part of the hand. If the dose equivalent is averaged over the entire hand, it would surely be considerably smaller.
2. If the NCRP concession on skin dose were removed the use of special injection techniques, possibly shielded syringes, would likely be required for compliance. This study indicates that the finger-skin dose might be in excess of the 290 mrems/week for technicians injecting regularly with unshielded syringes.

SUMMARY

Measurements of the dose equivalent to the fingers of nuclear medicine technicians have been re-

ported and discussed. Rings containing thermoluminescent dosimeters were used so the measurements could be made under actual working conditions. The dose equivalent measured was correlated with the amount of activity handled.

The average superficial dose equivalent accumulated during injection of ^{99m}Tc agents with standard syringes was about 1,600 mrems/Ci injected. This value is for the index finger of the right hand. Other fingers sustained considerably less exposure. The dose equivalent due to elution, calibration, and preparation was about 200 mrems/Ci eluted.

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