Evaluation of Radiation Exposure from an Automated Tc-99m Dispensing System

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Fingertip exposures using mini-thermoluminescent dosimeters (TLDs) were obtained from an automated technetium dispenser and were compared to the exposures obtained from manual preparation of doses—including generator elution, kit preparation, syringe filling, and individual dose assays. The automated dispenser reduces radiation exposure four-fold compared to the manual use of syringe shields, and fourteen-fold compared to unshielded syringes. Although the device had some limitations, research into this type of device should be continued.

For a number of years, our laboratories have been concerned with measurement of radiation exposure to the hands of personnel preparing and injecting radiopharmaceuticals. It is important to assess this exposure—because only these measurements make it possible to compare the usefulness of various exposure reduction devices.

We compared previously reported personnel exposure to fingertips from the manual preparation of radiopharmaceuticals (*1*) with exposures from use of the CintiChem technetium Tc-99m dispenser (Union Carbide, Rye, NY).

This dispenser receives the sodium pertechnetate eluate from a generator; then it automatically tests for Mo-99 breakthrough and computes the concentration in mCi/ml. When a unit dose radiopharmaceutical is desired, the user requests a specific activity, places the vial in the system, and starts the filling cycle. The dispenser adds the desired activity followed by saline to make a total volume of 1 ml. It then assays the dose. The Mo-99 breakthrough, Tc-99m concentration, and assay are determined using three internal G-M detectors. The shielded vial is then manually removed and the dose withdrawn into a specially designed shielded syringe.

Materials and Methods

Exposure values were made using duplicate mini-TLDs placed at various locations on the hand and fingertips. Each TLD's response has been calibrated to a known Tc-99m source and paired with care as reported by Branson et al. (*1*). Since previous studies show that fingertips receive two to three times the exposure as the base of the finger (where finger badges are usually worn), a majority of TLDs were placed at the fingertips (*2*).

To obtain an overall view of radiation exposure, data were gathered for generator elution, radiopharmaceutical preparation, dose preparation, and syringe assay, which are all the preparatory steps required up to patient injection. Because the exposure received during a single operation is quite small, each operation was repeated a number of times while wearing a single set of TLDs to increase the exposure and, therefore, the accuracy of the average exposure received per single operation.

Data were gathered in the following manner:

- Exposure for generator elution was obtained over a five-day period and included the installation, elution, Tc-99m and Mo-99 breakthrough assays of two 1,770-mCi Minitec ® generators (E.R. Squibb & Sons, Princeton, NJ). The results were then converted to an average exposure per day for one generator.
- Exposures for radiopharmaceutical kit preparation were obtained by adding 100 mCi of Tc-99m to a kit vial of DTPA or diphosphonate on four occasions and expressing the results as exposure received per single 100-mCi kit prepared.
- Exposures for the filling of syringes were obtained by removing 25-mCi aliquots in a volume of 0.2 to 0.3 ml from a shielded vial into a 1-ml syringe with a 23-gauge needle. Because the needle gauge is important in controlling the rate of filling a syringe, these data should not be applied to the use of alternate gauge needles (*1*).
- Exposure for individual dose assays was obtained by averaging ten individual assays of 25-mCi syringes in a factory-shielded dose calibrator. When syringe shields were employed during the manual preparation of drugs, the syringes were removed from the shield for assay, then returned to the shield.
- Exposure received when using the CintiChem system was assessed by loading the Tc-99m activity into the system, which automatically prepares and assays the radiopharmaceutical as an individual dose. Ten doses of 25 mCi each of various radiopharmaceuticals were prepared.

Results

All data presented are the average values for the TLD pair resulting in the highest exposure in each phase of the study.

From Table 1, the approximate exposure to personnel can be estimated. As can be seen, the use of syringe shields reduces this exposure five-fold in kit preparation and syringe filling. The reduction is much smaller than

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TABLE 1. Estimated Hand Radiation Exposure (mR) per Syringe during Various Segments of Radiopharmaceutical Preparation from Tc-99m

	Generator Elution	Kit Preparation (100 mCi)	Syringe Filling (25 mCi in 1-ml syringes with 23-gauge needle)	Syringe Assay
Unshielded Syringe	2.5	25	4.0	0.6
Shielded Syringe	2.5	5	0.8	1.2
Automated Dispenser	2.5	←	0.6	→

that implied by bench-top studies performed by syringe-shield manufacturers that claim reductions from 20 to over 200 times. The assay of a shielded syringe, however results in twice the exposure of an unshielded syringe because of the increased time required for manipulation. The use of the automated system, as expected, further reduces hand exposure.

To estimate daily exposure, the following assumptions were made: 1,770-mCi Squibb Minitec generator is eluted daily and replaced weekly; three radiopharmaceutical kits are prepared daily, each containing 100 mCi of Tc-99m; and ten 1-ml syringes with 23-gauge needles are each filled with 25 mCi of Tc-99m pharmaceuticals.

Based on these assumptions, the use of syringe shields results in an estimated three-fold reduction in hand exposure compared to the use of unshielded syringes (Table 2). The use of the automated dispenser results in an additional four-fold reduction. It should be mentioned that any of the three previously stated techniques used for a five-day period 50 weeks per year will result in less than 50% of the maximal permissable extremity exposure.

TABLE 2. Estimated Hand Exposure (mR) from Typical Daily Handling of Tc-99m

	Generator Elution	Radio pharma-ceutical Preparation	Syringe Filling	Assay	Total
Unshielded Syringe	2.5	75	40	6	124
Shielded Syringe	2.5	15	8	12	38
Automated Dispenser	2.5	←	6	→	9

The preproduction model of the dispenser used in our tests suffered from some drawbacks that negate a part of its radiation exposure advantages. The volume to be injected is fixed at 1 ml, which is larger than many practitioners desire for bolus injection. Also, the time for the system to complete a full preparation and dispensing cycle is quite long, which could be a hindrance in a busy lab. Most importantly, if the G-M detectors or electronics become defective or drift during the hours after its initial calibration check, patients could conceivably receive inaccurate doses. If used in our laboratory clinically, our confidence would be greatly increased by checking each dose with an ionization chamber dose calibrator prior to injection. This, however, would affect the reduction in exposure gained by using the device, resulting in approximately 1 mR/syringe additional exposure.

Conclusion

Our laboratories have compared the CintiChem technetium dispenser to manual methods of preparing doses. We find that the dispenser reduces typical radiation exposure to the fingers four-fold compared to the manual use of syringe shields and fourteen-fold compared to the use of unshielded syringes. Even though certain features of the dispenser already mentioned made the device impractical, a similar device could be useful in nuclear medicine if adequately designed. The CintiChem automated technetium dispenser, which is no longer marketed, was industry's first attempt to create such a device. We realize that the dispenser's engineers, like the designers of the Viking Lander now on Mars, face a difficult, expensive, time-consuming task—designing a machine which duplicates the actions of the human hand and mind—but we hope that further research into the design of these devices is continued.

Mention of a commercial product in this paper does not constitute recommendation or endorsement by the FDA, USPHS, or the University of Cincinnati.

References

1. Branson BM, Sodd VJ, Nishiyama H, et al: Use of syringe shields in clinical practice. *J Clin Nucl Med* 1: 56–59, 1976
2. Branson BM, Sodd VJ, Nishiyama H, et al: Hand and finger exposure reductions from the use of syringe shields in clinical practice (Abstract). *Health Phys* 31: 556, 1976