REDUCING PERSONNEL EXPOSURE IN NUCLEAR MEDICINE

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ABSTRACT

Nuclear medicine procedures are growing at a rate greater than 15%/yr and the radiopharmaceutical industry over 25%/yr. A nuclear medicine facility in a medium-large hospital routinely handles 300-700 mCi of ^{99m}Tc/day plus prepares ^{99m}Tc radiopharmaceuticals and handles millicurie amounts of other isotopes. As this specialty grows, so must exposure reduction techniques. Periodic assessment of personnel handling the molybdenum-technetium generators and ^{129}Cs were made using TLD's. These data are reviewed with comments about potentials for personnel exposures and exposure reducing methods. Additional shielding and new handling techniques have been incorporated and are discussed.

INTRODUCTION AND BACKGROUND

The Nuclear Medicine Laboratory is located and operated in collaboration with the Radioisotope Laboratory. In these laboratory facilities, the following contribute primarily to personnel radiation exposure:

1. daily handling of 500 mCi to 1.4 curies of ^{99m}Tc,
2. weekly processing of mCi amounts of ^{129}Cs,
3. preparing throughout the week a variety of ^{99m}Tc labeled radiopharmaceuticals from kits, and
4. weekly handling of mCi amounts of ^{131}I, ^{133}Xe and ^{113m}In.

Each of these can increase the daily exposure to laboratory personnel and result in exposure levels that exceed what we would have predicted just a few years ago.

Max Lombardi[1] reported on a 12 month survey of 69 hospitals that nuclear medicine procedures grew at a rate of 16% per year and that the radiopharmaceutical industry grew 25-26% in a similar 12 month period. Accompanying this growth in radiopharmaceutical usage and new nuclear medicine laboratories in many hospitals, the problem of personnel protection has been recognized by some but unrecognized by many.

The National Council on Radiation Protection and Measurements (NCRP)[2] recommends 75 rems/year, 25 rems/qtr., as the permissible dose equivalent to the hands. They have further characterized this as an "interim concession" in "comment" to this section and have also indicated that "all reasonable efforts should be made to keep exposure of the hands and forearms within the general limit for skin, 15 rems/year".

A study 4 years ago by Neil[3] on the radiation exposure to the hands from handling ^{99m}Tc showed a maximum dose equivalent of 10 rems/curie/minute for the index finger and thumb with lesser dose equivalents for other parts of the hands. Using Neil's data, a physician that gives 400 injections/year of 10 mCi each and in only 30 seconds handling time would receive 30 rems for that year for that portion of his hand alone, if handling of any other radioisotopes is neglected. (^{131}I, ^{133}Xe, ^{18}F, ^{129}Cs, etc.)

The need for additional personnel protection for all radioisotopes in the laboratory resulted in a complete rearrangement of our "hot" lab area. Lead-lined housings with sliding lead glass doors were specially built* for two molybdenum-technetium generators, figure 1. The two end doors must be moved to the middle where there is a third fixed plate of lead glass. These form a body shield while the hands may be inserted through the openings on either side of the lead glass. We have also built ^{99m}Tc eluate organizer racks, figure 2, that provide ¼" lead shields for each eluate bottle. Each shield has a lid with a hole for the head of the eluate bottle. The bottles are placed on a slant pointed away from the operator. Each tier of eluate shields is color coded to identify the eluate by the parent generator. Added positions are available for ^{99m}Tc radiopharmaceuticals, prepared from kits. An additional tier permits storage of other radiopharmaceuticals in use that day. All the ^{99m}Tc and most radioiodine doses are prepared behind the face and body shield[4] **seen just in front of the organizer rack.**

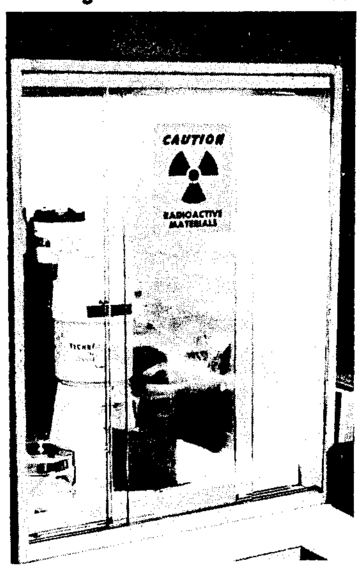

Figure 1. **Mo-Tc house** built of plywood, Pb lined epoxy painted, fluorescent light and 3 Pb glass doors. Base made as a tray to contain spills.

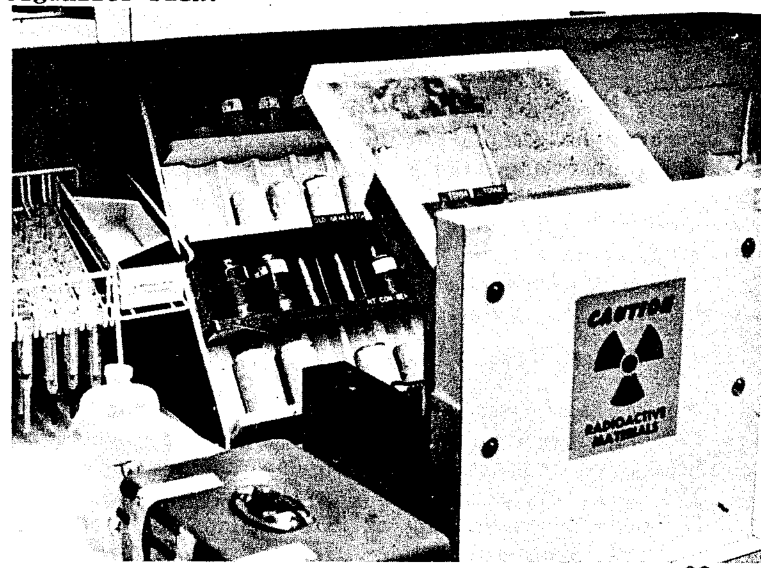

Figure 2. **Eluate organizer rack for ^{99m}Tc** placed immediately behind a face and body shield. Most radiopharmaceutical doses are prepared at this work station.

Most of the diagnostic administrations of radioisotopes in nuclear medicine are given at some location other than the hot laboratory. For injections, a transporting tray, with a lead syringe holder anchored to the side of the tray is used and is shown in figure 3. In addition, the tray is equipped with other items the physician will need for injection. This special tray has been helpful in reducing exposure and contamination and has proven very easy and convenient to laboratory personnel.

We conservatively estimate that the generator housing reduces major body exposure 2 times during the elution procedure. The eluate shields probably reduce personnel exposure by a factor of 5, and the face and body shield reduces the technicians total body exposure an estimated factor of 5. The personnel exposure reduction realized from the dose tray is difficult to calculate, but it is our conservative guess that the hand exposure is reduced a factor of 5 to 15 depending on the distance the dose syringe must be carried, etc.

* These were designed for one specific company's generator and might require modification for a different brand generator.

In order to assess the personnel exposures more specifically, we have studied some hand exposures during routine handling procedures using thermo-luminescent dosimeters (TLD's). For ^{99m}Tc and ^{129}Cs the procedure used was to place TLD* dosimeters in the anterior and posterior positions on one or two fingers, the thumb, and wrist of each hand. Additionally, TLD's were placed on the forehead or glasses frame, chest and gonadal area of the body. Unless otherwise stated the TLD's on the fingers were in the finger ring position. We assumed that all radiation absorbed by the lithium fluoride chip was from either ^{99m}Tc or ^{129}Cs. This actually is not the case; for instance, the aluminum holder for the target material in the cesium production was emitting high energy gamma rays from ^{22}Na and ^{24}Na and likewise for ^{99m}Tc the 740 and 780 keV ^{99}Mo radiation is emitted through the generator shielding. For each study two lithium fluoride chips were placed at each dosimetry point; each was measured separately and the count data averaged.

At the time of this study, two molybdenum technetium generators were received each week; each rated at 400 mCi 5 days after receipt. One technician had the responsibility for removing the old generator, installing the new one, and obtaining the daily elutions required (about 5 curies/week). For this study, the TLD's were worn only during these procedures. The resultant TLD data, Table I, reflects the expected higher exposure on the anterior surface of each hand and higher exposure to the right hand. Data from the forehead, chest and gonadal area of the body were all under 10 mR/week. The highest finger exposures averaged 131 mR/week which over 50 weeks would amount to 6.5 R maximum cummulative exposure. In some other laboratory with only one 400 mCi generator and using only the shielding provided with the generator, the annual exposure could be as much as 20 R for the same person performing this task.

Table I. TLD PERSONNEL DATA FOR ^{99m}Tc IN mR

\- Handling Generators Only -

		Weekly Average	
		LEFT	RIGHT
Fingers	- Anterior Surface	61	109
	- Posterior Surface	36	94
Thumb	- Anterior Surface	46	198
	- Posterior Surface	54	124
Wrist	- Anterior Surface	19	33
	- Posterior Surface	10	19
Totals	- Fingers	49	131
	- Hands	37	109

50 Week Total - Fingers (131 x 50) = 6550 mR

A more recent study has compared the preparation of ^{99m}Tc macroaggregated albumin prepared according to the method of Robbins[5] and ^{99m}Tc human albumin microspheres labeled according to the method described by the manufacturer (3M Company) using their equipment. For this latter study TLD's were placed as shown in figure 4. The TLD's were on the lateral and medial borders of the finger tips so as not to interfere with operator's finger tip sensitivities. The dosimeters were worn during five or more preparations of each radiopharmaceutical, each study involving the handling of more than 500 mCi of ^{99m}Tc. The exposure expressed is in mR/100 mCi of the prepared product. An analysis of this exposure data is given in Mr. Robbins' paper[6]. The higher exposure levels for ^{99m}Tc-HAM are due to the higher levels of ^{99m}Tc handled for the resulting

*The chips used in these studies, TLD-100 (1/8 x 1/8 x .0035 inch) were selected to have sensitivities within ± 5 percent of each other. In some ^{99m}Tc studies, two sets of TLD's were exposed, one at twice the activity level of the other. These became the calibration standards for the two isotopes.

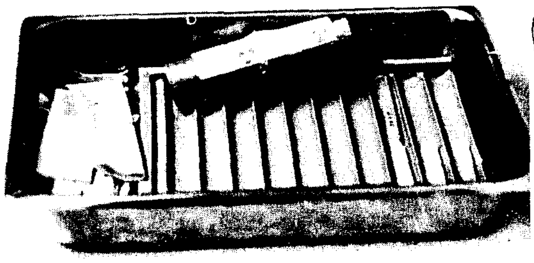

Figure 3. **Transporting tray with** lead holder for dose syringe plus items needed at injection site.

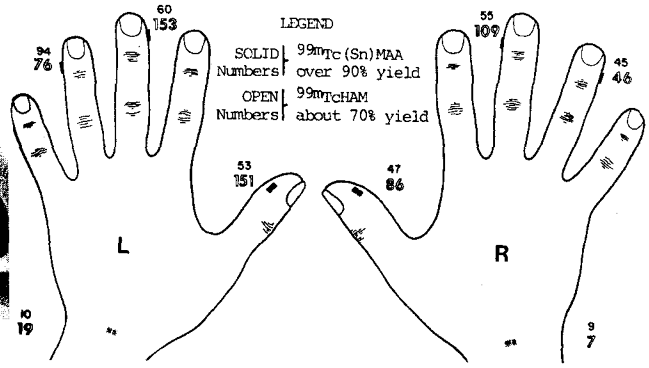

Figure 4. ^{99m}Tc Exposure in mR/100mCi ^{99m}Tc Prepared. Wrist TLDs anterior side only.

yield, and difference in handling procedures required. Unusual exposure data can be accounted for in specific handling operations. Yet, based on the left hand finger exposures recorded in this study, the preparation of 200 batches of 80 mCi each of ^{99m}Tc during a year would result in approximately 17 R/year to the hand. While this is within the 75 rem/year NCRP limit, (it exceeds the 15 rem/year skin exposure recommendations) it only accounts for exposure from the preparation of one radiopharmaceutical.

A new radioisotope for tumor and heart scanning, ^{129}Cs is produced by cyclotron* irradiation and is air shipped to Cincinnati where the target material is chemically processed to extract the cesium as cesium chloride. The chemical extraction takes about 60 minutes. In the first few production runs, the ^{129}Cs yield from each bombardment was 2 to 4 millicuries total. As the procedure was refined and the cesium yield increased, more shielding was incorporated throughout the extraction-purification process. Handling devices were likewise incorporated into the process. Figure 5 shows a pair of vice-grip pliers used to hold the aluminum target. A long bolt has been substituted for the adjustment screw on the pliers to add distance between the target and hands, yet maintain reasonable operation.

Figure 6 shows the special tools assembled for this procedure; tweezers permanently attached to tongs for handling the target cover, a long handle with a funnel stopcock in the slotted right end of the handle, a flexible pick-up tool and an allen wrench built into a long handle for removing the target cover. At the time of the cover removal the target was emitting more than 500 R/hour at 1 centimeter. One other device, figure 7, is a remote hydraulically operated syringe. By coupling two syringes tip to tip with small plastic tubing, one acts as a piston controlled by the other. The piston can push or pull the primary syringe plunger to deliver or take up liquid. The beauty of this system is that the personnel radiation exposure is essentially eliminated for this part of the procedure. Refinements on the procedure occurred over a period of 3 months and with each succeeding week we noted decreases in radiation exposure. Table II summarizes this exposure for the hands. Immediately after run #1 techniques to reduce the dose were incorporated. As will be noted, the effect was dramatic on run #2, one week later. With succeeding weeks, and with the employment of new shielding and tools, the average exposure dropped. For brevity of data presentation runs #3 and #6 are eliminated but fit as expected in the step-by-step exposure reduction - a 6-8 times reduction. If the exposures recorded in run #1 were received over a 50 week period, it would result in more than 8 rem exclusive of exposures in other duties with other radioisotopes. However, employing the techniques and shielding described, the ^{129}Cs exposure is about 1 R/year.

* In cooperation with the Naval Research Laboratory cyclotron, Washington, D.C.

Table II. TLD HAND DATA FOR ^{129}Cs EXTRACTION

		Run 1	2	4	5	7
FINGERS AND WRIST	Right					
	Average(mR)	149	46	35	28	20
	Reduction	← x3 →		x2 →		
	Left					
	Average(mR)	147	35	22	21	16
	Reduction	← x4 →		x2 →		
FINGERS ONLY	Right					
	Average(mR)	167	48.3	31.8	31.2	18.8
	For 50 Weeks(R)	8.4	2.4			1.0
	Left					
	Average(mR)	162	40	27	26	17
	For 50 Weeks(R)	8.1	2.0			0.9
	ek Total(R)	8.2	2.2			1.0

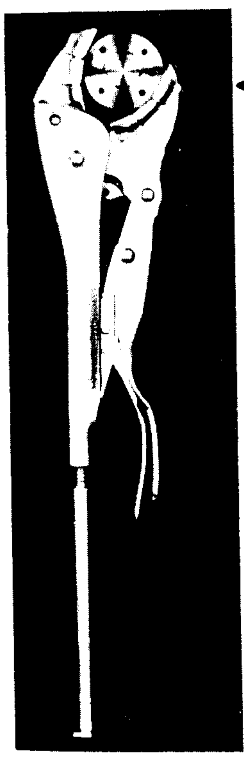

Figure 5. Modified vise grip pliers for holding irradiated cyclotron target secure and at a safe working distance.

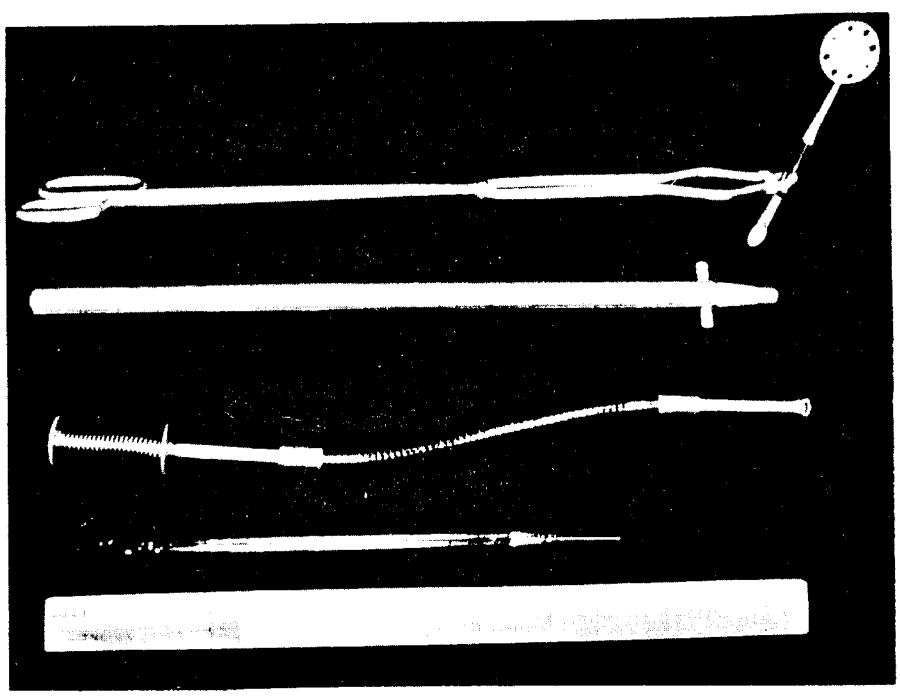

Figure 6. Special tools for ^{129}Cs extraction. Top to bottom: tongs and tweezers, long handle with funnel stop-cock (right end), pick-up tool, and allen wrench in a long handle.

In summary, we have indicated some of the ways we have assessed and reduced personnel exposure during routine radioisotope handling in our laboratory. The results are within or close to the recommended guideline of 15 rems/year for the specific function analyzed. From our experience, personnel exposures in nuclear medicine laboratories can and must be reduced by modifying current techniques and practices. In a growing clinical field radiation exposure assessments should be made every few months to determine where improvements can be made for the protection and exposure reduction of the laboratory personnel.

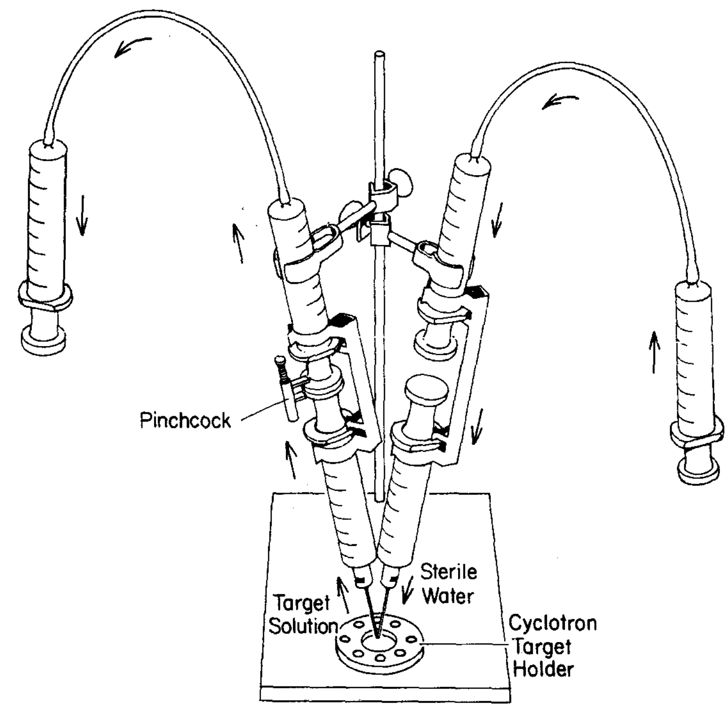

Figure 7. Remote control syringes used for target dissolution. The system on the right is used to wash the target, the one on the left is used to pick-up the solution.

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