The Effect of Job Duties in Contributing to Radiation Exposure of the Nuclear Medicine Technologist

Thomas P. Owens and Joseph C. Hung

Nuclear Medicine, Department of Diagnostic Radiology, Mayo Clinic, Rochester, Minnesota

Objective: Our unique and highly specialized nuclear medicine department provided an opportunity to analyze radiation exposure to nuclear medicine technologists (NMTs). The goal of our investigation was to determine the amount of hand and whole-body radiation exposure incurred from the performance of various job duties.

Methods: Whole-body and hand exposures were recorded over a 15–16 mo period using thermoluminescent dosimeters. Radiation exposure readings were collected in four different areas, nuclear pharmacy, radiopharmaceutical injection, nuclear cardiology and general nuclear medicine.

Results: Monitoring showed that higher hand exposure is caused by direct handling and injecting of radiopharmaceuticals. Whole-body exposure also increases, but correlates more closely to body shielding than to actual hand exposure. Higher whole-body exposure was seen in nuclear cardiology when compared to general nuclear medicine, even though general nuclear medicine performed three times the study load of nuclear cardiology.

Conclusions: In an area where imaging is the primary job duty of the NMT, the time of direct patient contact seems to be the principal factor affecting whole-body exposure. Although hand exposure increases with the amount of radioactivity handled in an area where handling radiopharmaceuticals is the main job duty of the NMT, whole-body exposure correlates more closely to body shielding than to the amount of radioactivity handled.

Key Words: personal radiation exposure monitoring; whole-body radiation exposure; hand radiation exposure; dose limits

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Radiation exposure received by the nuclear medicine technologist (NMT) can vary depending on the job duties being performed. Radiation exposure comes from radiopharmaceutical preparation, including generator elution, as well as administration of radiopharmaceuticals to patients and patient contact while performing nuclear medicine imaging procedures. The NMT should be concerned about his personal radiation exposure, not only for his own safety, but to ensure that he does not exceed annual radiation dose limits (*1*), attempting to keep his exposure as low as reasonably achievable (ALARA). In order to keep radiation exposure low, it is helpful to know which job duties are responsible for the higher exposures and what precautions should be taken to reduce exposure levels.

Our nuclear medicine area has been divided into several separate work areas (i.e., nuclear pharmacy radiopharmaceutical injection, nuclear cardiology and general nuclear medicine) in order to accommodate increased numbers of diversified patient studies. This specialization allows us to perform patient imaging procedures more efficiently and with higher quality, since most NMTs work in one specific area and become more efficient at the procedures they perform regularly. This specialization is only cost effective in a large department with a large patient volume. Equipment is also specialized for specific types of study to enable NMTs to image patients more efficiently. This unique setup of our nuclear medicine department allowed us to analyze the hand and whole-body radiation exposures received by the NMTs in different work areas.

The purpose of our study was to determine how work location and job duties affected hand and whole-body radiation exposures of the NMT.

MATERIALS AND METHODS

In our study we analyzed hand and whole-body radiation exposures to eight NMTs working in four different areas of our nuclear medicine department, nuclear pharmacy, radiopharmaceutical injection, nuclear cardiology and general nuclear medicine. Thermoluminescent dosimeter (TLD) whole-body and ring badges were used to monitor whole-body and hand radiation exposure, respectively, and were monitored over a 15–16 mo period in the four work areas listed above. Job duties are quite specific in each area of our laboratory and made it possible to determine the origin of each technologist's radiation exposure.

In nuclear pharmacy and radiopharmaceutical injection, one permanent NMT in each area was monitored over 16 mo. Three permanent NMTs were observed in both nuclear

For reprints and correspondence contact: Joseph C. Hung, PhD, BCNP, Nuclear Medicine, Dept. of Diagnostic Radiology, Mayo Clinic, 200 First Street SW, Rochester, MN 55905.

cardiology and general nuclear medicine. These six technologists were stationed permanently in either general nuclear medicine or nuclear cardiology.

The nuclear cardiology and general nuclear medicine imaging areas in our nuclear medicine laboratory are separated by a centrally located nuclear pharmacy where all radiopharmaceuticals, except high-activity ^{131}I doses, are prepared and dispensed for patient administration. The radiopharmaceutical injection room is located adjacent to the nuclear pharmacy for easy access.

Our nuclear pharmacy technologist was responsible for daily generator elutions with ^{99m}Tc eluate activity ranging from 59.2 GBq (1,600 mCi) to 325.6 GBq (8,800 mCi) and totaling 814 GBq (22,000 mCi) per week. This technologist also prepared 50% of the ^{99m}Tc-labeled radiopharmaceutical kits, for the average 1,962 nuclear medicine studies per month, and dispensed 25% of the doses for these studies.

The radiopharmaceutical injection technologist was responsible for injecting 35.3% of the average 559 monthly general nuclear medicine studies performed in our laboratory. More than 80% of the 25–30 daily doses injected by this technologist were 740 MBq (20 mCi) ^{99m}Tc-medronate (^{99m}Tc-MDP) or ^{99m}Tc-oxidronate (^{99m}Tc-HDP) injections for bone imaging. The other 20% of injections were 222 MBq (6 mCi) ^{99m}Tc-sulfur colloid injections for liver-spleen imaging, 185 MBq (5 mCi) sodium ^{99m}Tc-pertechnetate injections for thyroid scans, and 111 MBq (3 mCi) ^{99m}Tc-DMSA injections. Lung, brain, renal and hepatobiliary procedures were also performed. Cameras in this area consist of two whole-body cameras, one SPECT camera and four general purpose cameras.

In the nuclear cardiology area, we have two cameras for gated blood-pool imaging and four single-head SPECT cameras for tomographic imaging. The monthly average was 60 multigated acquisitions (MUGA) and 380 ^{99m}Tc-sestamibi and ^{201}Tl patient studies.

RESULTS

We found that the monthly hand exposure was highest in nuclear pharmacy at 1,767.3 ± 42.0 mrem per month. Hand exposure dropped to 83.1 ± 9.1 mrem per month in radiopharmaceutical injection, 6.3 ± 2.5 mrem per month in nuclear cardiology, and 5.3 ± 2.3 mrem per month in general nuclear medicine (Fig. 1). These hand radiation exposure doses are well below the annual limit of total effective dose equivalent (TEDE) of 50,000 mrem set by the International Commission on Radiological Protection (ICRP) (*2*) and the National Council on Radiation Protection and Measurement (NCRP) (*3*) and adopted by the NRC (*1*). The hand exposures correlate very closely to the time and amount of radioactive material handled by the NMTs. The time spent directly handling the radiopharmaceuticals was quite long in both nuclear pharmacy and radiopharmaceutical injection, which was evident by the higher hand exposure values when compared to the nuclear cardiology and general nuclear medicine imaging areas (Fig. 1). The total amount of radioactivity

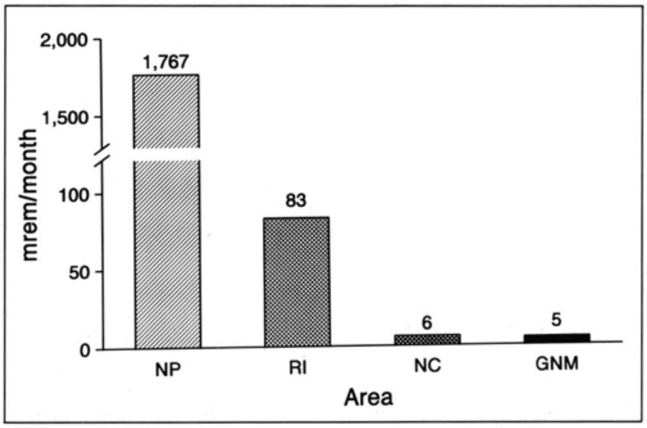

FIGURE 1. Monthly hand radiation exposures in the work areas of nuclear pharmacy (NP), radiopharmaceutical injection (RI), nuclear cardiology (NC) and general nuclear medicine (GNM).

required in our nuclear medicine laboratory amounts to approximately 3700 GBq/mo (100,000 mCi/mo) and thus accounts for the higher hand exposure values in both nuclear pharmacy and radiopharmaceutical injection.

The whole-body exposure of the NMTs in the four areas was: nuclear pharmacy 24.0 ± 4.9 mrem/mo; radiopharmaceutical injection 24.4 ± 4.9 mrem/mo; nuclear cardiology 11.7 ± 3.4 mrem/mo; and general nuclear medicine 6.0 ± 2.4 mrem/mo (Fig. 2). Comparison of these figures shows a correlation of increased whole-body exposure with the increased time of handling and injecting radiopharmaceuticals, especially when there is no protection between the NMT and the patient. When looking at areas where imaging patients accounts for the majority of the NMT's time, whole-body radiation exposure correlates to time of direct patient contact. Though the general nuclear medicine area performed nearly four times the number of studies (1582/mo) as compared to nuclear cardiology (380/mo) the whole-body exposures were nearly half that of nuclear cardiology (i.e., 6.0 ± 2.4 mrem/mo versus 11.7 ± 3.4 mrem/month) (Fig. 3). Whole-body radiation exposure in all four work areas was

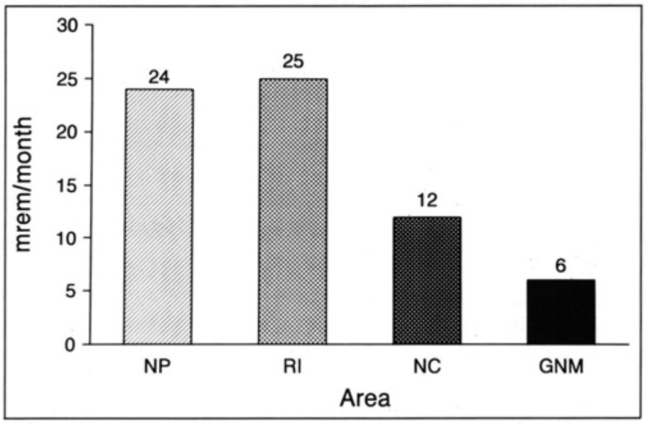

FIGURE 2. Monthly whole-body radiation exposures in the work areas of nuclear pharmacy (NP), radiopharmaceutical injection (RI), nuclear cardiology (NC) and general nuclear medicine (GNM).

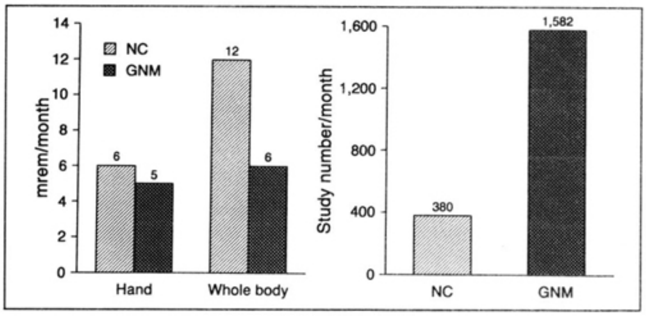

FIGURE 3. (Left) Comparison of monthly hand and whole-body radiation exposure in nuclear cardiology (NC) and general nuclear medicine (NM). (Right) Average number of monthly studies performed in nuclear cardiology (NC) and general nuclear medicine (NM).

well below the legal TEDE limit of 5,000 mrem in any one year, as set by the ICRP, NCRP and NRC (*1–3*).

DISCUSSION

Job duties are quite specific in each of the four work areas in our laboratory, and this made it possible to determine the source of each NMT's radiation exposure. In this study we found that NMTs performing different daily tasks experience different levels of radiation exposure.

Though the hand exposure of the radiopharmaceutical injection technologist was only 4.7% that of the nuclear pharmacy technologist, their whole-body exposures were nearly identical. Although the radiopharmaceutical syringe was shielded, there was no special radiation protection in place between the radiopharmaceutical injection technologist and the patient while the radioactive dose was administered. This might account for the similar whole-body exposures for radiopharmaceutical injection and nuclear pharmacy technologists.

In the imaging areas of nuclear cardiology and general nuclear medicine, the radiation exposure incurred in handling and injecting doses was minimal. This was evident in the relatively low hand exposures in nuclear cardiology and general nuclear medicine. The slightly higher hand exposure readings in nuclear cardiology can be attributed to the following factors:

(1) NMTs in nuclear cardiology are on the quality control rotation once every two months and are required to do a daily generator elution, prepare one or two 3.7–5.55 GBq (100–150 mCi) ^{99m}Tc-sestamibi kits, and draw 111 MBq (3 mCi) ^{201}Tl for the daily patients.
(2) Nuclear cardiology technologists also inject all 37 MBq (1 mCi) return ^{201}Tl doses, 555 MBq (15 mCi) rest ^{99m}Tc-sestamibi doses, 1,110 MBq (30 mCi) first-pass ^{99m}Tc-Sestamibi doses, and 1,110 to 1,295 MBq (30 to 35 mCi) ^{99m}Tc-RBC MUGA doses. Stress ^{201}Tl and ^{99m}Tc-sestamibi doses are injected by the attending nuclear cardiologist or nurse, not the nuclear cardiology technologist.
(3) Nuclear cardiology technologists also have increased direct patient contact while completing ^{99m}Tc-sestamibi, ^{201}Tl and ^{99m}Tc-RBC MUGA procedures since the technologist must ensure there is no patient motion and most patients have recently completed a cardiac stress test and need to be closely monitored.

In general nuclear medicine, the technologist's hand exposure came mainly from 740 MBq (20 mCi) three-phase bone scan injections of ^{99m}Tc-HDP or ^{99m}Tc-MDP and kidney scan injections of 555–740 MBq (15–20 mCi) ^{99m}Tc-DTPA or 370 MBq (10 mCi) ^{99m}Tc-MAG3. In nuclear cardiology and general nuclear medicine, hand exposure readings were lower when compared to nuclear pharmacy and radiopharmaceutical injection (Fig. 1) due to the limited time spent actually handling and injecting the radiopharmaceuticals.

Bone scans performed at three hours following radiopharmaceutical administration with the new dual-headed cameras are very efficient. The dual heads greatly reduce the time spent positioning the camera and increase the distance between the NMT and the patient during imaging, thus achieving lower whole-body exposure.

Though the radiation levels found in our study are well below the legal limits, the ALARA principle brings up the question, can these exposures be further reduced? In our nuclear medicine area, it seems as though it would be quite difficult to lower exposure without affecting patient safety, image quality or patient flow. Patient safety is an important aspect, especially in nuclear cardiology, where patients are imaged during or shortly after stress testing. Image quality is very important, and direct patient contact may be necessary to ensure a high-quality scan. The specialization of our nuclear medicine department is responsible for the higher whole-body and hand exposure which some technologists receive, but allows better patient flow as well as increasing the quality of our images. Individual common sense by the NMT as well as proper use of equipment, adequate shielding and good technique when handling radiopharmaceuticals can all help to keep radiation exposure as low as possible.

CONCLUSION

We conclude from our study that hand exposure to the NMT increases as the time and amount of radioactivity handled increases. We have also shown that increased whole-body exposure correlates more closely with an increased amount of time handling the radioisotopes without body shielding than with hand exposure. The final factor affecting whole-body exposure is the time of direct patient contact during imaging. As this time increases, so does the whole-body radiation exposure.

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