Radiation Exposure Associated with the Performance of Radiologic Studies in Radioactive Patients

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Radiologists and technologists are occasionally concerned about the radiation exposure that they may receive during the performance of routine diagnostic radiologic studies that require close proximity to patients who have recently had a radionuclide imaging procedure. For example, patients who undergo MUGA or Disida procedures often require ultrasound (US) and ventilation/perfusion (V/Q) or GI bleeding procedure patients often require angiography. This also impacts on other medical personnel including: transporters, nurses, surgeons, pathologists, etc. This study was conducted in order to calculate the radiation exposure that one may anticipate receiving from a patient who has recently had a nuclear medicine procedure. Radiation exposure (mrem/hr) was measured in 80 patients (10 patients/procedure type) for eight commonly performed nuclear procedures at the skin surface, at 30 cm, and at 1 m, within 1 hr postinjection, with a digital survey meter. The dose administered, patient height, patient weight and the time postinjection of the measurement were recorded. Calculations were made without any allowance for radiation shielding. The radiation exposure associated with performing a radiologic examination which requires close proximity to a radioactive patient is small (50% of a chest radiograph dose or equivalent to performing fluoroscopy with a lead apron). Furthermore, one's exposure may be reduced significantly by following several "common sense" radiation precautions: allowing time for radioactive decay, increasing one's distance from the patient, minimizing contact time with the patient or avoided entirely by performing the radiologic study first.

Exposure to ionizing radiation predominantly results from two sources: (1) natural or background radiation, and (2) medical radiation. In technologically advanced countries such as the United States, the latter has surpassed the former as the major annual source of exposure (Fig. 1) (*1*). Nuclear medicine examinations performed annually in the U.S. have progressively increased in number and represent a significant proportion of the total medical radiation exposure (Fig. 2) (*2*). Radiologists and technologists are concerned about the exposure that they may receive from radioactive patients

during the course of a radiologic examination. Very little exists in the radiologic or nuclear medicine literature concerning the radiation exposure to medical personnel who may be in close proximity to patients who have recently received radionuclides for a diagnostic scan. Therefore, it was decided to measure the radiation dose at various distances from patients who were injected for several commonly performed types of routine diagnostic radionuclide procedures.

METHODS AND MATERIALS

The radiation exposure in mrem/hr was measured at the skin surface, at 30 cm, and at 1 m (with a digital survey meter*) from the patient within 1 hr after radiopharmaceutical administration. The patient's weight, height, the radiopharmaceutical, the dose administered, and the time postinjection of the measurement were recorded. The types of procedures and radiopharmaceuticals studied are listed in Table 1. Standard recommended doses were employed, and the most common nuclear studies that may require secondary radiological procedures were evaluated. Ten patients were studied in each category. The results were calculated and reported as the mean of the 10 results. The average time postinjection during which the measurements were obtained was 10 min. The estimated radiation exposure for performing a particular radiologic study on a radioactive patient shortly after injection is simply derived by multiplying the anticipated time for the procedure times the exposure rate in mrem/hr at the expected distance.

RESULTS

The mean measurements (n = 10) of radiation exposure (mrem/hr) at different distances from the subject within 1 hr after injection of the radionuclide for eight types of procedures are shown in Table 1. For bone scans, a dose of 25 ± 2 mCi of technetium-99m-MDP (^{99m}TC-MDP) resulted in a radiation exposure of 9.6 ± 1 mrem/hr at the skin surface, 3.6 ± 0.5 mrem/hr at 30 cm, and 0.9 ± 0.2 mrem/hr at 1 m. Most patients did not void between the time of injection and the measurement. The measurement, therefore, represents the "worst possible situation" or maximum exposure since voiding would be expected to decrease the patient's radioactivity significantly (40%–50% of ^{99m}Tc-MDP is excreted in the

TABLE 1. Radiation Exposures from Common Nuclear Medicine Procedures

Procedure	Agent	Administered dose (mCi)	Exposure (skin)	(mrem/hr) (30 cm)	(1 m)
Bone	Tc-MDP	25	9.6	3.6	0.9
L/S	Tc-SC	5	5.9	1.7	0.3
GI Bleed	Tc-SC	10	7.2	2.3	1.2
Hepatobiliary	Tc-Disida	5	5.9	1.7	0.3
Renal	Tc-DTPA	15	8.9	3.1	0.7
Lung	Tc-MAA	4	5.2	1.4	0.4
Gated blood pool	Tc-RBC	25	19.8	6.2 ·	1.4
Myocardial	Tl-CL	3	1.3	0.4	0.1

urine). A dose of 15 ± 2 mCi of Tc-DTPA was injected for renal scans resulting in an exposure of 8.9 ± 1.5 mrem/hr at the skin surface, 3.1 ± 0.6 mrem/hr at 30 cm, and 0.7 ± 0.2 mrem/hr at 1 m. Most renal scan patients did not void prior to the measurement. Results and patient doses for the other eight procedures are shown in Table 1.

DISCUSSION

The perception of risk is often subjective and biased by one's personal attitudes and past experiences. The perceived risk associated with radiation exposure is often exaggerated by irrational fears due to its inherent invisible nature. This originates from unfamiliarity, ignorance, and misconceptions about radiation, even amongst physicians. The "dose/effect" concept of radiation exposure is controversial. However, we believe that most scientists now agree that there is no threshold dose below which radiation-induced injury is absent. This has given rise to the ALARA (as low as reasonably achievable) principle of radiation protection. In keeping with this goal, we conducted this study in order to measure the radiation exposure that one may anticipate receiving by being in close proximity to a radioactive patient. If we assume that most radiologic (US, angiography, fluoroscopy) or surgical procedures require a distance of 30 cm from the patient for a period of 30 min, our calculations indicate that one may anticipate receiving the following exposures in mrem: bone scan patient = 1.8, liver/spleen scan patient = 0.8, GI bleeding scan patient = 1.6, renal scan patient = 1.5, V/Q scan patient = 0.7, MUGA scan patient = 3.1, and thallium scan patient = 0.2. Similar results were obtained by Harding et al. (3). These figures represent an insignificant proportion of the established annual radiation protection guidelines (RPG) and do not justify taking any extraordinary precautions. Furthermore, these estimates represent the maximum exposure that one might expect, since the patients did not void prior to the radiation measurement, no shielding was employed, and the measurements were all performed within 1 hr postinjection. The National Council on Radiation Protection and Measurements (NCRP) has recommended a maximum permissible dose (MPD) of 5000 mrem/yr for individuals who work with ionizing radiation (occupational exposure) and 500 mrem/yr

for the general population (8). The Nuclear Regulatory Commission has established that the MPD for a pregnant woman is 500 mrem during gestation (9).

Mountford (4) has devised a method for estimating close contact doses to young infants from surface dose rates on radioactive adults. He reported that doses to infants from adults who have undergone diagnostic radiopharmaceutical procedures can be kept below 100 mrem without imposing restrictions in close contact. Burks et al. (5) conducted a study in which the radiation exposure of 13 nurses caring for patients who had a variety of diagnostic radionuclide scans was measured. In no case were measured radiation levels per quarter sufficient to result in occupational exposures in excess of the MPD (125 mrem/quarter) for occupational or non-occupational workers. The nurses received doses much lower than the MPD for non-radiation workers and even if the nurses were pregnant, their radiation exposure would be less than the fetal MPD. Brateman et al. (6), measured the potential radiation hazard to ultrasonographers exposed to patients who have received radionuclides for nuclear medicine procedures. One reason that many technologists specialize in US or MRI is their misconception of the lack of occupational exposure to ionizing radiation. Brateman et al. recommended that US technologists be considered radiation workers and should be monitored for radiation exposure although no unacceptably high occupational exposure rates were measured in their study. Their measured exposure rates (10 mrem/hr at skin surface, 5 mrem/hr at tableside) are in agreement with our findings. There are several "common sense" radiation protection guidelines that may be followed in order to minimize one's radiation exposure in dealing with radioactive patients, including encourage fluids and voiding; maximize distance from the patient; maximize the time from injection of the radionuclide to contact with the patient or perform the US exam before nuclear imaging or after 4 half-lives have passed; wear radiation protection gear (lead apron); minimize the duration of contact with the patient; and sharing the radiation exposure among more technologists. Huda et al. (7) investigated the efficacy of whether or not nuclear medicine technologists (which also would apply to US technologists) should wear lead aprons to decrease their radiation exposure. They concluded that a technologist's annual radiation exposure could be decreased by approximately 100 mrem by wearing a standard (0.25-mm thick) lead apron. However, it is impractical to wear a heavy lead apron all day long and only the front of the technologist is protected.

CONCLUSION

In summary, radiation exposure measurements have been made at several distances in close proximity to radioactive patients who have just had a routine diagnostic nuclear medicine scan. The measured levels of exposure were extremely small and do not justify any undue concern or the institution of any special precautions. However, in keeping with the ALARA concept, exposure may be minimized by following several "common sense" precautions that apply to radiation exposure in general, by performing the radiologic examination

before the nuclear study; and utilizing appropriate shielding and/or protective garments (gloves/lead aprons) when dealing with radioactive fluids whenever possible as well as other methods described above.

NOTES

* Digital Survey meter, Keithley Model #36150, Mallinckrodt Medical Inc., Diagnostic Imaging Services, Folcroft, PA

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