Time Dependent Radiation Exposures Surrounding Technetium-99m MDP Patients

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Radiation surveys of technetium-99m (^{99m}Tc) MDP bone scan patients were performed at 5 min, 4 hr, and 24 hr post administration. The measurement distances chosen were surface, 1 ft (30.5 cm) and 3 ft (100 cm) resulting in variable radiation exposures as a function of time and bony pathology. As expected the highest exposures were immediately after tracer administration. Thereafter, urinary excretion and biologic redistribution dominated, resulting in significantly lower exposures at 4 hr and 24 hr for the negative bone scan group. Patients with bony metastases retained more of the injected dose than those with negative scintigrams. This was reflected with the 4 hr and 24 hr surveys.

The purpose of this investigation is to document the radiation exposure at various projections and distances from routine bone scan patients over time. the availability of bone scan patients in the clinic at various times post administration presents an opportunity to measure time dependent exposure rates.

After the introduction of ^{99m}Tc diphosphonate skeletal imaging radiopharmaceuticals, bone imaging became a major part of the daily schedule in most nuclear medicine clinics (*1–4*). Investigations of the internal dosimetry from such agents have been published (*5,6*). However, the time dependent radiation exposure from bone scan patients to their surrounding environment has not been extensively studied. Bone scan patients are an ideal model to investigate in this manner. These individuals can either be out-patients or in-patients and receive a diagnostic radioactivity upper limit of 20 mCi (740 MBq). After administration of this radiopharmaceutical, the patient is free to wander about (out-patient) or remain in the hospital (in-patient) prior to the bone scintigram at 3 hr to 4 hr. During this waiting period, blood disappearance and urinary excretion of the tracer occurs; body fluids may need to be collected during this time (*7–9*). On occasion, whole body retention of the tracer is determined at 24 hr post administration (*10,11*).

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MATERIALS AND METHODS

We surveyed sixteen adult patients referred to our nuclear medicine department for routine ^{99m}Tc-methylene diphosphonate (MDP) scans, with subsequent 24 hr whole body retentions (WBR). The calibrated survey instrument, Victoreen Model 1470A (Victoreen, Inc., Cleveland, OH), was positioned at waist level for each survey. Measurements were initially obtained at 5 min post radiopharmaceutical administration for the anterior, posterior, left lateral, and right lateral projections. The survey distances were at the surface, 1 ft (30.5 cm), and 3 ft (100 cm). Subsequent surveys were performed similarly for the anterior and posterior projections at scan time (4 hr) and when the patients returned for their whole body retention determination at 24 hr. The 5 min survey results were expressed as the mean ± s.d. (n = 16) for a normalized administered dose of 20 mCi (740 MBq) in units of mrem/hr (mSv/hr/740 MBq). The 4 and 24 hr results were expressed in similar units. However, at these times, the original patient population was divided between those with skeletal metastases (n = 7) and those without (n = 9) as seen on the bone scan.

RESULTS

Of the 16 patients surveyed, 7 had bone metastases as determined by the bone scan. Table 1 lists the mean ± s.d. survey results for all patients at 5 min, 4 hr, and 24 hr post ^{99m}Tc-MDP administration. The study population was divided into two groups: those with positive bone scans and those with negative bone scans for the 4 hr and 24 hr survey periods. The initial radiation exposures at 5 min were reduced significantly in 4 hr for the negative bone scan group. Those patients possessing skeletal metastases, however, showed higher exposures at 4 hr than at 5 min.

Due to potentially higher tracer concentrations with involved bone, patients with metastases showed a radioactive hot spot or series of hot spots, each producing a greater photon flux than the normal surrounding bone. Consequently, the radiation exposure at or near such deposits would be expected to deliver relatively higher radiation exposure rates than similar bony locations without metastases. Conversely, variations

TABLE 1. ^{99m}Tc-MDP Patient Radiation Surveys

Time	Population	N	Projections*	mrem/hr/20mci** (mean ± s.d.) Surface	1 Ft (30.5 cm)	3 Ft (100 cm)
5 min	patient	16	anterior	9.0 ± 1.6	3.1 ± 0.4	0.9 ± 0.3
		16	posterior	9.1 ± 3.6	3.8 ± 0.4	1.1 ± 1.8
		10	right	5.2 ± 1.0	1.8 ± 0.3	0.78 ± 0.3
		10	left	5.7 ± 1.1	2.1 ± 0.3	0.82 ± 0.2
4 hr	without bone metastases	9	anterior	2.6 ± 0.7	1.0 ± 0.2	0.27 ± 0.1
		9	posterior	5.0 ± 0.9	2.1 ± 0.4	0.55 ± 0.1
	with bone metastases	7	anterior	14.0 ± 14.1	5.7 ± 6.2	1.5 ± 1.5
		7	posterior	48.6 ± 36.6	17.3 ± 6.4	4.3 ± 2.0
24 hr	without bone mestastases	9	anterior	0.4 ± 0.1	0.07 ± 0.02	BKG
		9	posterior	0.5 ± 0.2	0.10 ± 0.02	BKG
	with bone metastases	7	anterior	1.5 ± 1.6	0.30 ± 0.3	0.08 ± 0.05
		7	posterior	4.7 ± 2.06	0.9 ± 0.5	0.28 ± 0.2

* survey meter at patient's waist level.
** mSv/hr/740MBq = (mrem/hr/20mCi)(0.010).

in urinary excretion and elimination patterns also affected the survey reading at this time period. Those with bone metastases showed significantly higher readings than those without, with the posterior projection dominating. Many of these patients had lower lumbar metastases, which retained higher concentrations of the tracer throughout the investigation. The exception is when a higher survey result is obtained with the anterior projection, which can be due to pelvic metastases, urinary retention, or contamination.

At 24 hr the radiation exposures around bone scan patients were equivalent to background at the 3 ft (100 cm) distance for patients without bone metastases and were approximately 10 times the background for those with pathology. Exposures at 1 ft (30.5 cm) were near 100 times ambient levels. The surface exposures, however, were significantly greater than background values especially at the posterior projection for patients with bone metastases.

DISCUSSION

The present investigation documents the radiation exposures around ^{99m}Tc MDP bone scan patients up to 24 hr post administration. The patients produced the highest measured radiation exposure at 5 min after injection, as is exemplified by Table 1. The patient is not required to return for the bone scan until the tracer has accumulated onto the skeleton with minimal interference from other tissues, usually at 3 hr to 4 hr. During this intervening time period, the patient is not required to abstain from any task nor is any individual handling (in-patient) or accompanying (out-patient) the patient issued a "hands off" instruction. Health care units, however, may be given special precautionary instructions relative to handling the radioactive urine (*14*). In this regard, universal precautions have for the most part satisfied this requirement.

When the patient returns for the scan at 4 hr, the survey results reflect the urinary excretion and redistribution of tracer as well as the extent of bony pathology. For example, in Table 1 the 5-min anterior surface values decrease by 28.9% by 4 hr for non-involved bone, while the positive scan population shows an increase of 155.5%. The posterior projection changes are even more dramatic; 54.9% decrease without bone metastases and a 534.1% increase with metastases. This trend continues to a lesser degree at 1 ft (30.5 cm) and 3 ft (100 cm). During this time period, the nuclear medicine technologists performing the scans receive their greatest radiation exposure (*13*), due to close proximity to the patient and frequent repositioning during a multiview study. Automatic anterior/posterior whole body scanning systems, where less time is spent near the patient, would reduce personnel radiation exposure.

By 24 hr the mean surface exposures essentially followed the physical $T_{1/2}$ of ^{99m}Tc (6.06 hr). However, further redistribution and urinary excretion occurs after 4 hr, which may account for these data not fitting the decay model perfectly (*8,14*). Bone metastases retain the tracer more avidly than normal bone where the mean posterior surface reading is approximately 5 mr/hr/20 mCi after 24 hr for metastatic bone.

For the same projection and patient population, the value at 1 ft (30.5 cm) approximates 1 mr/hr/20 mCi. At 3 ft (100 cm) negative bone scan values are background, whereas those with bone metastases are slightly greater than background. Table 2 lists the percent of whole body retention of ^{99m}Tc-MDP at 24 hr for positive and negative bone scans (*10,11, 15*). Obviously, the greater the bony pathology the higher the tracer retention and subsequent radiation exposure around bone scan patients. The survey results correlate with this reported observation.

CONCLUSION

The radiation exposures surrounding ^{99m}Tc-MDP patients drop rapidly over a 24 hr period. Patients with bone metas-

TABLE 2. Percentage ^{99m}Tc-MDP Retained at 24 Hr According to Bone Pathology

Patient population	Number	% Retained at 24 hr*
No bone metastases	10	2.02 ± 0.37
With bone metastases**	5	4.51 ± 1.36

* not corrected for decay, mean ± s.d.
** Patients in relapse.

tases exhibit higher exposures at 4 hr and 24 hr post administration.

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REFERENCES

1. Castronovo Jr FP, Callahan RJ. New bone scanning agent: ^{99m}Tc-labeled 1-hydroxy-ethylidene-1, disodium phosphonate. *J Nucl Med* 1972;13:823–827.
2. Welman HN, Browne A, Kavula M, et al. Optimization of a new kit prepared skeletal imaging agent: ^{99m}Tc-SN-EHDP and labeled compounds. Vienna: IAEA: 1973:1.
3. Pendergrass AP, Potsaid MS, Castronovo Jr FP. The clinical use of ^{99m}Tc-diphosphonate (HEDSPA): a new agent for skeletal imaging. *Radiology* 1973;107:557–562.
4. Subramanian G, McAfee JG, Blair RJ, et al. Technetium-99m methylene diphosphonate—a superior agent for skeletal imaging: comparison with other technetium complexes. *J Nucl Med* 1975;16:744–755.
5. Grossman LW, Sodd VJ, Nishiyama H, et al. Measurement of the distribution of technetium-99m sulfur colloid and technetium-99m HEDP in normal humans. *Med Phys* 1983;10:79–82.
6. Weber DA, Makler Jr PT, Watson EE, et al. Radiation absorbed dose from technetium-99m labeled bone imaging agents (MIRD dose estimate report no. 13). *J Nucl Med* 1989;30:1117–1122.
7. Krishnamurthy GT, Huebotter RJ, Tubis M, et al. Pharmaco-kinetics of current skeletal seeking radiopharmaceuticals. *Am J Roentgenol* 1976;126:293–301.
8. Castronovo Jr FP, Guiberteau MJ, Berg G, et al. Pharmacokinetics of technetium-99m diphosphonate. *J Nucl Med* 1977;18:809–814.
9. Weber DA, Keyes Jr JW, Wilson GA, et al. Kinetics and imaging characteristics of 99m-Tc-labeled complexes used for bone imaging. *Radiology* 1976;120:615–621.
10. Castronovo Jr FP, McKusick KA, Dann J, et al. A simplified technique for quantifying 24-h whole body retention of Tc-99m labeled methylene diphosphonate. *Int J Nucl Med Biol* 1985;12:209–215.
11. Dann J, Castronovo Jr FP, McKusick KA, et al. Total bone uptake in management of metastatic carcinoma of the prostate. *J Urol* 1987;137:444–448.
12. Castronovo Jr FP, Webster EW, Strauss KW, et al. A health physics guide for patient care units. Boston: Massachusetts General Hospital; 1982.
13. Barral RC, Smith SI. Personnel radiation exposure and protection for Tc-99m radiation. In: Keriakes JG, Carey KR, eds. *Biophysical aspects of the medical uses of technetium-99m.* AAPM monograph no. 1. New York: American Institute of Physics; 1976:77–97.
14. Castronovo Jr FP, McKusick KA, Strauss HW. Bladder wall dosimetry after the administration of Tc-99m-diphosphonate. *Health Physics* 1980;40:744–746.
15. Castronovo Jr FP, Prout Jr GR, Strauss HW, et al. A refined method for assessing Tc-99m MDP whole body retention in prostate cancer patients. *Int J Nucl Med Biol* 1987;14:475–477.