Dosimetric Considerations while Attending Hospitalized I-131 Therapy Patients

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Radiation exposure to hospital personnel attending I-131 therapy patients was calculated relative to patient dose, distance, and time after administration. Routine or emergency contact with these patients would not exceed occupational maximum permissible doses for hands and whole body for attendance up to 30 min immediately after administration.

Metastasis to the skeletal system from follicular carcinoma may be treated with oral I-131 (^{131}I-NaI) with an adult dose of 100–300 mCi (3.7 to 11.1 GBq). After drug administration the I-131 body burden is monitored daily until it is below an acceptable quantity for patient discharge. This acceptable quantity is based on the possible exposure other individuals may receive when associating with the patient and may range between 8 mCi (0.296 GBq) and 90 mCi (3.33 GBq) (*1*). Up to the time of the patient's release, various radiation safety procedures are issued daily listing personnel "precautions" associated with patient handling, housekeeping, food service, linen, objects in the room, disposal of excreta, visitors, and accidents. Strict adherence to these precautions may be interrupted when the patient requires additional care or handling associated with his illness. This may be the result of a myocardial infarction, an emergency operation, the drawing of blood samples, the maintenance of an IV line, or the administration of pharmaceuticals. Each necessitates close contact with the patient and, consequently, increases risk of exposure.

To evaluate the radiation exposure to hospital personnel attending an I-131 therapy patient, calculations were performed relating exposure at several distances as a function of time after ^{131}I-NaI administration.

Materials and Methods

1) *Radiopharmacokinetic studies*:

In order to quantitate the biologic behavior of ^{131}I-NaI (Iodotope, Squibb Pharmaceutical Company), profiles were determined for adult thyroid cancer patients (N = 25) after oral administration of 3mCi (0.11 GBq) to 150 mCi (5.55 GBq) of radioactivity. The following investigations were performed for up to 168 hr:

a) *Percentage excreted by urine*:

Excreted urine was collected (N = 25) and its content of radioactivity determined by a dose calibrator (Capintec model CRC 4R) for the following collection periods: administration to 24 hr; 24 to 48 hr; and 48 to 72 hr. A histogram was then constructed relating the "I-131 excreted" as a function of "time post (hours) administration".

b) *Whole body retention of I-131*:

The instrument used to determine whole body retention of I-131 in a single patient was a specially designed counter consisting of an 8 in. × 4 in. NaI (Tl) crystal (2-cm Pb shield) mounted on an angiography gantry above the patient (*2*). The counting geometry allowed for a vertical subject-to-detector distance of 2.75 m with the patient lying supine on a stretcher near the floor. Total body counts were determined 5 min after oral administration of the ^{131}I-NaI (baseline) and daily up to 168 hr. The counting window was 270 to 500 keV and the mean value of five 60-sec counts was calculated for each time period. The resulting data points were then plotted on semilog graph paper as "% I-131 retained in whole body" as a function of "time after administration". Conventional curve stripping techniques were used to determine the radiopharmacokinetic parameters associated with the retention data (*3,4*).

2) *Dosimetry measurements and calculations*:

a) *Measurements*:

A series of adult thyroid cancer patients (N = 25) were positioned supine in hospital beds shortly after administration of ^{131}I-NaI. As adapted from Thomas et al., a survey meter (Victoreen model 470A) was positioned midline 100 cm from each patient and three separate measurements were recorded for each patient (*5*). The results were expressed as the mean mR/hr (nC/Kg/sec) at this distance for the patient population.

b) *Calculations*:

For purposes of this study it was assumed that the radioactive "portion" of the adult body was the torso with a length of 61 cm (2 ft). The mean dose rate at 100 cm from the geometric center of the patients' torsos was determined as outlined previously. Utilizing this information the radiation exposure was calculated at 10 cm (0.328 ft) and 30.5 cm (1 foot) from the patient as follows (*6*).

The intensity of radiation from an extended source,

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0091-4916/82/1003/157-04$2.00/0

viewed broadside and assuming uniform self-absorption in the medium, is given by:

$$I = \frac{I_0 \theta}{Y}$$

where;

I = intensity at a perpendicular distance "Y" from the extended source.

I_0 = original intensity at a perpendicular distance < "Y" from the extended source.

θ = angle theta subtended by the line at the point of measurement where θ is expressed in radians,

$$\frac{\theta(\text{in degrees})\ 2\pi}{360}.$$

3) *Practical applications*:

The resultant exposure levels obtained were related to current quarterly maximum permissible doses (MPD) of 1250 mR whole body and 18750 mR hands. These results were expressed as:

a. Exposure rates at 10, 30.5, and 100 cm from the patient at various times after oral administration of 1-150 mCi (0.037-5.55 GBq) of ^{131}I-NaI. The exposure rate equals (reading at administration) (1 − fraction excreted in urine at time = t) ($e^{-(0.693/194\ hr)\ (t)}$).

b. Exposures received by hands and whole body for 1 min, 5 min, 15 min, and 30 min of exposure at 10, 30.5, and 10 cm from the patient at various times after oral administration of 100 mCi of ^{131}I-NaI. The exposure rate equals (reading at administration) (1 − fraction excreted in urine at time = t) ($e^{-0.693/194\ hr)\ (t)}$).

Results

1) *Radiopharmacokinetic studies*:

a) *Percentage excreted by urine*:

The urinary excretion pattern of ^{131}I-NaI is illustrated in Fig. 1. The patients excreted 62.92 ± 10.94% of the dose within 24 hr, 81.66 ± 6.59% by 48 hr, and by 72 hr, 92.12 ± 3.08%. The half-time for excretion was calculated to be 21 hr.

b) *Whole-body retention of I-131*:

The whole-body retention data are illustrated in Fig. 2. A triexponential clearance pattern was observed consisting of a rapid initial component and two delayed components. Component I has a biological half-time ($t_{1/2}b$) of 7.5 hr, comprises 40.5% of the administered dose, and represents initial excretion of the tracer by the kidney. Component II ($t_{1/2}b$ = 41 hr) represents 8.5% of the dose after redistribution with ultimate kidney excretion. Component III ($t_{1/2}b$ = 52 hr) comprises 51% of the dose and represents the relatively long residence time of the ^{131}I-NaI in the gastrointentinal tract and other organs.

The overall percentage retention (%R) relationship is:

$$\%R = 40.5e^{-0.0924t} + 8.5e^{-0.0169t} + 51e^{-0.0133t}$$

where t = time after administration.

2) *Dosimetry measurements and calculations*:

The exposure rate at 100 cm from the center of the torso was measured to be 21.64 ± 4.31 mR/hr (1.55 ±

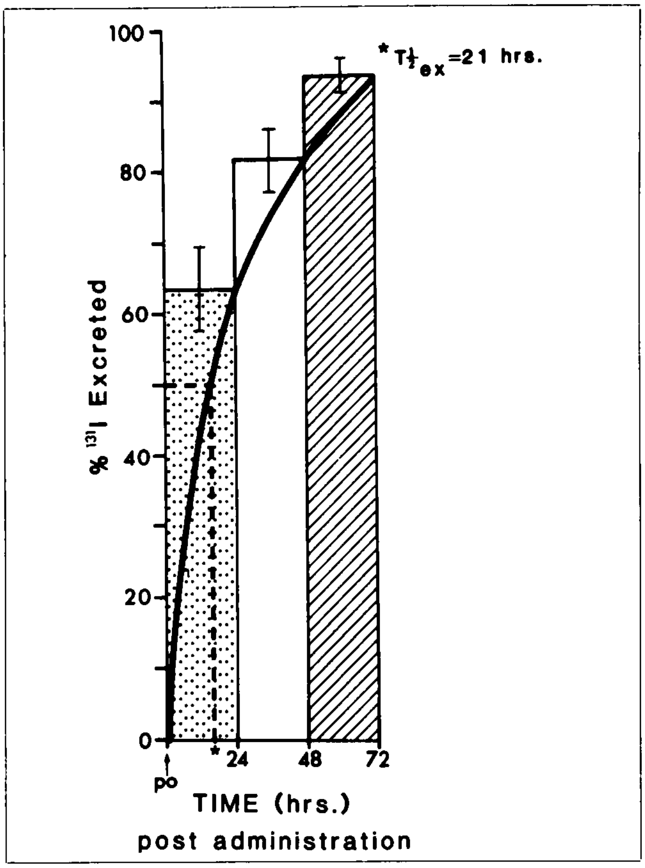

FIG. 1. Urinary I-131 excretion histogram for 25 patients up to 72 hr postadministration. Half-time for excretion was 21 hr.

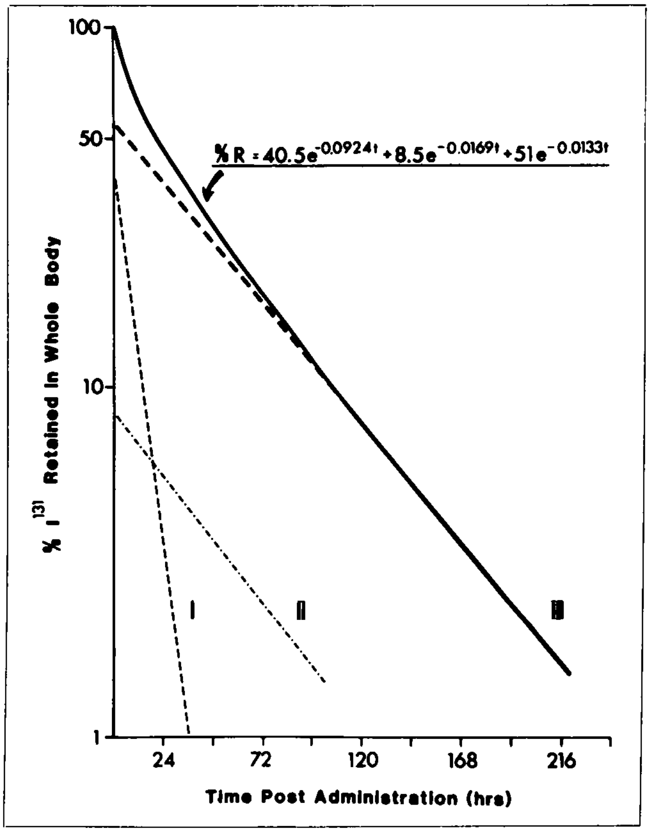

FIG. 2. I-131 whole-body retention of a cancer patient illustrating a triexponential release pattern as a function of time after oral administration.

0.39 nC/Kg/sec) for 25 patients. Using data and assuming the radioactive portion of the body to be a 2-ft long torso containing 100 mCi, exposure rates were calculated at distances of 10 cm (0.328 ft) and 30.5 cm (1 foot). The calculations were based on distances from the center of the torso using the model illustrated in Fig. 3.

a) The exposure at 1 cm (I_o) distance is initially calculated by rearranging the formula,

(1) $I_o = \dfrac{IY}{\theta}$;

(2) where $I = 21.64$ mR/hr at 1 meter (Y);

(3) θ = angle theta, where angle ACB = angle DCB and $\tan \theta/2 = AB/BC = 30.48/100 = 0.3048$, which is equivalent to 0.593 radians.

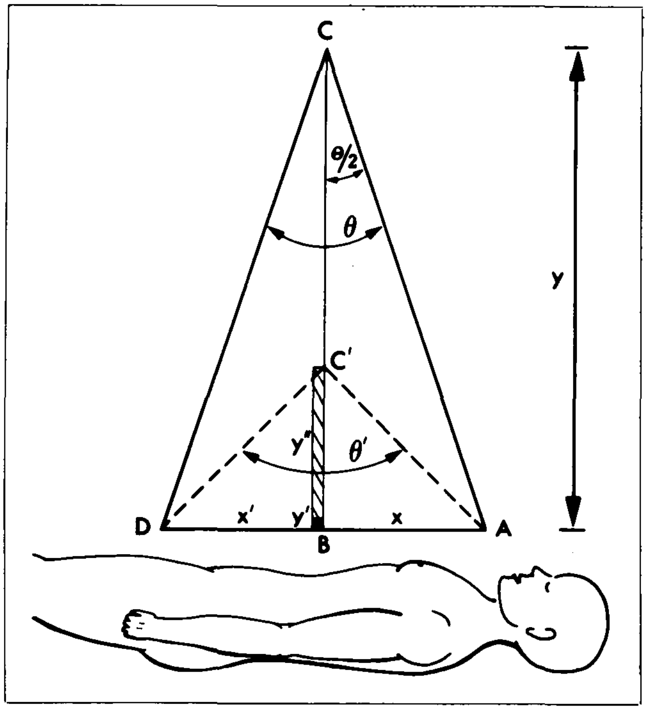

FIG. 3. Diagram of model utilized for calculating exposure rates at various distances (y, y', y'') from the midpoint (B), of an extended source of activity (torso ABD)

(4) The exposure at 1-cm distance is;

$$I_o = \frac{(21.64 \text{ mR/hr})(100\text{cm})}{0.593}$$
$$= 3{,}649 \text{ mR/hr } (261 \text{ nC/Kg/sec}).$$

b) From the above information, the exposure rates at 10 cm and 30.5 cm were calculated to be 571.8 mR/hr (4.1×10^1 nC/Kg/sec) and 92.7 mR/hr (6.65 nC/Kg/sec), respectively.

3) *Practical application*:

Based on the I-131 radiopharmacokinetic patient profile and the data calculated via Fig. 2, exposure rates were determined at 10 cm, 30.5 cm, and 100 cm as a function of time after administration (Table 1). The cumulative exposures for various patient contact times based on a 100-mCi dose are shown in Table 2. These exposures exhibit a rapid decrease as a function of time and distance.

Discussion

The principal intention of medical health physics programs is to achieve and maintain safe and satisfactory working conditions for hospital personnel. Following the ALARA (as low as reasonably achievable) principles, satisfactory working conditions are those that have the minimal amount of exposure reasonably achievable, regardless of the lack of demonstrated risks. Thus, according to the ALARA philosophy, exposures are to be reduced if possible, even though much higher exposures have shown no deleterious effects. In regard to hospital personnel, specifically nurses, it is emphasized that unnecessary contact with a radioactive therapy patient be avoided as a reasonable way to minimize exposures.

Occasionally a condition may arise when a radioactive patient needs care that has the potential to increase his contact with an attendant. Even during routine patient care an individual may spend time with the radioactive patient dispensing a drug, cleaning a wound, or adjusting an IV line. During an emergency, such as a myo-

TABLE 1. Exposure Rates at Various Times and Distances after Administration of I-131

mCi	Activity (GBq)	Distance cm	Administration mR/hr	24 hr mR/hr	48 hr mR/hr	72 hr mR/hr
1	(0.037)	10.0	57.24*	19.48	8.88	3.48
		30.5	0.928	0.316	0.143	0.057
		100.0	0.216	0.074	0.033	0.013
100	(3.7)	10.0	572.4	1948.0	888.0	348.0
		30.5	92.84	31.6	14.3	5.65
		100.0	21.64	7.4	3.33	1.32
150	(5.55)	10.0	858.6	2922.0	1332.0	522.0
		30.5	139.3	47.4	21.5	8.48
		100.0	32.46	11.1	4.99	1.98

*1 mR/hr = 0.00072 nC/Kg/sec.

TABLE 2. Exposures Accumulated for Various Contact Times with Therapy Patients Receiving 100 mCi of I-131

Time (min)	Position (cm)	Administration (mR)	24 hr (mR)	48 hr (mR)	72 hr (mR)
1	hands (10)	10.0†	3.40	1.54	0.609
	WB* (30.5)	1.56	0.531	0.24	0.095
	WB (100)	0.36	0.123	0.056	0.022
5	hands (10)	50.0	17.0	7.17	3.04
	WB (30.5)	7.80	2.66	1.2	0.475
	WB (100)	1.80	0.615	0.28	0.110
15	hands (10)	150.0	51.0	23.1	9.12
	WB (30.5)	23.42	7.98	3.6	1.27
	WB (100)	5.41	1.84	0.84	0.33
30	hands (10)	300.0	102.0	46.2	18.2
	WB (30.5)	46.84	15.96	7.2	2.55
	WB (100)	10.82	3.68	1.68	0.66

*WB = whole body.
†10 mR = 2460 nC/Kg.

cardial infarct or an operation, the length of time may be even longer. Estimated times to perform certain routine nursing tasks are listed in Table 3. With this information and the results of the present study, exposure rates were calculated for hands and whole body for various time periods of patient contact after the administration of 100 mCi of I-131. The cumulated exposure at the time of administration for all time periods does not exceed occupational MPD levels, and after 24 hr these exposures drop dramatically.

These data illustrate that hospital personnel's routine or emergency contact with I-131 therapy patients would not exceed MPD for hands or whole body up to periods of 30 min immediately after administration. Multiple health care tasks during a radioactive patient's hospital stay, or an increase in the number of such tasks over a period of time, may result in longer patient contact for personnel. It is unlikely, however, that resulting exposure will even exceed the MPD for the general public. Projected nursing care times for a variety of patient-related procedures are listed in Table 3. The data provided could easily be utilized for the calculation of cumulative exposure for any number of situations and thus demonstrate that exposures are indeed very low for routine health care tasks.

TABLE 3. Projected Nursing Care Times for Various Patient-Related Procedures*

Classification	Task	Time (min)
Moderate care†	greet, shift rounds	2
	complete visit	5
	give medicines	2-5
	straighten linen	2-5
	backrub	2
Moderate to heavy care	patient assessment	5
	ambulate to and from bathroom	5
	IV mainline (total care)	15
	piggyback IV dose and resetting mainline	5
	central venous pressure or subclavian dressing change (includes total parenteral nutrition)	20-45
	assess for and administer cardiac medicines	2-5
	chest physiotherapy	20
	endotracheal or track suctioning	10
	troubleshoot problems (IV site)	5-10
	12-lead ECG	10

*Based on personal communication with L. Hertzberg, MGH Nursing Service.
†May be done 1 to 3 times per shift.

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