
Radiation Safety Considerations for Post-Iodine-131 Hyperthyroid Therapy

Cheryl M. Culver and Howard J. Dworkin

Nuclear Medicine Department, William Beaumont Hospital, Royal Oak, Michigan

The purpose of this study was to develop guidelines based on patient measurements as to when iodine-131- (¹³¹I) treated hyperthyroid patients may resume close personal contact. External exposure rates were measured on 59 patients using an ionization survey meter in the upright position. The initial measurement was recorded within 20 min post-dose administration at one meter. Exposure rates were measured 2–11 days post-dose administration at 1, 0.6, and 0.3 meters from the patient's thyroid. In the administered dose range of 3 to less than 12 mCi of ¹³¹I, all 40 patients measured ≤ 2.0 mR/hr at one meter on Day 0, and 25 patients (25/29) were ≤ 2.0 mR/hr at 0.6 meter on Days 2–4. Guidelines can be prepared based on the administered dose that are rational and in conformity with existing radiologic health standards.

J Nucl Med 1991; 32:169–173

Radioactive iodine therapy (¹³¹I) is the treatment of choice for most adult patients with Graves' disease (1). The ¹³¹I treatment dose (up to 30 mCi) is almost always given on an outpatient basis, and patients continue with their daily routine. While the radioactive iodine is indicated for these patients, there are precautions patients may take to avoid radiation exposure to their families and to other people with whom they come into contact.

Following administration of therapeutic doses, contamination from excretion of radioiodine in urine, perspiration, and saliva can be associated with internal accumulation of radioiodine by family members or those who come in contact with the patient (2). Patients carefully instructed in personal hygiene, eating habits, and contamination control can minimize the internal radiation exposure to others (3).

The ¹³¹I present in the patient also poses an external source of radiation exposure to individuals who come into close contact with the patient. The external radiation exposure can be minimized by reducing the duration of time spent in close proximity to others and by

increasing the distance. Previous studies suggest that the external exposures often exceed the internal thyroid dose equivalent in family members of therapy patients (3,4).

Recommendations for minimizing the external exposure were published in NCRP Report #37 in 1970 (5). The report recommended that children and persons under 45 yr of age avoid being in the same room or at a distance of less than 2.7 meters for more than a few minutes from a patient who had received therapeutic doses of ¹³¹I, until the measured exposure rate fell below 1.8 mR/hr at 1 meter. Since it is impractical, in most cases, to monitor a patient's external exposure rates, physicians may base recommendations on other published guidelines for resuming close contact. The Society of Nuclear Medicine recommends that the treated patient sleep alone for the first few days after the treatment (up to 30 mCi ¹³¹I) (6). The Society suggests that if caring for a baby, the patient should minimize the amount of time spent in close proximity with the infant during the first two days after treatment. It also recommends that the patient try to minimize the time spent with pregnant women and young children for 2–5 days after treatment. In another published guidebook for thyroid patients, the patient is encouraged to have someone else care for their infant for 2 wk after having received radioiodine therapy, if possible (7). It suggests that patients avoid contact with pregnant women at home and at the workplace.

This study was, therefore, undertaken to derive more specific guidelines as to when ¹³¹I-treated hyperthyroid patients may resume close contact with their children, spouses, and co-workers post-therapy.

MATERIALS AND METHODS

Fifty-nine patients treated with ¹³¹I for hyperthyroidism (53 with Graves' disease and 6 with Plummer's disease) volunteered to participate in this study. The ages ranged from 27–83 yr with a mean value of 47.7. Forty-four of the patients were females and 15 were males. All patients had ¹³¹I thyroid uptake measured prior to treatment. All patients had external exposure rates measured at one meter initially within 20 min post-therapy dose administration (PDA). With the patient sitting, the exposure rate at one meter from the patient's waist up to their neck was measured. The maximum exposure rate

Received Nov. 17, 1989; revision accepted Jul. 6, 1990.
For reprints contact: Cheryl M. Culver, MS, Nuclear Medicine Department, William Beaumont Hospital, 3601 West Thirteen Mile Rd., Royal Oak, MI 48072.

was recorded for each patient. All patients were asked to return three times following their ^{131}I therapy dose. Whenever possible, the time intervals were scheduled at 3, 7, and 10 days PDA. To accommodate weekends and patient's convenience, however, the time intervals were extended to 2–4 days, 5–7 days, and 8–11 days. The date and time of the return visits were recorded on an appointment card and the patients were asked to call and reschedule their appointments if necessary. No attempt was made to call the "no show" patients. At each return appointment, the patients' external exposure rates were measured at distances of 1 meter, 0.6 meter, and 0.3 meter from their thyroid gland. The patients sat and held a meter stick parallel to the floor with the end placed midway between their cricoid cartilage and the suprasternal notch for each measurement.

The ionization survey meter (Victoreen 470A, Cleveland, OH) was calibrated semi-annually on two points of each scale using a calibrated cesium-137 (^{137}Cs) source, traceable to the National Bureau of Standards (accuracy $\pm 3\%$) (8). The energy response of the meter is 0.97 for ^{131}I and 0.96 for ^{137}Cs .

CRITERIA FOR RESTRICTING CONTACT

NCRP Report No. 37 (5) states that 1.8 mR/hr is the initial exposure rate, which results in a total integrated exposure of 0.5 R at 1 meter during complete decay of ^{131}I . The recommended maximum permissible dose equivalent for persons not occupationally exposed is 500 mrem per year. The report recommended that patients measuring less than 1.8 mR/hr at 1 meter be released from hospital care with no restrictions.

The Nuclear Regulatory Commission describes an unrestricted area as one in which the radiation exposure to an individual is less than 2 mrems in any one hour (9). The Nuclear Regulatory Commission states that a licensee may authorize release of a patient containing radiopharmaceuticals if the measured dose rate is less than 5 mrem/hr at a distance of one meter. (10). The licensee must provide the patient with radiation safety guidance to minimize radiation dose to household members and the public (11). On the basis of these references, the radiation exposure level of less than 2 mR/hr was selected as our criterion for resuming contact.

Statistical Analysis

The results are presented as mean \pm standard error of the mean. Linear regressions were calculated by the least-square's method. Statistical significance was determined by applying the Student's t-test. A p value < 0.05 was considered statistically significant.

RESULTS

Positive correlation between exposure rate and percent thyroid uptake was significant only for the initial (within 20 min PDA) measurement at one meter ($r = 0.50$, $n = 59$, $p < 0.001$). Significant positive correlations between dose administered and exposure rate were found throughout the series of measurements.

The initial exposure rates measured at 1 meter within 20 min PDA are shown in Figure 1A. All patients receiving less than 12 mCi (40 of 59) had initial exposure rates ≤ 2 mR/hr at one meter. Of the patients receiving a dose ≥ 12 mCi (19 of 59), all but one had

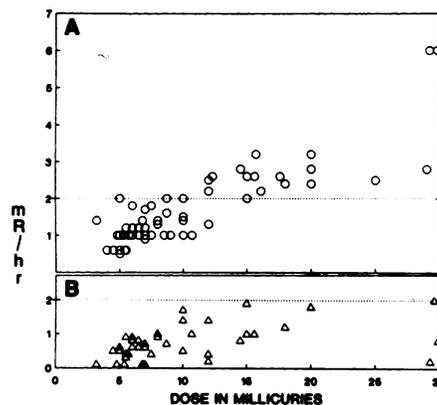


FIGURE 1 Exposure rate versus administered dose of ^{131}I at one meter. The criterion for restricting contact, 2 mR/hr, is represented by the dotted line. (A) Within 20 min PDA, circles, ($r = 0.86$, $p < 0.001$, $n = 59$, slope = 0.14, intercept = 0.22). (B) 2–4 days PDA, triangles, ($r = 0.48$, $p < 0.001$, $n = 41$, slope = 0.04, intercept = 0.37).

an initial exposure rate ≥ 2 mR/hr at one meter. The subsequent exposure rates measured at 2–11 days PDA were, therefore, placed in two groups (Table 1): Group L (low dose) for the patients receiving 3 to less than 12 mCi and Group H (high dose) for those who received 12–30 mCi of ^{131}I .

Patient exposure rates at one meter measured 2–4 days PDA are shown in Figure 1B. Forty of 41 patients had exposure rates ≤ 2 mR/hr at one meter.

Patient exposure rates at 0.6 meter measured 2–4 days, 5–7 days, and 8–11 days PDA are shown in Figure 2 (A, B, C, respectively). For Group L patients, the average exposure of 29 patients (29/41) was 1.6 ± 0.6 mR/hr (range 0.7–3.4) at 2–4 days PDA. Seventy-nine percent of the patients (25/29) had exposure rates ≤ 2 mR/hr (Fig. 2A). For Group H patients, the average exposure of 12 patients (12/41) was 2.8 ± 1.6 mR/hr (range 0.9 – 6.0) at 2–4 days PDA. Forty-two percent of the patients (5/12) recorded readings ≤ 2 mR/hr (Fig. 2A). At 5–7 days PDA, the average exposure of 11 patients (11/31) was 1.8 ± 0.9 mR/hr (range 0.30–3.80). Seventy-two percent of patients (8/11) were ≤ 2 mR/hr (Fig. 2B). At 8–11 days PDA, the average exposure of 6 patients (6/15) was 1.3 ± 0.4 mR/hr. All patients (6/6) were less than 2 mR/hr at 0.6 meter (Fig. 2C).

Patient exposure rates at 0.3 meter measured 2–4 days, 5–7 days, and 8–11 days PDA are shown in Figure 3 (A, B, C, respectively). For Group L patients, the average exposure of 29 patients (29/41) was 5.5 ± 2.5 mR/hr (range 2.1–15.0) at 2–4 days PDA (Fig. 3A). The average exposure of 22 patients (22/33) was 3.4 ± 1.7 mR/hr (range 1.2 – 9.3) at 5–7 days PDA. Eighteen percent of the patients (4/22) were ≤ 2 mR/hr (Fig. 3B). At 8–11 days PDA, the average exposure of nine

TABLE 1
Measured External Exposure Rates (mR/hr)^a

Distance days	0 day	2-4 days	5-7 days	8-11 days
Group L (3 to <12 mCi)				
1.0 m	1.2 ± 0.4	0.6 ± 0.4	0.4 ± 0.2	
0.6 m		1.6 ± 0.6	1.0 ± 0.6	0.8 ± 0.5
0.3 m		5.5 ± 2.5	3.4 ± 1.7	2.7 ± 1.8
N	40	29	22	9
Group H (12-30 mCi)				
1.0 m	2.9 ± 1.2	1.1 ± 0.7	0.7 ± 0.4	
0.6 m		2.8 ± 1.6	1.8 ± 0.9	1.3 ± 0.4
0.3 m		8.9 ± 5.1	6.1 ± 2.6	4.4 ± 1.5
N	19	12	11	6

^a Mean mR/hr ± s.d.

patients (9/15) was 2.7 ± 1.8 mR/hr (range 0.2-6.8). Twenty-two percent of patients (2/9) were ≤ 2 mR/hr (Fig. 3C).

For Group H patients, the average exposure of 12 patients (12/41) was 8.9 ± 5.1 mR/hr (range 1.3-18.0) at 2-4 days PDA (Fig. 3A). The average exposure of 11 patients (11/33) was 6.1 ± 3.6 mR/hr (range 1.0-13.0) at 5-7 days PDA. One of the patients (1/11) was ≤ 2 mR/hr (Fig. 3B). At 8-11 days PDA, the average exposure of six patients (6/15) was 4.4 ± 1.5 mR/hr (range 2.6-6.0) (Fig. 3C).

DISCUSSION

There is no evidence suggesting that small amounts of radiation from ¹³¹I-treated patients cause any problem to others; nonetheless, guidelines developed from the reported data (when properly applied) could reduce unnecessary radiation exposure to others. The groups of people at greatest risk from the external radiation exposure to ¹³¹I-treated hyperthyroid patients are embryos, fetuses, infants, and children. The younger the child, the greater the sensitivity to ionizing radiation

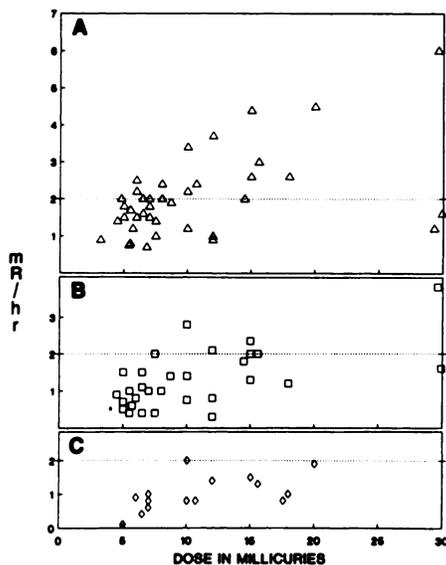


FIGURE 2
Exposure rate versus administered dose of ¹³¹I at 0.6 meter. The criterion for restricting contact, 2 mR/hr, is represented by the dotted line. (A) 2-4 days PDA, triangles ($r = 0.51$, $p < 0.001$, $n = 41$, slope = 0.08, intercept = 1.14). (B) 5-7 days PDA, squares ($r = 0.64$, $p < 0.001$, $n = 33$, slope = 0.08, intercept = 0.44). (C) 8-11 days PDA, diamonds ($r = 0.57$, $p < 0.05$, $n = 15$, slope = 0.06, intercept = 0.34).

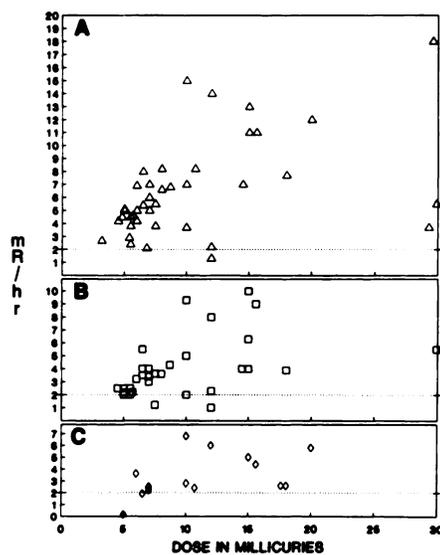


FIGURE 3
Exposure rate versus administered dose of ¹³¹I at 0.3 meter. The criterion for restricting contact, 2 mR/hr, is represented by the dotted line. (A) 2-4 days PDA, triangles ($r = 0.47$, $p < 0.01$, $n = 41$, slope = 0.25, intercept = 3.89). (B) 5-7 days PDA, squares ($r = 0.62$, $p < 0.001$, $n = 33$, slope = 0.27, intercept = 1.48). (C) 8-11 days PDA, diamonds ($r = 0.47$, $p < 0.051$, $n = 15$, slope = 0.06, intercept = 1.47).

TABLE 2
Suggested Guidelines for Resuming Close Contact Post-Iodine-131 Hyperthyroid Therapy

Days (PDA)	0.3 meter		0.6 meter		1 meter	
	<12 mCi	≥12 mCi	<12 mCi	≥12 mCi	<12 mCi	≥12 mCi
0-1	Restrict amount of time	Restrict amount of time	Some restrictions for contact with small children and pregnant women	Restrict amount of time	No restrictions	Some restrictions for contact with small children and pregnant women
2-4	Restrict amount of time	Restrict amount of time	No restrictions	Some restrictions for contact with small children and pregnant women	No restrictions	No restrictions
5-7	Restrict amount of time	Restrict amount of time	No restrictions	No restrictions	No restrictions	No restrictions
8-11	Some restrictions for contact with small children and pregnant women	Restrict amount of time	No restrictions	No restrictions	No restrictions	No restrictions

(12). A group of 10,902 Jewish children whose scalps were irradiated for treatment of tinea capitis were reported to have a sixfold increase in incidence of thyroid cancer even though the average dose to the thyroid was estimated to be 6.5 rads. The risk of developing childhood cancer and leukemia from in utero exposure to low-dose radiation is estimated to be 250 cases of leukemia and 300 cases of fatal cancer per million fetuses exposed per rad. The estimated risk of induction of leukemia in a young adult (age 20) is 100 times less; 2.5 cases per million persons per rad. The NCRP (14) recommends that family members of a radioactive patient receive less than 0.5 rem in any one year; and that fertile women with respect to the fetus receive less than 0.5 rem in the gestation period. Using the maximum external dose rates measured at 0.3 meters from all

patients at 2-4 days, 5-7 days, and 8-11 days PDA (18 mR/hr, 10 mR/hr, and 7 mR/hr, respectively) and estimating the exposure rate from 30 mCi of activity at 0.3 meter for Days 0 and 1 PDA, a person continuously exposed (24 h/day for 11 days) at 0.3 meters would receive 6.0 rads. A person exposed to these dose rates for 2 hr per day would receive 0.5 rads in 11 days.

Guidelines for when patients may resume contact to within certain distances are shown in Table 2. The criterion for removing restrictions is when the average exposure rate measures 2 mR/hr at that distance. A person continuously exposed to 2 mrem/hr (i.e., 24 hr/day) for 10 days would have a cumulative dose of 0.48 rem, which is less than the 0.5 rem recommended as the dose limit for the general public. Average exposure rates between 2 mR/hr and 3 mR/hr were considered borderline, when applied to estimation of adult radiation risks.

To make practical use of this data as presented, one should understand the daily pattern of distances separating two persons. Anthropologists have described distinct distances human beings use in social situations or in work environments (Table 3) (15). The results obtained at one meter, therefore, provide the basis for conservative recommendations for when a patient may return to work or resume normal social interactions.

In the context of more personal space at 0.6-1 meter, the results provide guidance for patients who are caring for children and infants; whether to sleep alone and for how long; and how long to avoid close personal contact with pregnant women.

Close contact to within 0.3 meter almost always involves physical contact. Proximity to the thyroid is a

TABLE 3
Distance Zones Common to Americans

Zone	Description	Distance range
Intimate distance	Close phase (lovmaking, comforting, protecting)	0-0.15 meter
	Far phase (not used by Americans in public)	0.15-0.46 meter
Personal distance	Close phase (proximity used between husbands and wives)	0.46-0.76 meter
	Far phase (arms length)	0.76-1.22 meters
Social distance	Close phase (personal business, social gatherings)	1.22-2.13 meters
	Far phase (formal business)	2.13-3.66 meters

consideration here. An adult patient holding an infant on their lap may be guided by recommendations for contact at 0.6 meter, as opposed to a patient holding an infant near their shoulder. A patient embracing a pregnant woman may have a brief proximity of 0.5–0.6 meter between their thyroid and the fetus.

Other radiation safety considerations are contamination resulting from radioiodine excreted in urine, perspiration, saliva, and breath of the patient and radiation dose to the thyroid gland, especially the dose effect on fetal and infant thyroid from internal uptake of radioiodine from the patient. Patients should be carefully instructed to prevent significant transfer and uptake of radioiodine by others (16). A woman receiving any dose of ¹³¹I (sodium iodide) should be instructed not to resume breast feeding for a period of at least 8 wk (17). Prior to resuming nursing, a patient treated with ¹³¹I for hyperthyroidism should have the breast milk activity measured to ensure that only background activity is present.

ACKNOWLEDGMENTS

The authors thank Nena Collier, Maureen Rotarius, and Nancy Sawyer for their valuable help in preparing this manuscript.

REFERENCES

1. Wartofsky L. Management of hyperthyroidism due to Graves' disease: lessons from a survey of American Thyroid Association members. *The Endocrine Society Program Abstracts* 1989:21.
2. Buchan RCT, Brindle JM. Radioiodine therapy to outpatients—the contamination hazard. *Br J Radiol* 1970;43:479–482.
3. Jacobson AP, Plato PA, Toeroek D. Contamination of the home environment by patients treated with iodine-131: initial results. *Am J Pub Health* 1978;68:225–230.
4. Buchan RCT, Brindle JM. Radioiodine therapy to outpatients—the radiation hazard. *Br J Radiol* 1971;44:973–975.
5. NCRP. Precautions in the Management of Patients who have Received Therapeutic Amounts of Radionuclides. National Council on Radiation Protection and Measurements, Washington DC, Report No. 37, October 1, 1970, p. 20.
6. Becker DV, Siegel BA. *Guidelines for Patients Receiving Radioiodine Treatment*. New York: The Society of Nuclear Medicine, Inc., 1983:5–6.
7. Hamberger JI. In: *The thyroid gland: a book for thyroid patients*, 3rd Edition. West Bloomfield, Michigan: Joel I. Hamberger; 1985:51.
8. Noz ME, Maguire GQ. *Radiation protection in the radiologic and health sciences*, Second Edition. Philadelphia: Lea & Febiger; 1985:82–85.
9. Title 10, Chapter 1, Code of Federal Regulations—Energy Part 20, Section 20.105, March 31, 1987.
10. Title 10, Chapter 1, Code of Federal Regulations—Energy Part 35, Section 35.71, October 31, 1986.
11. Title 10, Chapter 1, Code of Federal Regulations—Energy, Part 35, Section 35.315, October 31, 1986.
12. NCRP. Protection in Nuclear Medicine and Ultrasound Diagnostic Procedures in Children. National Council on Radiation Protection and Measurements, Washington, DC, Report No. 73, December 31, 1983.
13. Committee on the Biological Effects of Ionizing Radiations (BEIR). *The effects on population of exposure to low levels of radiation*. Washington, DC: National Academy Press; 1980.
14. NCRP. Review of the Current State of Radiation Protection Philosophy. National Council on Radiation Protection and Measurements, Washington, DC, 1975.
15. Hall ET. *The hidden dimension*. New York: Doubleday Co., Inc.; 1966:117–121.
16. Nishizawa K, Ohara K, Ohshima M, Maekoshi H, Orito T, Watanabe T. Monitoring of I-131 excretions and used materials of patients treated with I-131. *Health Phys* 1980;38:467–481.
17. Romney BM, Nickoloff EL. Diagnostic nuclear medicine and the nursing mother. *Applied Radiology* 1987;5:51–56.