Radiation Safety

Reducing Radiation Exposure During Oral I-131 Therapy Administration

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A new, closed-system method to reduce air-, direct-, and incidental-contamination during therapeutic administration of oral I-131 was experimentally evaluated on twelve patients. We studied a standard control population using the routine practice of drinking the solution through a straw and compared results with our new technique. Various measurements were performed throughout all phases of dose administration to assess the relative difference of the two approaches. Using the closed system method before and during iodine administration revealed between 100 and 1000 times less activity per millimeter of air sample; whereas, the direct radiation exposure values were higher for the control population. Both the experimental and control methods had similar levels of incidental contamination.

Radioactive iodine (I-131) has widespread use within nuclear medicine particularly in the treatment of thyroid diseases. Despite the fact that usually only millicurie activities are used, I-131 has been described as perhaps the single most dangerous radionuclide in nuclear medicine (*1*). Consequently, the Nuclear Regulatory Commission has established a maximum permissible concentration of 9×10^{-9} μCi/ml for airborne exposure (*2*). Because of iodine's volatile nature it readily becomes a contaminating radioactive gas. Further, its rate of vaporization is dependent upon such factors as pH, temperature, exposure to light, volume, and use of distilled water for washing (*3,4,5*). As a response to this problem at least one commercial supplier of oral I-131 has reformulated its product to reduce its volatility.

Research to monitor the various phases of I-131 therapeutic administration has been done including studies of air pollution monitoring and whole body counting, and thyroid burden estimates. Air sample measurements using activated charcoal traps indicate that as much as 2 to 3% of the activity may escape the vial upon venting (*1*). In one study observations reveal a loss of up to 4 mCi of iodine vapor from a 200-mCi therapeutic dose (*3*). In a second study, 50 nCi of activity was measured in a technologist's thyroid gland (*3*) the day following I-131 administration to a patient. Further work shows that a technologist may be exposed to airborne concentrations of up to several thousand times the maximum permissible concentration (*1*).

In view of these significant problems, we attempted to assess I-131 air contamination during all phases of therapeutic administration. We performed air samples, wipe tests, and direct radiation measurements of our routine procedure and a new closed-system method of iodine administration in the hope that this new approach would yield substantial reduction in radiation exposure to nuclear medicine personnel.

Materials and Methods

We divided our patients receiving I-131 oral therapy solution into experimental and control groups. The groups consisted of twelve experimental and nine control patients. The experimental patients received their activity (range = 8.26–25.3 mCi; mean = 14.28 mCi) via our radioiodine administration device. The control patients received their iodine activity (range = 10.2–30.6 mCi; mean = 18.8 mCi) in the routine manner by drinking through a straw from an uncapped vial.

The 21 I-131 therapeutic doses were monitored before and during administration. We evaluated the relative merits of the radioiodine experimental administration device by examining and testing for I-131 air exposure, direct exposure, and incidental contamination.

We used an air pollution sampler (Fig. 1) using charcoal cartridges (CP-100(0750-18) RADeCo radioiodine sampling cartridges, San Diego, CA), which when factory tested at flow rates used in our study were 98 to 99% efficient for I-131 retention. The flow rates through the air pollution sampler ranged from 4.3 to 5.0 ft^3/min. The charcoal cartridges were counted in a NaI well sys-

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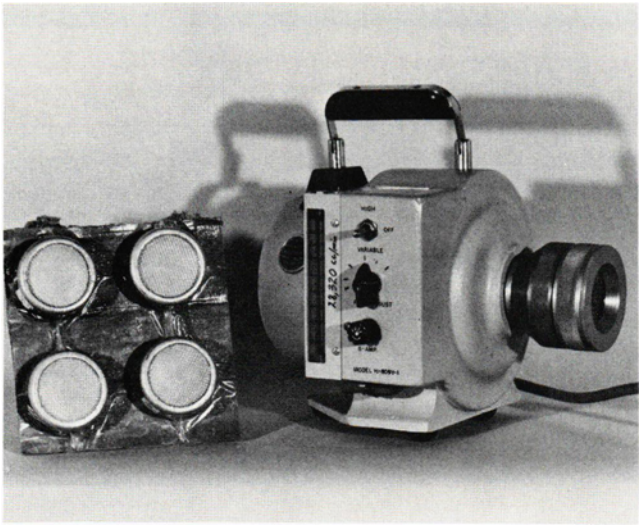

FIG. 1. Air pollution sampler and charcoal cartridges used in monitoring I-131 air exposure levels during radioiodine preadministration and administration phases.

tem whose efficiency for I-131 was known. Since we knew the air sampler's flow rate, the well system's efficiency for I-131, and the cartridges' retention efficiency for I-131, we could calculate airborne activity from a previously established formula (*6*).

A centralized radiopharmacy in our city drew up the iodine under a fume hood according to our technique and assayed each sample. The activities were delivered directly to us in the original manufacturer's shipping shield. All were commercial oral I-131 therapy solutions (Mallinckrodt, Inc., St. Louis, MO) with volumes ranging from 2.5 to 10 ml.

The experimental radioiodine administration device (Figs. 2 and 3), designed to operate as a closed system, consists of a 30-cc clear glass vial. The vial has a 1.3-cm diameter top opening to allow the insertion of a rubber stopper following addition of radioactive material. The rubber stopper has two openings (4.0 mm in diameter) through which venotubing of 20-in. length is inserted to reach the bottom of the glass vial. Between the venotubing and stopper opening, intimate contact is established; to insure a closed system, removable plastic tips seal the exposed end of the venotubings. Further, each venotube can be individually clamped off as necessary.

After the glass vial has been loaded, assayed, and properly sealed, it is placed in a generator elution vial shield (Union Carbide elution vial shield stock 5074) equipped with a screw-on top. The venotubing extends through the top of the elution shield and is clamped off prior to securely screwing the elution shield's top into place. This procedure makes the accidental removal of the stopper virtually impossible as the diameter of the elution shield's opening is less than that of the rubber stopper.

The therapeutic solution (now secure in the elution shield) is inserted into the manufacturer's shipping shield ready for shipment from the centralized radiopharmacy to the hospital.

During various phases of the procedure, test wipes were taken to assess the I-131 contamination (Tables 1 and 2). The first wipe, over the outer surface of the unopened shipping shield, was to establish proper measurement of the experimental and control activity leakage; in addition, repeated test wipes were obtained.

Subsequently, the unopened shipping shield was placed into the center of the cylindrical metal can, which had a height of 22.5 cm and a diameter of 15.5 cm (Fig. 4).

Furthermore, the metal can with three semicircular, equally spaced bottom openings allowed the air pollution sampler to maximize its test volume of air throughout the entire air monitoring phase.

A G-M survey meter with probe was also placed against the cylindrical surface at the mid-region of the shipping shield to measure exposure readings for both experimental and control activity phases. After mon-

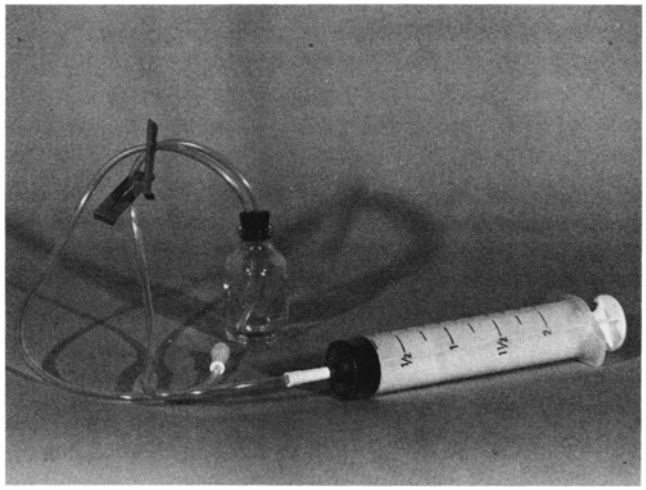

FIG. 2. Experimental radioiodine device (30-cc clear glass vial with venotubing and 60-cc luer-lock syringe) as it would appear without generator elution vial shield.

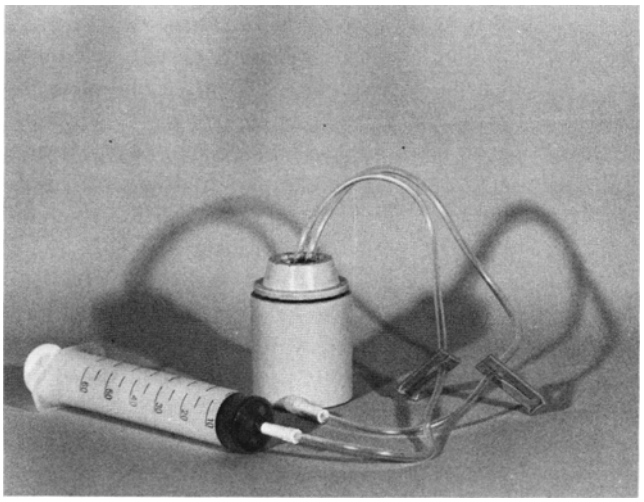

FIG. 3. Experimental radioiodine administration device (30-cc clear glass vial with venotubing and 60-cc luer-lock syringe) as it would appear secured inside generator solution shield.

TABLE 1. I-131 Contamination during Various Phases of I-131 Administration (Control System)

Activity mCi	Outer surface unopened shipping shield (dpm)	Wipe outer and inner surfaces of unopened vial and shield combined (dpm)	Air sampler head before air sample no. 1 (dpm)	Air sampler head after air sample no. 1 (dpm)	Table top after administration (dpm)	Gloves worn during prep, administration, and clean-up (dpm)
30.6	112,000	13,400	410	310	ND	280,000
29.3	340	118,000	ND	ND	ND	68,000
20.8	30,400	27,300	140	110	ND	30,300
20.4	—	17,300	ND	ND	ND	75,900
15.3	370	310	ND	ND	ND	5.60×10^6
15.0	130	ND	ND	ND	ND	821,000
15.0	290	ND	570	ND	60	5,200
12.3	82,000	390	—	—	8,500	293,000
10.2	1,500	60	ND	ND	210	9,800

TABLE 2. Contamination during Various Phases of I-131 Dose Administration (Experimental System)

Activity mCi	Outer surface unopened shipping shield (dpm)	Wipe outer and inner surfaces of experimental vial and shield combined (dpm)	Air sampler head before air sample no. 1 (dpm)	Air sampler head after air sample no. 1 (dpm)	Table top after administration (dpm)	Gloves worn during prep, administration, and clean-up (dpm)
25.3	11,500	10,980	ND	ND	ND	ND
21.0	1,990	13,210	ND	ND	ND	187,100
16.3	180	110	2,300	400	80	1,100
15.7	1,200	190	ND	ND	240	902,000
15.0	600	1,820	ND	ND	ND	396,000
15.0	1,300	100,080	ND	ND	110	1.94×10^6
12.4	5,700	15,400	ND	ND	ND	64,000
12.0	720	110	ND	400	1,200	2,460
10.5	180	ND	ND	ND	120	6,700
10.0	11,300	4,300	ND	ND	1,300	4,400
10.0	1,600	850	ND	ND	ND	14,300
8.26	2,700	20,700	ND	ND	ND	90,000

itoring the radiation exposure, the air sampler was placed above the shipping shield with its top removed and 5-min air readings at flow rates of 4 to 5 ft^3/min were sampled. This was done for the control group with the vial top uncapped as is our routine practice and for the experimental group with the stopper remaining in place.

This entire procedure was repeated for all control and experimental patients as they drank their therapeutic doses. We monitored for 1 min at a distance of 30 cm from the patient's face. The control subjects drank via the straw; the experimental group used the closed-system venotubing.

The experimental device was carefully inspected for any possible leakage sites. To prevent capillary action in the sealed venotubing from drawing iodine into the tubing and prevent escape of iodine vapors, the following sequence was established.

We proceeded to fill a 60-cc luer-lock syringe with distilled water and connected it to one of the venotubes with plastic tip removed. This venotube's pinch clamp was then removed. The second venotube was placed open-ended into the patient's mouth, after removing the second plastic tip. When the patient was ready to commence drinking, a prearranged signal was given by the patient and the technologist then unclamped the remaining pinch-clamp.

To create a positive pressure effect, the syringe was held above the elution shield, and while the patient drank, his suction enabled water to push radioiodine from the shielded glass vial compatible with his rate of imbibing. At any time during the procedure the patient, if he so desired, could stop drinking (Fig. 5).

Upon completion of the therapy, the venotubing and glass vial were examined for residual radioactivity.

Results and Discussion

The I-131 air exposure data in Fig. 6 demonstrate a marked quantitative difference between control and experimental iodine administration. This appears true both before and during administration with respect to

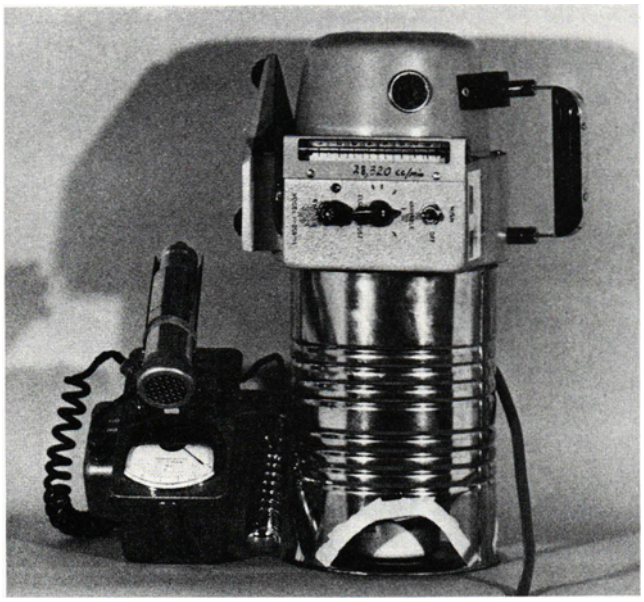

FIG. 4. G-M survey meter and air pollution sampler as they were positioned next to and within cylindrical metal can during the radioiodine preadministration and administration phases.

system subject to virtually no airborne I-131 contamination in either preadministration or administration phases.

We found that ten out of twelve experimental preadministration values were below the 9×10^{-9} μCi/ml maximum-permissible-concentration threshold and close to our instrument's detection limits. In fact six of the values were lower than the limits of our instrument's detectability.

Moreover, the data points of Fig. 6 support a quantitative difference of 100 to 1000 times less contamination with our experimental technique compared to the standard control procedure. Further, our work suggests that lower millicurie doses when measured properly still present a health hazard. It should be mentioned that with our sampling cartridges the retention efficiency of iodine directly decreased as flow rate increased.

Unlike the experimental preadministration phase, the control preadministration phase yields larger values than the control administration phase. This is as expected, since this phase occurs when maximum I-131 vapors emerge during initial venting of the uncapped vial.

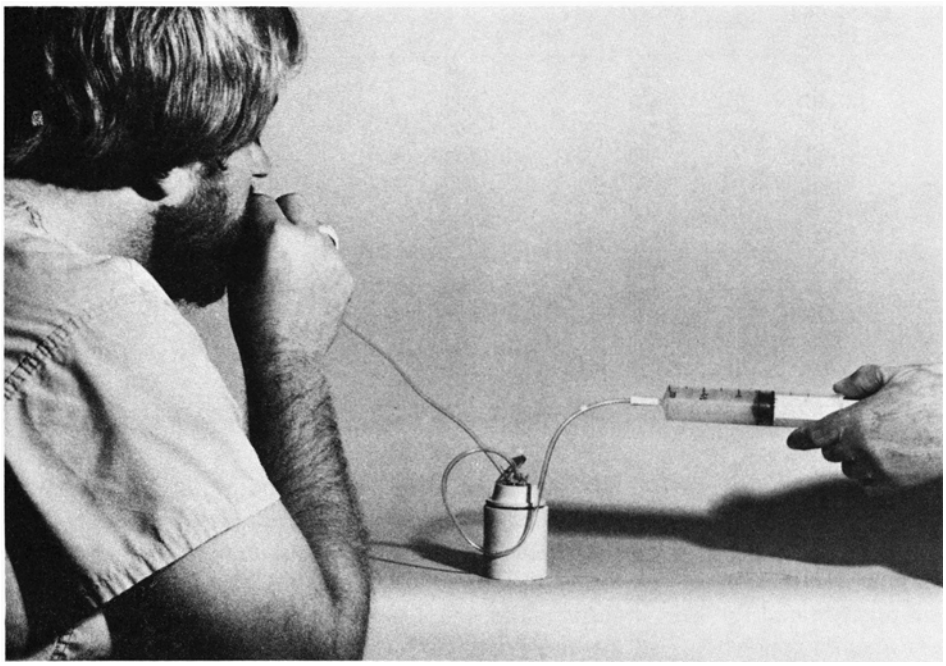

FIG. 5. Experimental device as it is used in therapy administration procedure.

I-131 air contamination assessment.

The experimental data concerning administration reveal slightly higher values than the preadministration experimental data. (This probably results from most of the I-131 contamination coming directly from the patient's breathing zone following therapy. This effect was independent of tube length or straw length since all measurements were 30 cm from the patient's mouth. Test wipes and residual activity measurements of both systems were very similar in value, indicating that tube or straw iodine adherence could not be major factor affecting these results). Logically this is what we expected because the experimental method is a closed

Tables 1 and 2 list data acquired on our test wipes for both systems. Both experimental and control methods had similar levels of contamination. The areas with maximum measured contamination were those taken on the shipping shield and vials as well as the technologist's gloves following therapy administration. It is our belief that shipping shield and vial contaminations occurred in the centralized radiopharmacy or manufacturing site. Since we had to reassemble the control and experimental vials and tubings to check for residual activity, a significant opportunity for glove contamination occurred.

Figure 7 shows our results for measured residual ac-

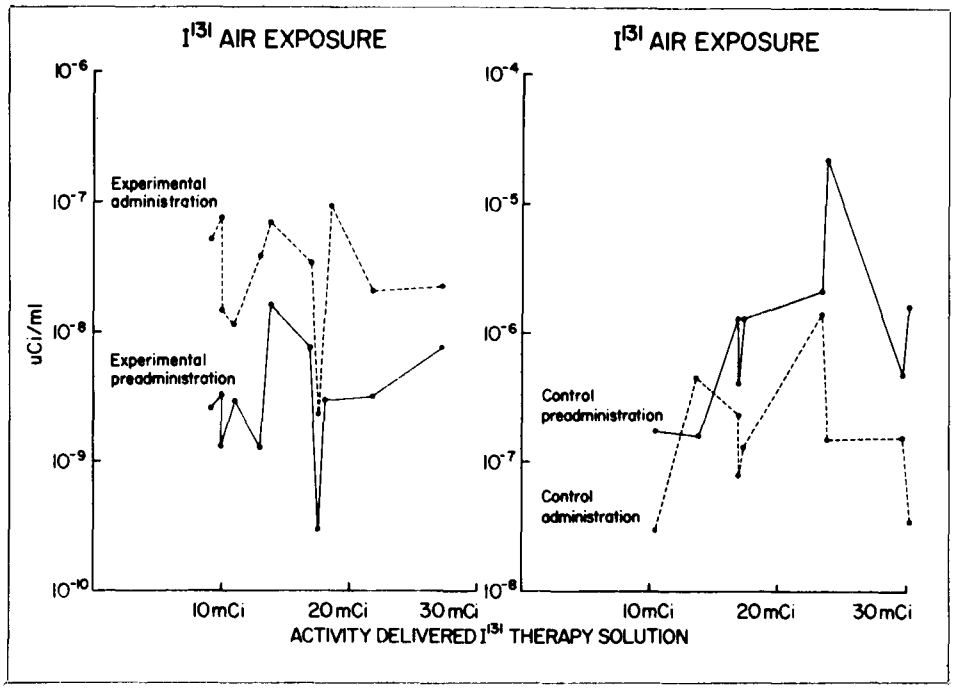

FIG. 6. Administered therapeutic I-131 activity versus I-131 air exposure resulting from this administration.

tivity. This aspect of the study was performed because of our concern that a fraction of the administered activity might be trapped in the expermental system's tygon tubing. The data points indicate that the experimental system has marginally more residual activity than the control straw method.

Finally, Fig. 8 shows that direct radiation exposure values are higher for the control system. This result is as predicted since the experimental method had the extra shielding associated with the elution shield.

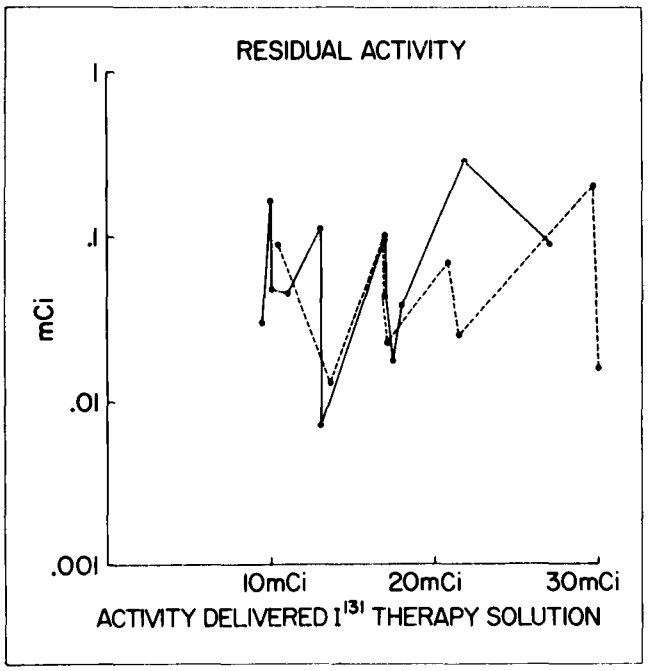

FIG. 7. Administered therapeutic I-131 activity versus residual activity in experimental (solid line) and control (broken line) methods.

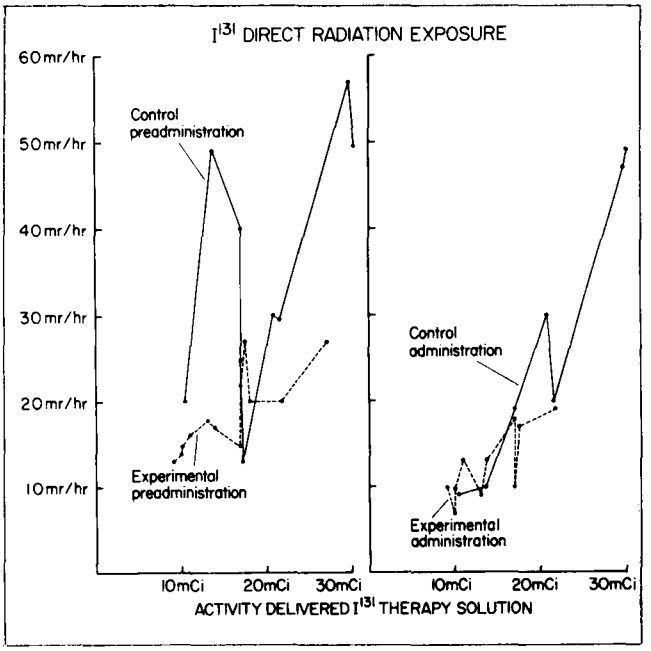

FIG. 8. Administered therapeutic I-131 activity versus I-131 direct radiation exposure.

In our institution only one or two therapy patients are treated per month and hence, although the data point to the above conclusions, we do not have a sufficient case load to do a valid statistical analysis. Nevertheless, the trend in the data is quite apparent and our measured values do indicate significant reduction in unwanted radiation exposure with the closed-system technique described herein.

With increasing concern over radiation exposure, we hope other hospitals will attempt to pursue similar avenues of safer therapeutic administration. It is our

firm belief that, ultimately, some such closed-system technique will become mandatory.

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References

1. Miller KL, Bott SM, Jelkley DE. Review of contamination and exposure hazards associated with therapeutic uses of radioiodine. *J Nucl Med Technol* 1979; 7:163–66.
2. U.S. Nuclear Regulatory Commission, Rules and Regulations, Title 10, Part 20: Standards for protection against radiation, U.S. Government Printing Office, Washington, DC 1978.
3. Maguire WJ. A precaution for minimizing radiation exposure from iodine vaporization. *J Nucl Med Technol* 1980; 8:90–93.
4. Luckett LW, Stotler RE. Radioiodine volatilization from reformulated sodium iodine I-131 oral solution. *J Nucl Med* 1980; 21: 477–79.
5. Howard BY. Safe handling of radioiodinated solutions. *J Nucl Med Technol* 1976; 4:28–30.
6. Browning EJ, Banerjee K, Reisinger WE. Airborne concentration of I-131 in a nuclear medicine laboratory. *J Nucl Med* 1978; 19: 1078–81.