Advantages of Using Thin Sodium Iodide Detectors for Thyroid Monitoring of Personnel Working with $^{125}\text{I}$

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Measurements of neck count-rates for personnel who regularly iodinated proteins with $^{125}\text{I}$ showed that, generally, count rates were higher after iodination than before. The major pathway for the intake of $^{125}\text{I}$ during iodination was through skin that was exposed to the free-iodine atmosphere of the fume hood. Neck count-rates were measured in 34 other subjects who were working with $^{125}\text{I}$. The rates for 25 of them were significantly greater than for a control group of 36 subjects. Significant activities were also detected in seven of nine subjects who had never worked directly with $^{125}\text{I}$ but who were located within areas where it was used extensively. To minimize thyroid burdens of $^{125}\text{I}$, it is essential that neck count-rates be measured routinely, in order to monitor the safety of procedures involving the use of $^{125}\text{I}$.

Additional Keyphrases: occupational hazards  ·  laboratory safety  ·  neck count-rates

Radioactive iodine is used frequently in diagnostic medicine because of its desirable chemical properties with respect to radiolabeling of proteins. Because its physical half-life is suitably long and its emissions are easily shielded, $^{125}\text{I}$ is the most commonly used radioisotope of iodine. At McMaster University, about 30 mCi of $^{125}\text{I}$ is purchased each week for in vitro use. Another 40 mCi is required each week for the production of $^{125}\text{I}$-labeled fibrinogen, used for in vivo diagnostic tests.

The recommendations of the International Commission on Radiological Protection (1) state that, within the thyroid of a radiation worker, the amount of activity that produces one-twentieth (1.5 rem) of the annual permissible thyroid dose constitutes an investigational level. If this amount of activity were to be detected, procedures and techniques used by personnel handling radioiodine should be thoroughly investigated to eliminate the source of contamination and to reduce the possibility of future intake to a minimum. The investigational level for $^{125}\text{I}$ is about 0.3 μCi. This activity in the thyroid would result from an acute intake of about 1 μCi (2) or, about 1/40 000 of the activity used in a 40-mCi iodination.

It has been shown that radioiodine may be liberated from test tubes during $^{125}\text{I}$ radioimmunoassay procedures (3) and that all surfaces, including walls and ceilings, of an $^{125}\text{I}$ radioimmunoassay laboratory can become contaminated when ventilation is inadequate (4). The National Radiological Protection Board recommends that thyroid burdens of $^{125}\text{I}$ should be measured with a sodium iodide detector once every two weeks in people who regularly do iodinations (5). Klots et al. (6) used a thin sodium iodide crystal to detect radioactivity in the thyroid glands of individuals working with $^{125}\text{I}$. They showed that the amount of $^{125}\text{I}$ in the thyroid was related to the quantity handled, to the chemical form of the iodine, and to the technique and experience of the person considered.

Here we present our experience with thyroid monitoring and illustrate its importance in alerting personnel to the hazards of working either with or within the vicinity of $^{125}\text{I}$.

Materials and Methods

Detection systems. Two detection systems have been used. Initially, the only detector available was a 5.1 × 5.1 cm NaI(Tl) crystal, which had a fixed collimator designed according to IAEA recommendations for clinical measurements of 24-h $^{131}\text{I}$ uptake in the neck (7). Because the volume of this crystal was relatively large and because it was necessarily located in a busy nuclear-medicine department, background count rates in the energy region of interest were high and variable because of the detection of higher energy photons emitted from patients undergoing imaging procedures in adjacent rooms. Unfortunately, the detector could not be transported to a low background area. Only qualitative estimations of $^{125}\text{I}$ thyroid burdens were possible using this detector.

The second detector was a sodium iodide crystal, 3.8 cm in diameter and 0.8 mm thick, which was operated in the shadow of a 10-cm thick lead shield. The crystal was collimated with a brass frustum of a cone, 2 cm long and 3 cm in diameter at the crystal face and 6 cm at the collimator face. The crystal was coupled through an amplifier to a multichannel analyzer (Nuclear Data, Schaumberg, IL 60196; type ND-60) and the counting time for in vivo measurements was generally 20 min. The counting efficiency was measured with a calibrated $^{125}\text{I}$ solution (New England Nuclear, Boston, MA 02118; cat. no. NES-050S) contained within a 30-ml plastic bottle placed in a standard thyroid uptake phantom (Nuclear Associates, New York, NY 11590; cat. no. 74-360). This phantom is similar to that recommended by IAEA for clinical measurements of $^{131}\text{I}$ uptake in the neck but allows efficiency to be measured for the equivalent of both thick (2.5-cm tissue equivalent thickness between phantom surface and surface of bottle) and thin (0.5-cm tissue equivalent thickness) necks. Because the energies of the emissions of $^{131}\text{I}$ and $^{125}\text{I}$ differ more than 10-fold it was necessary to show that this phantom was appropriate for use with 28 keV photons.

Subject groups. Using the larger detector, we made measurements on 21 individuals, during a two-year period before and after some 200 iodinations. Initially all iodinations were performed in a fume hood and disposable gloves were worn. To identify potential pathways of $^{125}\text{I}$ uptake, respirator masks incorporating charcoal filters were worn by those doing the iodinations, and air samples were collected from locations in and around the fume hood during the iodinations.

All other subject measurements reported here were made by using the thin NaI(Tl) crystal. The increase above room background count rate (counts due to natural in vivo radioactivity) was measured in 36 subjects (group 1) who had never worked with or, to their knowledge, in the vicinity of $^{125}\text{I}$. Subjects were positioned supine and the detector was centered above the thyroid, as close as possible to the skin. Generally the collimator face was 1 cm away from the skin immediately above the thyroid. We did not attempt to correct for the

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Received Feb. 12, 1979; accepted Aug. 23, 1979.
thickness of the tissue overlying the thyroid. If the normal (i.e., non-contaminated) count rate for the neck depends on natural total body radioactivity, then the observed count rates in this group of subjects will be related to body weight or to total body potassium as measured with a whole-body counter (9). This possibility was investigated in some individuals in group 1.

The second group consisted of nine subjects who had never worked directly with $^{125}$I but were located in departments where the isotope was used extensively.

Subjects who worked directly with $^{125}$I were divided into two groups according to the amount of activity handled per month. Typically, a laboratory technologist doing routine radioimmunoassay procedures would be allocated to group 3 (25 subjects), while someone performing regular iodinations with more than 500 $\mu$Ci would be allocated to group 4 (nine subjects). In all cases, the count rate for the neck was not measured until 24 h after an iodination procedure.

Case histories. Neck count rates were sequentially measured in six subjects. Four of these six worked in the same laboratory and were monitored during a three-month period. Two of the four had started protein iodinations shortly before this three-month period.

Results

Air samples collected immediately after opening a vial containing 5 mCi revealed nanocurie quantities of $^{125}$I on the filters. Samples taken from inside the fume hood over the separation columns showed smaller activities, and samples collected outside the hood in the vicinity of the iodinator’s face mask showed no traces of $^{125}$I at all. No activity was detected on the respirator filters.

With use of the larger NaI(Tl) detector, the background count rate in the room varied from 20 to 130 cpm. Such background fluctuations led to uncertainties in the interpretation of subject neck count rates. However, in 65% of the iodinations the neck count rate was greater after iodination than before. Accordingly, we modified iodination procedures to prevent skin contact with the free iodine atmosphere inside the fume hood. The arms of the iodinator were covered with plastic or rubber, and aprons were used to cover the chest and abdomen. The incidence of increased post-iodination count rates then declined to about 15%.

The background count rate for the thin detector ranged from 3 to 6 cpm. The energy spectrum recorded from this detector for the $^{125}$I standard solution is shown in Figure 1. The full width of the observed photopeak at half maximum is 29%. Whenever an energy spectrum was evident in an in vivo measurement, it was of the same shape as that observed for the standard (Figure 1). Successive measurements of the activity of the standard solution yielded a mean value of 61.3 days ± 0.8 day (SD) for the half-life of $^{125}$I.

The counting efficiency for the phantom was 0.55 and 0.23% for the thin and thick neck geometries, respectively. The calculated mass attenuation coefficient for Lucite at 28 keV is 0.325 cm$^2$/g (9). This compares favorably with the accepted value of 0.312 cm$^2$/g for soft tissue (10).

The mean count rate for the subjects of group 1 was 2.4 cpm above room background. The standard deviation was 54% of the mean. More than half of this deviation is attributable to counting statistics. We found no correlation between count rates and either body weight or total body potassium.

The means and standard deviations of the count rates for each of the four subject groups are shown in Figure 2. The mean values for groups 2, 3, and 4 correspond to thyroid burdens of about 1, 4, and 16 nCi, respectively.

The sequential measurements for the four subjects working in the same laboratory are shown in Figure 3. The patterns of accumulation for the two subjects who had not worked previously with $^{125}$I are essentially the same. The patterns of decrease for three of the four were similar. These decreases are shown in Figure 4 on a logarithmic scale normalized to the same time scale. The half-times were 76 ± 3, 53 ± 1, and 43 ± 1 (SD) days respectively. Effective half-times were also calculated for each of these three subjects from two single measurements of neck count rates taken immediately before and after absences from the department ranging from 10 to 34 days. The corresponding half-times were 41 ± 4, 26 ± 1 and 43 ± 1 days.

The two other case histories are shown in Figures 5 and 6. The gradual increase in thyroid activity in a subject who was learning iodination techniques is shown in Figure 5. Figure 6 shows a drastic change in thyroid activity observed in another subject, who used a nonfunctioning fume hood.

Discussion

For several years, the thyroids of subjects working with $^{125}$I at McMaster University were monitored with a detector that could yield only qualitative results in the range of activities to be measured. Nevertheless, with this detector and from measurements of air concentrations of $^{125}$I it was possible to monitor (and as a result to modify) iodination procedures so that thyroid burdens were decreased. Thyroid count rates fell when skin contact with free iodine in the fume hood was
Thus considering either the room during fields of Two first the Fig. for With three subjects same background in laboratory iodination (A-A, This the the Fig. autoradiolysis a of frequent thyroid monitoring and by the presence of health physics personnel at most iodinations. The estimated thyroid burdens ranged from 0.5 to 29 nCi. These activities represent, at most, 10% of the activity above which investigation of procedures and techniques is required. However, contamination of the thyroid with radioactivity can only be minimized when such amounts as these can be detected with confidence.

One surprising aspect of this survey was that seven of nine individuals who had had no direct contact with radiiodine showed detectable radioactivity; count rates of up to 10-fold the average non-contaminated count rates were observed. We do not know how these subjects acquired this contamination.

The high thyroid count rates shown in Figures 3 and 6 were the result of an inefficient fume hood in one case and a non-functioning fume hood in the other. This is not an uncommon cause of contamination with radiiodine (10). Clearly, testing the air circulation through fume hoods will reduce the risk of iodine escape.

The maximum effective half-time for $^{125}$I is 60 days, the physical half-life. The effective half-time for certainly one, and probably two, of the three subjects shown in Figure 4 suggests a continued accumulation of $^{125}$I. The mean effective half-time for these three subjects, measured during a period when they were not exposed to $^{125}$I, was 37 days. This corresponds to a biological half-life for iodine of 96 days, a value that agrees well with both predicted (11) and measured (12) half-lives.

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**Fig. 3.** Sequential neck count-rates for four subjects working in the same laboratory

Two subjects (△-△, □-□) started protein iodinations two weeks before the first measurement.

Eliminated. This free iodine is produced continually as a result of autoradiolysis because of the extremely high radiation/fields of about 3 Gy/month per mCi (0.3 Mrad/month per mCi) in the stored $^{125}$I solution. Free iodine is also present during the iodination procedure itself.

With the thin detector-shadow shield system the count rate for a subject with no $^{125}$I in the thyroid is about 150% of the room background count rate. The lack of correlation between the count rate obtained from an uncontaminated thyroid and either body weight or total body potassium is not surprising, considering the statistical error in the measured count rate. Thus it was not possible to predict for each subject the increment above room background expected from natural radioactivity alone.

The extent of thyroid contamination was fully appreciated only when the thin detector system was used. Of the 43 individuals in groups 2, 3, and 4, 32 (74%) had neck count rates exceeding those of group 1, and this incidence was in a population who had been made keenly aware of the hazards involved, by frequent thyroid monitoring and by the presence of health physics personnel at most iodinations. The estimated thyroid burdens ranged from 0.5 to 29 nCi. These activities represent, at most, 10% of the activity above which investigation of procedures and techniques is required. However, contamination of the thyroid with radioactivity can only be minimized when such amounts as these can be detected with confidence.

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Our results show that thyroid burdens can be decreased
when neck count rates are used to monitor the radiation safety of procedures involving $^{125}$I. Qualitative results were obtained with a NaI(Tl) detector of a size frequently used in departments of nuclear medicine. With such a detector we could demonstrate the advisability of covering the skin during iodination procedures. Nevertheless, when one is working with ionizing radiation the objective must be to minimize exposures. Such an objective can only be realized when thyroid burdens of a few nanocuries can be measured precisely. This requires a thin NaI(Tl) crystal. With such a crystal we have shown that significant radioactivity in the neck can be detected, not only in those individuals working routinely in radioimmunoassay laboratories, but also in subjects who, although not in direct contact with $^{125}$I, work in areas where the radioisotope is handled. Therefore, a thin NaI(Tl) crystal can be used to monitor effectively the radiation safety of all procedures involving use of $^{125}$I.

References