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THYROID MEASUREMENTS OF IODINE — 125 WORKERS

BY

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ABSTRACT

The accumulation of ^{125}I in the thyroid presents a real hazard to workers who use this radionuclide. Recent assessments of the maximum permissible thyroid burden for ^{125}I have tended to be lower than those previously adopted. Workers using ^{125}I may receive small doses to a film badge monitor from external radiation while accumulating significant doses to the thyroid from internal contamination. It is therefore necessary to perform some form of thyroid monitoring on such workers. In the past two years the Australian Radiation Laboratory has monitored ^{125}I workers from six different institutions in the Melbourne area to determine the activity of ^{125}I in their thyroids. Several monitoring techniques were investigated and discarded in favour of a two probe technique which gave the accuracy and sensitivity desirable in making such measurements. With this technique it was possible to measure activities as low as one nanocurie. The ability to monitor at these levels makes it possible to identify potentially hazardous procedures before a worker has accumulated significant quantities of ^{125}I in the thyroid. Most of the levels monitored were less than one tenth of the most recently recommended thyroid burden of 400 nanocurie. The highest levels were measured in workers who actually perform iodinations. Workers who handle the iodinate generally had lower levels than those performing the iodinations. Only a very small number of the workers measured were below the detectable limit of the system indicating that even when low activities of ^{125}I are handled in relatively stable forms it is still possible to accumulate ^{125}I in the thyroid.

INTRODUCTION

The use of proteins labelled with ^{125}I is common in many institutions around Melbourne and preparation of the iodinate usually takes place on site and is performed in a fume cupboard. As ^{125}I emits low energy X and gamma radiations, a simple shield will protect the user from the external radiation hazard and the wearing of film badges will probably result in zero or very low readings being received. Iodine and the reagents used in the iodination process are volatile substances and significant quantities of ^{125}I can become airborne when performing this work. In addition although the volume of material is small the specific activity is high so that aerosol droplets of the solution are also a potential hazard as inhaled ^{125}I is readily taken up by the body and deposited in the thyroid. Once located in this organ the low energy radiations deposit most of their energy within the thyroid. As ^{125}I has a physical half life of 60.2 days and the biological half life of iodine is 138 days I.C.R.P. 2,(2) the residence time in the thyroid is quite long. The accumulated dose deposited is consequently comparable with that from ^{131}I which releases much more energy per disintegration but has a physical half life of 8 days. Gavron and Feige (1) recommended a thyroid burden for ^{125}I of 770 nanocuries but carried a recommendation that it would be prudent to lower this figure by a factor of 2 because of uncertainties in their assumptions. The recommended thyroid burden for ^{131}I given in I.C.R.P. 2 (2) is 700 nanocurie. ^{125}I is therefore a comparable hazard to ^{131}I and its use in volatile forms necessitates the use of fume cupboards. However, many fume cupboards are not properly designed and are often not properly used so that it is still possible for an operator to accumulate a significant dose of ^{125}I in the thyroid. In order to determine this dose it is necessary to monitor the worker for ^{125}I thyroid burden.

THYROID MONITORING

The simplest way to monitor ^{125}I in the thyroid is place a NaI crystal close to the thyroid then, with a single channel analyser set so that the window covers the 30 keV region, determine the peak counts above background. The problem is to determine a suitable calibration factor so that an activity for ^{125}I can be obtained. Producing a standardized source of ^{125}I does not present a great problem but there is a problem in producing a standard thyroid. The size and shape of thyroids in humans varies considerably and the precise position of the thyroid is not always well known. In addition the thickness of tissue lying over the thyroid can vary. These variations lead to three types of problems when measuring thyroids: geometric problems due to size, shape and position; self absorption problems due to size of the thyroid; and attenuation due to the overlying tissue. When measuring ^{131}I in the thyroid, the self absorption and attenuation problems are minimal because of the more energetic radiations emitted. A large source to detector distance is used to reduce the geometric problem, by moving the thyroid far enough away so that it approximates a point source. When measuring ^{125}I self absorption in the thyroid and attenuation in the overlying tissue are much more significant and can cause large variations in the calculated activity. The geometry problems can be overcome by large source to detector distances but dring this also causes a loss of sensitivity.

MEASUREMENT TECHNIQUES

The problem of calibrating the detection system for ^{125}I can be overcome because of the unique decay scheme of this radionuclide. ^{125}I decays 100% by electron capture and emits low energy gamma and X radiation. The gamma ray has an energy of 35.5 keV and the energies of the K X rays vary from 27.2 to 31.7 keV. Because it is an electron capture nuclide coincidental emission of two X rays or one X ray and one gamma ray occur from the same atom as it undergoes nuclear transformation. By using coincidence counting techniques it is therefore possible to determine the detection efficiency for a source as it is being counted. The simplest method is to place a NaI detector in front of the source and to determine the nett areas in the 30 keV region where single events have been detected and in the 60 keV region where coincidence events have been detected. Eldridge and Crowther (3) used this technique and derived an expression to enable calculation of the activity of the source (No).

$$No = \frac{(Sa + 2Ca)^2}{4\,Ca} \qquad (1)$$

where Sa is the nett count rate in the 30 keV peak and Ca is the nett count rate in the 60 keV peak. The factor 4 is determined from the emission probabilities of the K X rays and the gamma rays from ^{125}I.

When the Australian Radiation Laboratory first received requests to measure ^{125}I workers for thyroid burden this sum peak method was tried. However it was soon discovered that the sensitivity required could not be attained with the 5 cm by 5 cm NaI probes available. The problem was that the background count rate in the 60 keV region was high and tended to mask the sum peak, which is much smaller than the 30 keV peak.

The problem was overcome by introducing a second probe and counting coincidence events between probes. The background in the coincidence counting channel was extremely low and it was then possible to measure ^{125}I in nanocurie amounts. The number of coincidence events between probes Cc is greater than the number of sum peak events in one probe (Ca). Equation (2) was used to calculate the activity.

$$No = \frac{(SaSb + Sa\ Cc)^2}{2SaSbCc} \qquad (2)$$

No, Sa and Cc are as previously defined and Sb is the count rate in the 30 keV region of the second probe, b.

When performing actual measurements it is of course necessary to correct equation (2) for background, dead time and accidental coincidences.

In the measurement system used two 5 cm by 5 cm NaI probes are mounted side by side with an angle of approximately 20^o between them. The outputs from these probes are fed through separate preamplifiers, amplifiers and single channel analysers. The windows of the single channel analysers are set to include the region from the K alpha-2 X ray at 27.2 keV to the gamma ray at 35.5 keV. Outputs from these analysers drive two scalers, which give the Sa and Sb count rates. Outputs are also taken from these single channel analysers into a coincidence unit with a resolving time of 0.5 microseconds. The output from the coincidence unit drives a third scaler which gives the coincidence count rate (Cc). Use of a short resolving time reduces the accidental coincidence correction required for active sources. For the system used the accidental coincidence correction is 2 to 3 per cent when measuring activities of approximately one microcurie. As this correction increases as the square of the count rate it becomes very significant as the activity increases beyond this level.

MEASUREMENTS

In the past 18 months measurements to determine thyroid burden have been performed on over 30 workers who were exposed to ^{125}I. Just under half of these people actually performed protein iodinations. Of the remainder most worked with the iodinate once it had been prepared while the others did not use ^{125}I themselves but shared a laboratory where a contamination accident occurred. All the workers came from six institutions in the Melbourne area.

Table 1 shows the thyroid burdens of the workers who performed iodinations. Most of these workers had performed iodinations within one week of being measured. Various reagents had been used including, peroxide, cyclamine T and Hunter and Bolter reagent but no correlation could be obtained between type of reagent, frequency of iodination or time of last iodination, as there were large numbers of variables and too few workers. All workers showed measurable levels of ^{125}I in their thyroids and although none of the burdens measured represented a significant hazard the higher levels indicate that a review of working procedures might be warranted. Two of the levels monitored were high enough to enable comparisons to be made with published effective half lives. Bordell et al (4) estimated the effective half life to be 41 ± 2 days. The two workers who received the 145 and 139 nanocurie doses both ceased work with ^{125}I for several months and this enabled subsequent measurements to be made. Table 2 shows the measured activity, compared with that calculated using a 41 day half life. All the measured values were within 10% of the expected values which is within the limits of the uncertainty of the measurements.

Table 1

Thyroid Burdens of Workers
Performing Iodinations

Institution	Activity nCi	Institution	Activity nCi
5	145	3	18
6	139	4	17
4	55	2	14
1	53	4	14
2	48	4	12
2	36	4	9
1	21	2	5

Table 2

Comparison with Effective
Half Life of 41 days

Activity nCi Measured	Activity nCi Calculated	Days Elapsed	Activity nCi Measured	Activity nCi Calculated	Days Elapsed
145		0	139		0
70	73	41	101	104	17
20	20	119	34	31	88

Table 3 shows the results of measurements made on workers who do not perform iodinations but handle the iodinate once it is made. In general they are handling much smaller activities and in a much more stable form than those performing iodinations. As expected the results obtained are generally lower than those given in Table 1 - the highest reading being

13 nanocurie. Seven of the workers recorded 1 nanocurie while only 2 showed no sign of ^{125}I in their thyroids. At these low levels the amplifier output was connected to a multi channel analyser during the count and the spectrum obtained helped confirm the presence of ^{125}I.

The accuracy of the measurements below 5 nanocurie is approximately ± 3 nanocurie.

Table 3

Thyroid Burdens of Workers
Who do not Perform Iodinations

Institution	Activity nCi	Institution	Activity nCi
4	13	2	1
4	10	1	1
2	8	1	1
2	8	1	1
1	5	1	1
3	3	1	1
2	1	2	0
1		1	0

The final group of workers who were measured are shown in Table 4. These people did not use ^{125}I themselves but shared a laboratory in which a contamination accident occurred. As can be seen, most of the workers received significant thyroid burdens. In this case the measurement problem was complicated by the fact that some of the workers were also contaminated with ^{99m}Tc. Technetium like iodine will also accumulate in the thyroid and produces an increased background in the 30 keV region which must be allowed for when making the calculations. This was done by making up a solution of ^{99m}Tc in a polythene bottle, approximately the same size as a thyroid, and comparing the nett counts in the 140 keV peak with the background level in the 30 keV region. When a thyroid count was performed on a worker a spectrum was acquired simultaneously so that the area of the 140 keV peak could be measured. From this measurement a suitable background count rate could be determined for the 30 keV region and the ^{125}I thyroid burden estimated.

Table 4

Workers not using ^{125}I Exposed
Following Contamination of Laboratory

^{125}I Thyroid Burden nCi	Other Nuclides Present
69	Tc-99m
51	
31	
25	Tc-99m
24	
8	
5	

DISCUSSION

There is no generally accepted value for the maximum permissible thyroid burden for ^{125}I. Gavron and Feige (1) calculated the thyroid burden to be 770 nanocurie assuming that the maximum permissible dose to the thyroid is 600 mrem per week. Bordell et al (4) when measuring six workers accidentally exposed to ^{125}I, calculated a maximum permissible thyroid burden of 400 nanocurie assuming a maximum permissible dose to the thyroid of 300 mrem per week. From these values it can be calculated that of the workers measured, doses to the thyroid varied from zero to approximately 100 mrem per week. The groups of people performing iodinations appeared to be the group potentially at risk as they were the only ones to record significant thyroid burden. While none of the thyroid burdens were excessive the hazard to the workers was higher than external monitoring with film badges would have indicated.

The results of measurements on workers performing iodinations and from workers exposed as the result of a contamination accident, demonstrate the ease with which ^{125}I, in the form used for protein iodination, can become airborne and present a hazard. Work of this type should always take place in a well designed fume cupboard and the fume cupboard should be used properly. Workers performing iodinations should be monitored to determine their thyroid burden in order that working procedures can be assessed and if necessary modified. Every effort should be made to keep thyroid burdens to a minimum.

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