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Radioisotope X-Ray Fluorescence Technique in the Dynamic Study of Thyroid Behaviour under Iodine Load* **

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Abstract. A presentation is made of equipment based on the principle of excitation of X fluorescence by means of radioisotope sources. The technique has been used to study the evolution of stable iodine concentration (^{127}I) in the human thyroid *in vivo* with a minimum variation in weight of ~50 parts per million.

The equipment is characterized by the use of 2 collimated sources of ^{241}Am, each of 45 mCi, and by a proportional gas counter. The measuring times required are of approximately 100 sec each. The dose absorbed for each measurement is less than 30mrem at the level of the neck surface and less than 1 mrem at the thyroid.

Preliminary tests have been carried out over one month in an apparently normal subject given increasing doses (6–30 mg) of stable iodine.

Curves of the spatial distribution and of the temporal evolution of the counts due to the radiation of X_k fluorescence emitted from the stable iodine atoms present in the thyroid were obtained in a preestablished constant area of the thyroid.

Since, under constant geometrical conditions, these counts are proportional to the concentration of iodine the pattern of the curve enables an assessment to be made of the increase of iodine in the thyroid; this increase dropped in correlation with the increase in the amount of iodine given, within the range of dose employed.

Further research will be carried out on more patients in order to establish the possibility offered by this technique in the field of thyroid pathophysiology.

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Introduction

The radioisotope X-ray fluorescence method [3], as is well known, is based on absorption through the photoelectric effect of X and gamma rays emitted by selected radioisotope sources. Following the deep ionisation thus produced, the atoms of the elements present in the sample exposed emit series of X-ray lines (K, L series etc.) of energies which are characteristic for each element, the intensities being correlated to the concentration of each element in the sample. Using X-ray spectrometers, qualitative and quantitative analyses can thus be performed by measuring the energy and intensity of the characteristic lines detected.

Material and Methods

The experimental equipment consists of a measuring head connected to an electronic chain. The measuring head is mounted on a device which enables vertical regulation in order to centre the thyroid of the subject under examination.

The X-ray fluorescence of the stable iodine present in the thyroid is produced following exposure to two collimated sources of ^{241}Am mounted symmetrically so that each one illuminates one lobe of the thyroid. (Fig. 1)

The fluorescence KX-rays of the iodine for which the half thickness in soft tissue is about 2.0 cm, are detected by a proportional gas counter (gas filling Kripton), which is connected to an electronic chain.

The X-ray energy spectrum relative to a water solution of iodine (7×10^3 micrograms per gram) is obtained by means of a multichannel analyzer. The area of the "escape" peak, isolated and superimposed on a relatively low background, may be correlated to the concentration of iodine in water solution. It is thus possible to reach a minimum detectable concentration of 40 micrograms per gram in 10^2 s of measurement.

The sensitivity of this technique thus enables the natural iodine content of the human thyroid to be detected. It is worthwhile pointing out that the fluorescence radiation energy of a few tens of KeV is strongly attenuated by the interposed superficial tissues;

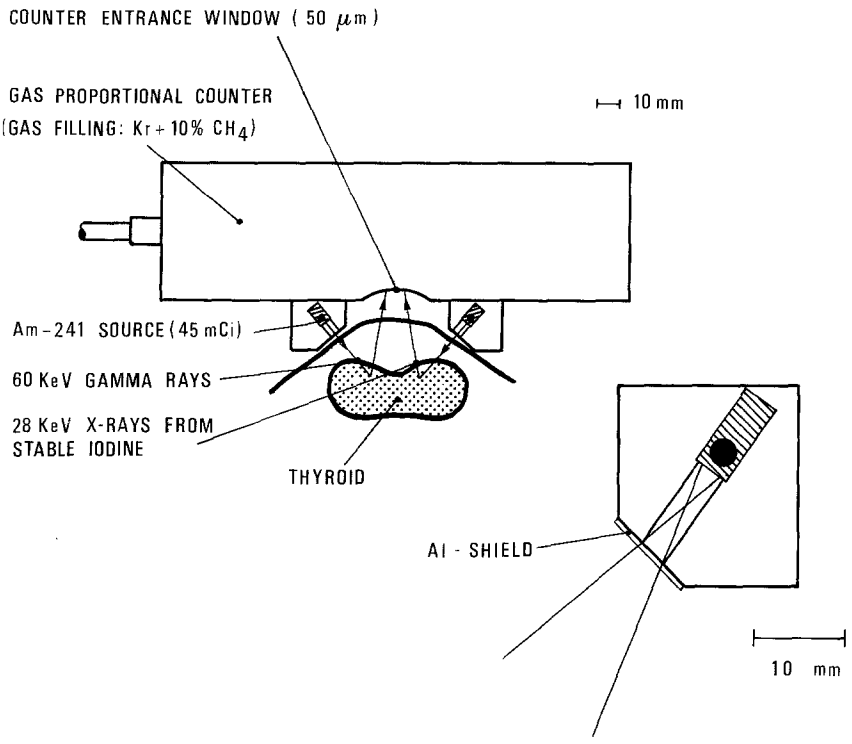
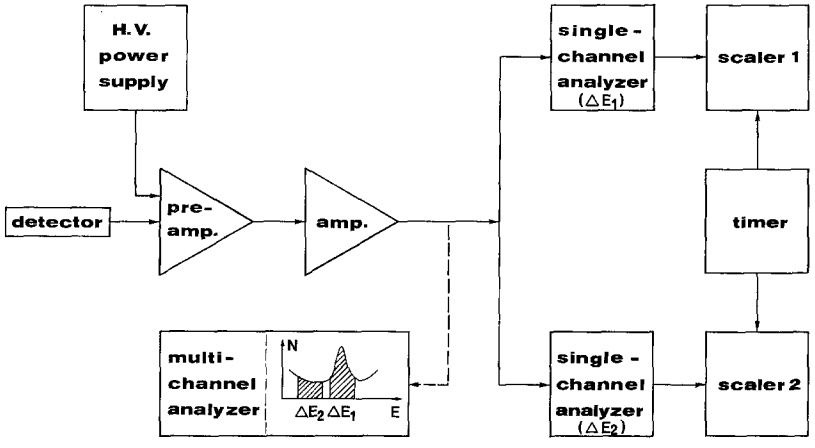


Fig. 1. Schematic drawing of the measuring head



ΔE_1: iodine KX escape peak and background **ΔE_2: background**

Fig. 2. Block diagram of the electronic chain

this does not occur with gamma rays emitted by radioactive tracers. On the other hand the radiation emitted from the source gives rise to diffused radiation from the same tissue.

In the quantitative measurement subsequently performed the output signal from the amplifier is sent simultaneously to two single channel analyzers each connected to a scaler (Fig. 2). One of these analyzers has the "window" centered on the iodine escape peak, whilst the second has the "window" centered on the background. The difference between the counts accumulated during the preset measuring time, respectively in the iodine channel and the background channel, is proportional to the concentration of iodine in the thyroid.

Fig. 3 shows the iodine escape peak relative to the thyroid of a normal subject; this spectrum is superimposed on the background spectrum obtained in a phantom human thyroid not containing iodine. The difference in the two spectra is due to the iodine content which, in a normal subject, is a few hundred micrograms per gram [1].

In order to define the characteristics of the experimental equipment a phantom thyroid was set up; the calibration curve was then obtained by correlating the difference between the counts accumulated in 10^3 s, respectively in the iodine channel and in the background channel, with the water iodine solution in the phantom (Fig. 4). The pattern of the relative resolution power enables an evaluation to be made of the minimum detectable concentration of iodine which results as approximatively 100 micrograms per gram, in corrispondence to 100% relative resolution power.

From a dosimetric point of view the radioisotopic source of ^{241}Am is particularly convenient as can be seen in Fig. 5 in which the photon flux needed to determine a 1 mrem soft tissue absorption per second exposure is plotted against the energy.

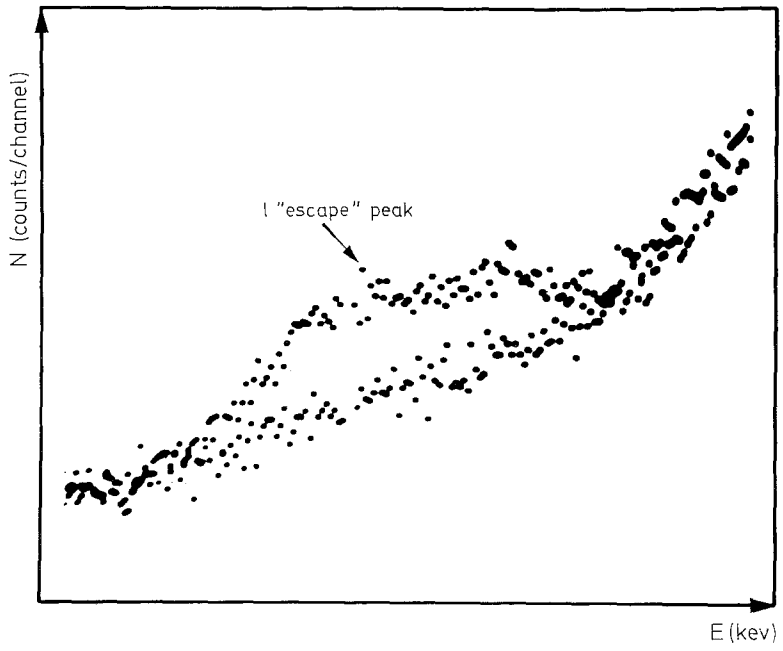


Fig. 3. Iodine escape peak from human thyroid superimposed on background obtained from the "phantom" not containing iodine

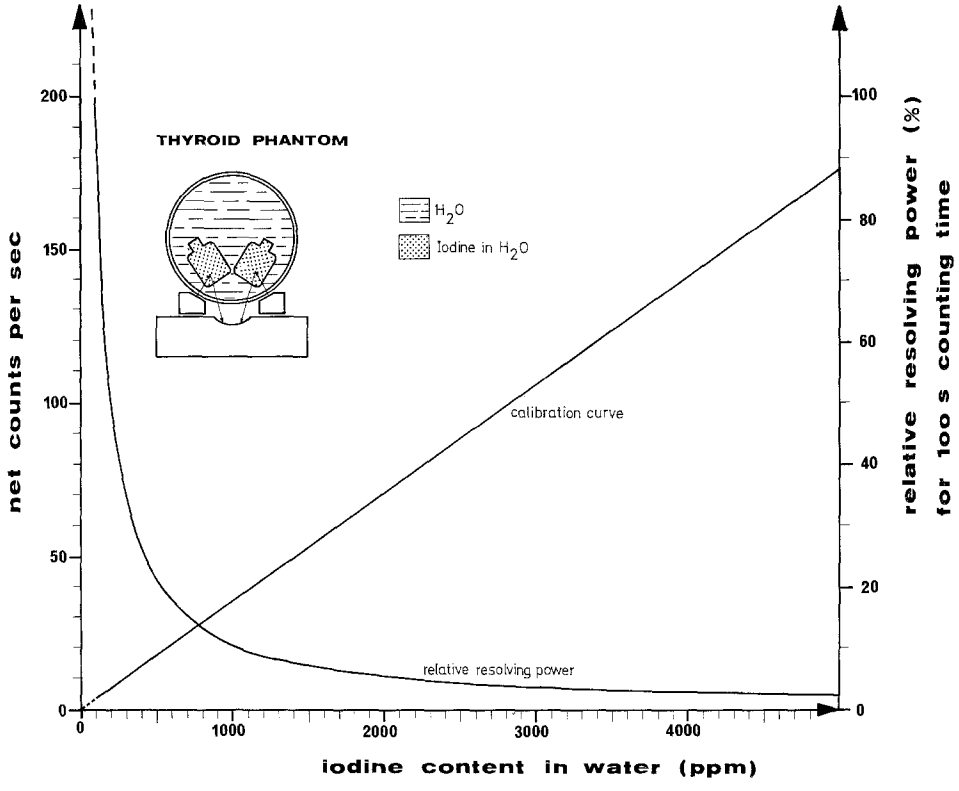


Fig. 4. Calibration and resolving power curves obtained from the "phantom"

Bearing in mind the absorption of the superficial tissues, the dose in the thyroid is 1 mrem per 100 s of exposure. This value is so low that several measurements can be carried out in a same subject without approaching the maximum permissible dose.

Results

The information obtainable with the described equipment is relative to the fraction of thyroid limited by the penetration of radiations involved and the collimation of the sources.

With this information no absolute evaluation can be made at present of the iodine concentration inasmuch as this is greatly influenced by the shape of the thyroid and the thickness of the superficial tissues of the neck. Nevertheless the same information allows us to follow the local evolution of the iodine con-

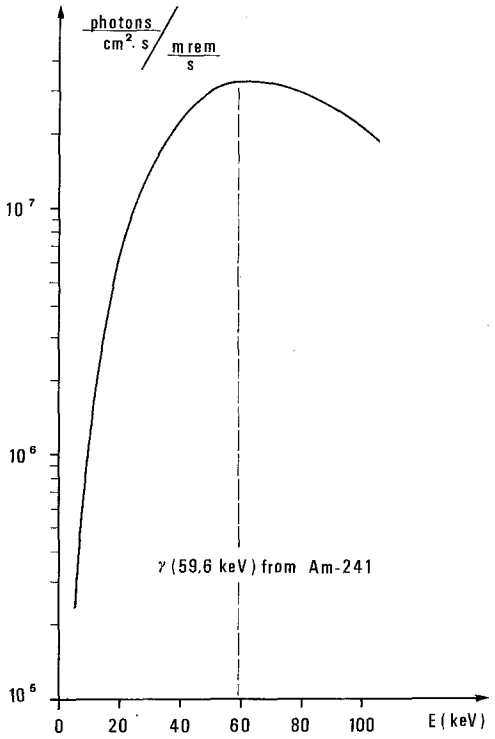


Fig. 5. Photon flux necessary to determine I mrem/s dose rate in soft tissue

centration. To this end, some preliminary investigations have been performed to study the uptake under stable iodine load in apparently normal subjects.

The optimal position of the measuring head on the neck was previously established by determining the axial distribution of the iodine KX-ray counting rate on the neck of the subject under examination.

The above mentioned distribution in the two subjects are shown in Fig. 6. It can be seen that even the concentration of iodine normally present in the thyroid already enables a good localisation of the gland to be made.

Preliminary determination of axial distribution is necessary not only to improve the useful information/background ratio but, above all, to ensure the best possible reproducibility.

Some preliminary tests were performed under stable iodine load in subject B (Fig. 6) who presented a plateau in the axial distribution of the counts which therefore ensures less critical measuring conditions.

Fig. 7 shows the uptake curve obtained after oral administration of 25 ml Lugol (containing ~6 mg of iodine). The points correspond to the mean of series of 3–5 measurements lasting 10^2 s each. This uptake pattern looks far different from the typical pattern

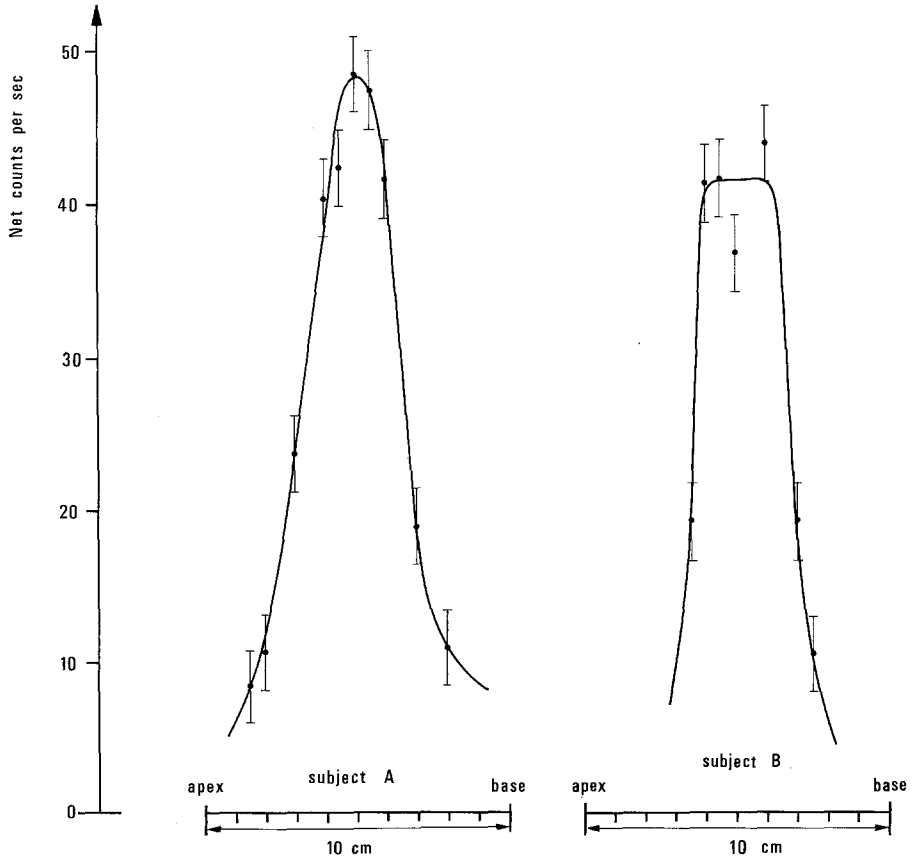


Fig. 6. Axial distribution of counting rate due to iodine in the thyroid of subjects A and B

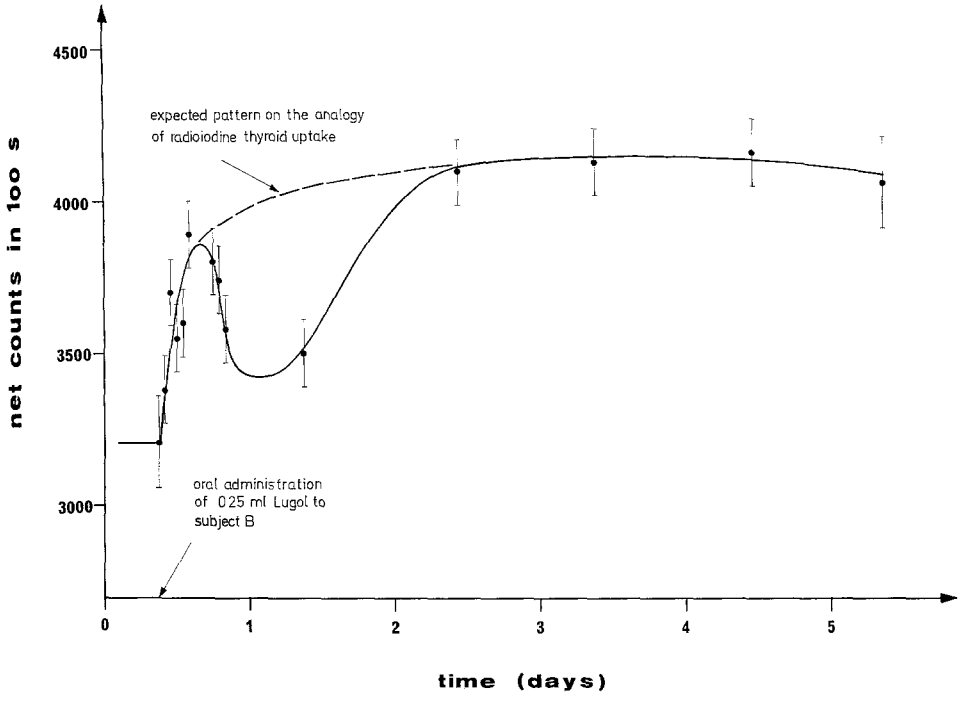


Fig. 7. Uptake curve in subject B corresponding to administration of 0; 25 ml Lugol (6 mg iodine)

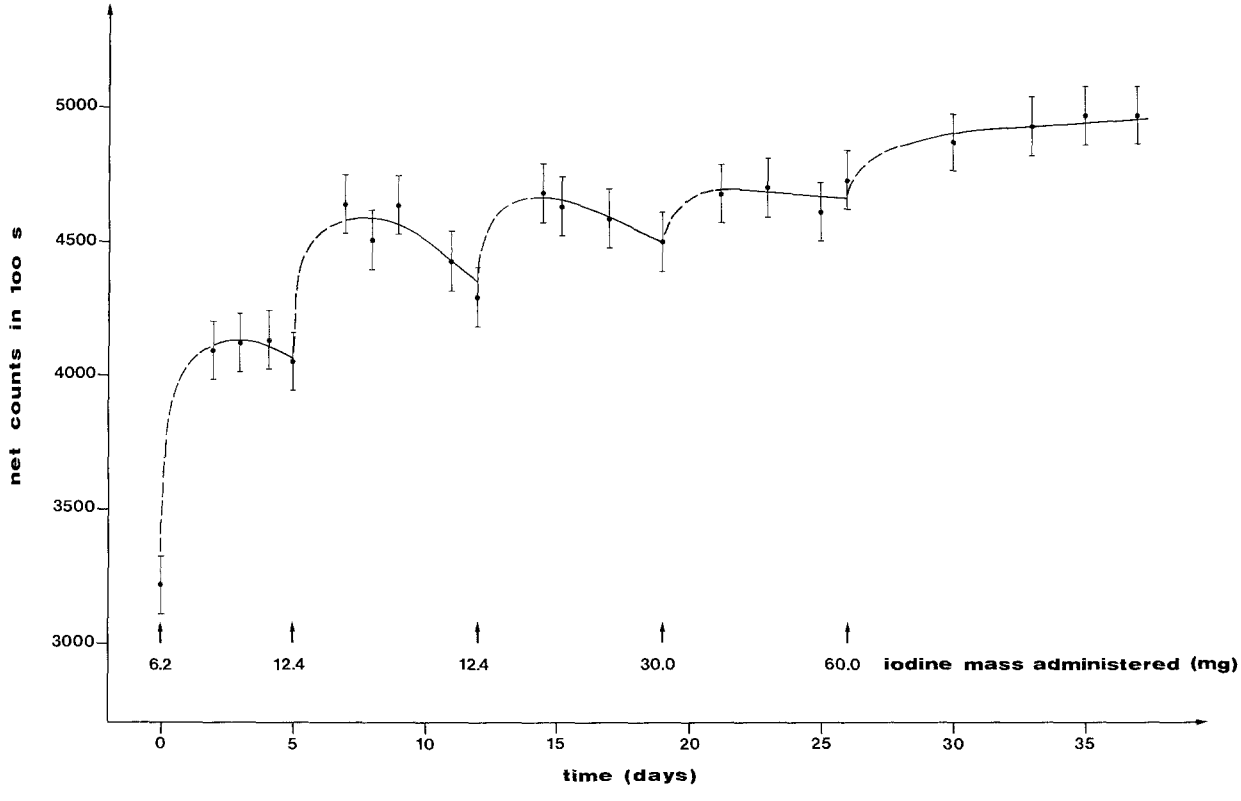


Fig. 8. Uptake curve in subject B corresponding to periodic administration of increasing quantities of Lugol

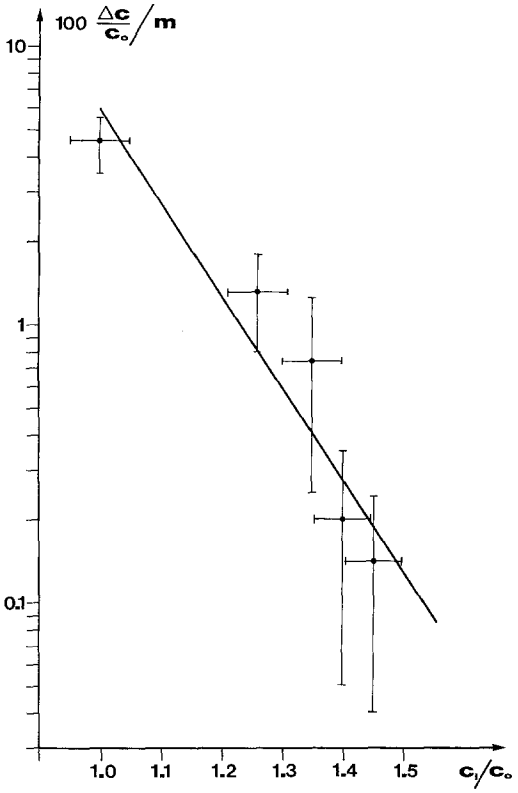


Fig. 9. Pattern of maximum uptake (per mg of iodine administered) versus the concentration of iodine in the thyroid at the time of administration

Table 1. Dosimetric data characteristic of the technique proposed compared with those from radioactive tracer methods

Tracer	Radiation utilized	Typical activity administered (μCi)	Thyroid dose (rem)	Whole body dose (mrem)
I^{127} (stable)	Characteristic X-rays [a]	0	10^{-3} [b]	0
I^{125} (radioactive)	γ-rays	5 [c]	6 [c]	8–19 [c]
I^{131} (radioactive)	γ-rays	5 [c]	6–10 [c]	2–18 [c]
Tc^{99} (radioactive)	γ-rays	250 [c]	$2–6 \cdot 10^{-2}$ [c]	$2–4 \cdot 10^{-3}$ [c]

[a] Excited by ^{241}Am (2×45 mCi).
[b] For each measurement lasting 100 s.
[c] Data obtained from ICRP Report 17 (1971).

obtained with radioactive iodine tracers, because of a transitory phenomenon of accelerated discharge which takes place between the 6th and 24th hour. In this regard it is worthwhile pointing out that, in radioactive iodine uptake, iodine mass administered is negligible compared with iodine mass present in thyroid.

Measurements were subsequently carried out in subject B submitted to periodic administration of increasing amounts of Lugol; the results (Fig. 8) clearly demonstrate that there is a reduction in the increases of maximum uptake, i.e. the concentration of iodine in the thyroid tends to a saturation level.

A quantitative analysis of the results was carried out bearing in mind the linear correlation between net counting rate and iodine concentration. It was thus possibile to calculate the pattern of the maximum increases of the iodine concentration (per mg iodine administered) in percent of the initial concentration, related to the thyroid uptake level before each new administration (Fig. 9).

Discussion

The results so far obtained are particularly encouraging and it seems worthwhile developing the technique described for use in the field of thyroid physiology.

Furthermore it should eventually be possible to draw up parameters useful for the recognition of functional disorders of the thyroid and for dynamic studies on single nodules. In fact, it seems that the outstanding feature of this technique, as a diagnostic tool, will be the low dose administered as is clearly visible from Table 1 showing a comparison of data related [2] to radioactive tracers currently used in diagnostic techniques.

It is hoped that tests of thyroid function based on the technique described will be forthcoming in order to overcome the present limitations of "in vivo" studies, i.e. in children and in pregnancy.

References

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