DIAGNOSTIC NUCLEAR MEDICINE

Use of I-123 in Early Radioiodide Uptake and Its Suppression in Children and Adolescents with Hyperthyroidism

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Absolute activity measurement of I-123 by coincidence counting was used to study the early thyroidal iodide uptake in 20 hyperthyroid children. Patients were pretreated either with methimazole or propylthiouracil before injection of $Na^{123}I$. The usual method of analysis of the early uptake was modified to account for a rapidly equilibrating compartment, to give thyroidal iodide trapping rate constant (K_1) and absolute iodide uptake (AIU).

The suppressibility of the early uptake by triiodothyronine (T_3) was evaluated in some patients. The upper limit of normal for K_1 was 0.03 min^{-1} and for AIU was 0.04 $\mu g/min$. In the hyperthyroid subjects, K_1 and AIU were in the hyperthyroid range before and after T_3 suppression. For patients with suppressible uptake, remission from hyperthyroidism was maintained for 6 mo to 2½ yr. Only two patients with nonsuppressible uptake achieved remission from hyperthyroidism, perhaps because of coexistence of thyroiditis.

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Thyrotoxicosis is characterized by escape of the thyroid gland from the normal regulation of the pituitary-thyroid axis. The thyroidal hyperfunction can be controlled by antithyroid medication, radiation therapy, or surgery (*1,2*). When antithyroid medication is well tolerated by the patient, medical management with antithyroid drugs has been considered the treatment of choice, especially in children, and medication is terminated when remission is achieved (*1*). Remission is characterized by return of suppressibility of thyroid radioiodine uptake by exogenous triiodothyronine (T_3) (*3–5*). Medical therapy with thionamides depresses thyroid-hormone synthesis by inhibiting the iodination of tyrosyl residues and the coupling of the iodinated tyrosyl moieties after the iodide is trapped by the thyroid gland (*6*). Since thionamides do not interfere with the trapping of iodide (*7*), the early thyroidal radioiodine uptake, which depends mostly on the trapping of iodide by the thyroid, is useful in evaluating patients while they are on antithyroid drug treatment (*8*).

Valuable as this information may be in determining whether remission of thyrotoxicosis has occurred, early radioiodine uptake measurement has not gained general acceptance. This is largely because of inherent difficulties in the method and because of reluctance to expose patients, especially children and adolescents, to repeated administration of radioactive agents (*9,10*). Use of I-123 ($T_{1/2}$ = 13 hr) permits considerable reduction in radiation dosage. Introduction of coincidence counting of this nuclide permits the determination of absolute activity without regard for variation in counting efficiency introduced by geometric factors, and eliminates the need to use comparisons with an external phantom stand-

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ard (*11–13*). We report here the application of these newer principles to a group of 20 children with thyrotoxicosis in whom we achieved enhanced accuracy of counting and reduction in radiation dosage.

PATIENTS, MATERIALS, AND METHODS

Patients with thyrotoxicosis of varying duration were chosen at random from the pediatric endocrine clinic. Proper informed consent was obtained before each study. The initial early radioiodine uptake test (as described later in this section) was performed on patients while they were on antithyroid medication. Those patients who were in good control while taking a small dose of antithyroid drug had the uptake repeated after taking 25 μg of triiodothyronine (T_3) three times a day for 7 days. Antithyroid medication was discontinued in those patients in whom standard clinical and laboratory evaluation suggested remission of the hyperthyroid state. They were then followed by frequent clinical examination and measurement of serum thyroxine (T_4) and T_3 for recurrence of hyperthyroidism. A blood sample was obtained for serum T_4, T_3, and thyroid-stimulating hormone (TSH) concentration on each patient before each uptake test. T_4, T_3, and TSH were determined by radioimmunoassay (*14–16*).

Patients were prepared by overnight fasting and by taking a dose of 20 mg of methimazole or 200 mg of propylthiouracil about 1 hr before the test. Carrier-free [^{123}I] sodium iodide was obtained as an aqueous solution of about 2 μCi/ml*. The purity of the preparation exceeds 99%. The iodide was diluted to a concentration of about 1 μCi/ml in sterile normal saline, and 1.5–2 μCi were injected intravenously after appropriate neck-background counts had been obtained. Three sets of serial 2-min measurements were made of x-ray, gamma, and coincidence count rates simultaneously for approximately 30 min. The detection system and its circuitry were the same as described by Herman et al. (*11*). Two NaI(Tl) detectors were used, a 3- by ¼-in. crystal for the x-rays, and a 1.5- by 1.5-in. crystal (later replaced by a 3- by 1-in. crystal) for the gamma radiation. A third channel of data was obtained by measuring the overlap coincidence of the x-ray and gamma photons. Three scalers recorded the count rates from the x-ray and gamma detectors and from the coincidence events. The detectors were placed close to the patient's neck, at a 90-degree angle to each other.

The absolute activity of I-123 is calculated by the following equation:

$$N_o = 0.86 \frac{N_x N_\gamma}{N_c}, \qquad (1)$$

where N_o = absolute activity of source in disintegrations per minute; N_x = net count rate of x-ray detector in counts per minute (cpm); N_γ = net count rate of gamma detector in counts per minute (cpm); and N_c = net count rate in coincidence circuit (cpm). The derivation of Eq. 1 is given by Herman et al. (*11*).

The efficiency factors that normally relate count rates to disintegration rates and depend, in part, on geometric factors, do not appear explicitly in Eq. 1. The factor 0.86, arising from the nature of the decay scheme of I-123, allows for the fact that not every disintegration results in escaping photons (*11,13*), and is applicable to the range of source-to-crystal distances encountered in our experiments (*17*).

Each patient was asked to urinate before the tracer injection, and this urine sample was discarded. Another urine specimen was obtained at the end of the 30-min uptake procedure, and its concentrations of I-123 and I-127 were determined, the latter by a modification of Barker's alkaline ash method. A conversion factor, Ku, was calculated as the urinary I-127 concentration (μg/ml) divided by I-123 concentration (μCi/ml). This factor is used to calculate absolute iodide uptake from the trapping rate.

Using the 3- × 1-in. spectrometer and appropriate discriminator windows, the x-ray and the gamma emitted by the I-123 nucleus can be measured in parallel with the coincidence counting. In tissue, the x-ray (28 keV) is attenuated more than twice as rapidly per centimeter as the gamma (159 keV), the half-value layers (HVL) for narrow-beam geometry being 1.86 and 4.65 cm of tissue, respectively (*18*). It is therefore possible to measure the depth of the center of distribution of activity in tissue by determining the ratio of the x-ray count rate (N_x) to the gamma count rate (N_γ). By measuring N_x/N_γ with a small source (1.8 μCi of I-123) at various depths in a cylindrical water phantom with a radius of 7.6 cm, a calibration curve was constructed showing the relationship of N_x/N_γ to the in tissue depth (Fig. 1) (*19,20*).

By determining the N_x/N_γ during the I-123 uptake procedure and using the calibration curve, the relative anatomic location of activity can be estimated. In order to determine the relative location of the I-123 activity in the neck vasculature, [^{123}I] iodohippurate was used in five normal volunteers, and this depth was further compared with the depth measured by giving [^{123}I] sodium iodide to two volunteers after Lugol blocking of the thyroidal uptake. The Hippuran used was prepared by the free iodine exchange method and had a purity exceeding 99%.

The total neck activity as measured by coincidence counting during an uptake procedure is plotted against time (Fig. 2). The uptake of iodide by the

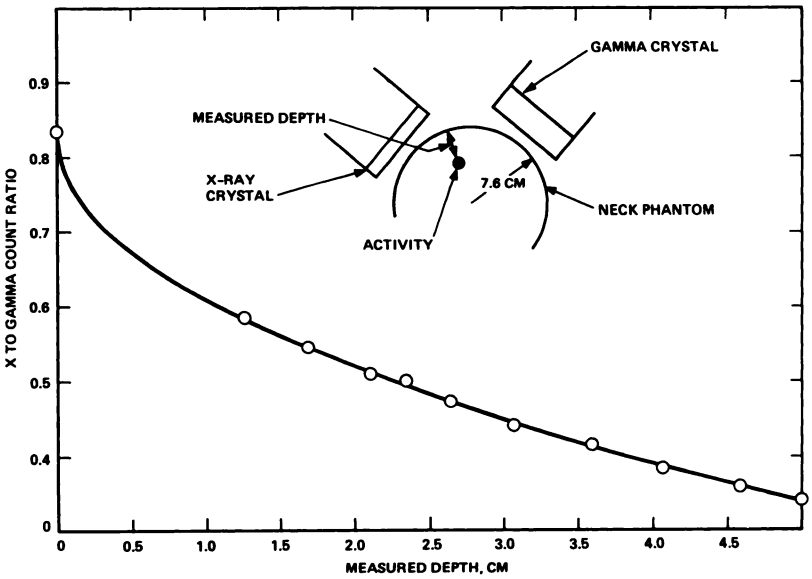

FIG. 1. The x-ray-to-gamma count ratio vs point-to-source depth in water phantom. The insert roughly indicates geometry used.

thyroid generally shows a rapid rise and then an asymptotic approach to the maximum value within 20–25 min (*21*). Berson and Yalow attributed the apparent biphasic nature of the uptake curve to the superposition of the iodide dilution curve due to the expansion of the iodide space (*21*), assuming the initial rise to be from the background activity of the neck. By using the technique of determining relative depth, we were able to show that such an explanation would be inadequate to describe the presence of large amounts of thyroidal activity during the very early phase. The analysis of the thyroid-uptake curve was therefore modified to accommodate this observation.

Traditionally, a fixed amount of activity is subtracted from the total as the average correction for the neck background. The neck-volume background correction is an estimation of the ratio of the volume of radioiodide space of the neck to the total volume of distribution of the same agent. We adopted a value of 3% of the total injected activity as the correction from that of Armstrong et al. (*22*) who used radioindium; this choice is also in close agreement with the finding of Chopra et al. (*23*) who used the I-131 isotope. By assuming a constant trapping rate, the approach to equilibrium can be fitted to a single exponential (Appendix) to give the leakage rate, K_2. Extrapolation of the uptake curve back to the time of injection would give the activity representing the sum of the vascular or extrathyroidal neck activity (ENA), and the activity of a rapidly equilibrating compartment (S_{ic}). The intrathyroidal inorganic iodide pool S_2 is given by the total activity minus the sum of ENA and S_{ic}. The trapping rate is given by the product of K_2 and S_2 at equilibrium. If one assumes that iodide enters first S_{ic} and is then transported into S_2, a trapping rate constant can be derived by dividing the trapping rate by S_{ic}. This constant will then be independent of the stable-iodide concentration.

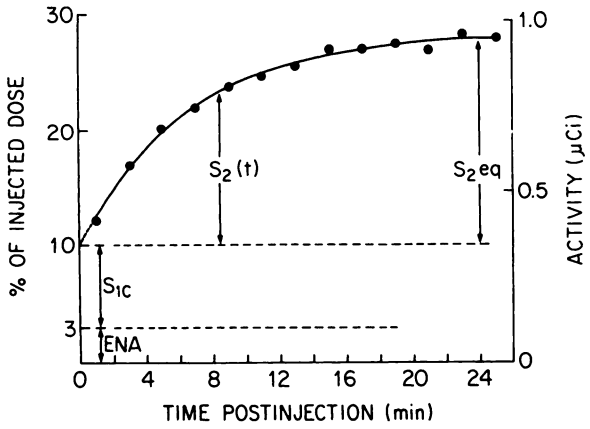

FIG. 2. Total neck activity plotted as a function of time. (For symbols see Appendix.)

The standard deviation of the absolute activity measurement is largely dependent on the number of coincidence counts (N_c), and ranges from 5 to 10% in our in vivo measurements. The standard error for K_2 is derived by the least-squares fitting method on values of $\frac{S_{seq} - S_2}{S_{2eq}}$ vs. time, and has a range of 5–25%. The accuracy of the estimation of S_2 depends on validity of the assumption about the constancy of ENA + S_{ic}. Since we are studying a system in which the organification of iodide is blocked, the quantity of inorganic iodide in the plasma and the thyroid remains approximately constant except for a small decrease of 5% by urinary loss. In the euthyroid subject, whose uptake is relatively small,

TABLE 1. IN TISSUE DEPTH OF SOURCE AT 1 MIN

Tracer administered (n = No. of subjects)	Average depth ± s.d. (cm)	Range (cm)
$Na^{123}I$ without Lugol blocking (n = 10)	1.6 ± 0.2	1.4–1.8
$Na^{123}I$ with Lugol blocking (n = 2)	3.2	3.1–3.3
[^{123}I] Hippuran (n = 5)	3.3 ± 0.3	2.5–4.1

the error resulting from the assumption of constancy would be a little over 5%, whereas in the hyperthyroid subject the maximum error would be that of the magnitude of the uptake, which is usually under 25%. The error resulting from the mixing of the tracer has been shown by Berson and Yalow to be about 5% if plasma activity is assumed to be constant throughout the half-hour period (*24*). The estimation of K_1 is affected greatly by the use of the average value of 3% for neck background activity. The error is greatest in subjects whose initial total activity is small (i.e., <5%). With errors of this magnitude (5–25%) one can still clearly separate euthyroid from hyperthyroid subjects using our analysis of AIU and K_1.

RESULTS

Table 1 shows the average depths of the source of activity (at 1 min postinjection) of the three groups of subjects. The source of vascular activity was estimated as 3.3 ± 0.3 cm deep when Hippuran was injected. When $Na^{123}I$ was injected, the activity was located at 1.6 ± 0.2 cm. These values are significantly different at a p level of <0.001.

The validity of using Hippuran to mark the location of the vascular space is supported by the fact that when thyroid uptake was blocked by Lugol's solution, the location of the source of I-123 activity was 3.2 cm, which is the same depth as that found when Hippuran was used. Iodide therefore occupies the same place as Hippuran when thyroid uptake is blocked. Since the distribution of initial I-123 activity represents some weighted average between the vascular activity and thyroid activity, we have calculated, with the aid of Table 1, the average thyroid activity to be about 1½ times that of the vascular background activity.

The clinical features of the twenty patients are summarized in Table 2. The female-to-male sex ratio of this population is 3/2. The average age at time of study is 15.4 yr. They have been treated for an average of 2.3 yr. These patients were followed for a period of 6 mo to 2½ yr after the uptake test. At the time of diagnosis 18 of 20 patients had goiter and 8 of 20 had exophthalmos. At the time of study, 12 of 20 had goiter and 8 of 20 had exophthalmos. Of the two patients who did not have goiter, Patient 14, whose disease course was very short, probably

TABLE 2. CLINICAL FEATURES OF PATIENTS

Patient No.	Age	Sex	Duration of treatment before study	Initial presentation		At time of study		Medication* at time of study
				Goiter	Exophthalmos	Goiter	Exophthalmos	
1	17	M	2 yr	+	−	+	−	No medication
2	15	M	0 yr	+	+	+	+	No medication
3	15	F	1 yr	+	+	+	+	MMI 10 mg. bid.
4	14	M	5 yr	+	+	+	+	MMI 15 mg. bid
5	17	M	2 yr	+	+	+	+	PTU 100 mg. qd.
6	16	F	3 yr	+	+	−	+	MMI 5 mg. bid
7	16	F	1½ yr	+	+	+	+	MMI 10 mg. qd.
8	13½	F	2 yr	+	−	−	−	MMI 10 mg. qd.
9	15	M	1 yr	+	−	−	−	MMI 10 mg. qd.
10	20	F	1 yr	+	−	+	−	MMI 5 mg. qd.
11	17	F	2 yr	+	−	+	−	MMI 20 mg. qd.
12	21	F	1 yr	+	−	−	−	No medication
13	18	F	5 yr	+	−	−	−	No medication
14	12	M	1 yr	−	−	−	−	No medication
15	8	M	2 yr	−	−	+	−	MMI 10 mg. tid.
16	20	F	4 yr	+	+	−	+	No medication
17	13	F	1 yr	+	+	−	+	MMI 15 mg. qd.
18	14	F	3 yr	+	−	+	−	MMI 10 mg. bid
19	16	M	1½ yr	+	−	+	−	MMI 10 mg. qd.
20	10	F	2 mos	+	+	+	+	MMI 10 mg. tid.
Average	15.4		2.3 yr					

* MMI = methimazole
PTU = propylthiouracil

TABLE 3. RESULTS OF SERUM T_4, T_3, TSH, AND KINETIC PARAMETERS K_1 AND AIU

	Presuppression					Postsuppression						
Patient No.	T_4* (μg/dl)	T_3† (ng/dl)	TSH‡ (μU/ml)	K_1§ (min^{-1})	AIU§ (μg/min)	T_4 (μg/dl)	T_3 (ng/dl)	TSH (μU/ml)	K_1 (min^{-1})	AIU (μg/min)	Suppressible|| Yes/No	Remission Yes/No
1	22.4	819	2	0.737	26.4	—	—	—	—	—	No	No
2	16.5	726	2	0.142	—	—	—	—	—	—	No	No
3	18	702	2	0.35	—	—	—	—	—	—	No	No
4	6.6	294	2	0.34	40.7	—	—	—	—	—	No	No
5	6.5	215	2	0.11	—	8.6	475	2	0.11	0.70	No	No
6	4.6	92	2	0.094	—	2.0	700	2	0.12	—	No	No
7	11.0	195	—	0.19	—	10.0	340	—	0.18	—	No	No
8	1.5	170	8.5	0.038	—	3.5	455	2	0.127	0.25	No	Not tested
9	7.5	153	2	0.062	—	6.2	690	—	0.028	—	No	Not tested
10	5.0	128	—	0.096	0.69	3.3	220	—	0.084	0.40	No	Yes
11	8.8	150	2	0.10	—	8.1	525	—	0.135	—	No	Yes
12	10.0	153	2	<0.005	<0.005	6.8	650	2.4	<0.005	<0.01	Yes	Yes
13	8.0	120	2	0.13	0.146	5.3	180	—	<0.005	<0.03	Yes	Yes
14	7.8	—	12	<0.005	—	4.1	625	2	<0.005	~0	Yes	Yes
15	13.0	135	8.4	0.14	—	8.4	675	2	<0.005	~0	Yes	Yes
16	5.3	166	—	<0.005	<0.005	—	—	—	—	—	Yes	Yes
17	8.6	175	2	0.11	—	—	—	—	—	—	—	Not tested
18	8.3	190	2	0.16	—	—	—	—	—	—	—	No
19	6.8	145	2	0.37	0.98	—	—	—	—	—	—	Not tested
20	4.9	130	2	0.11	5.5	—	—	—	—	—	—	No

* Normal = 4.5–13.2 μg/dl.

† Normal = 90–220 ng/dl.

‡ Normal: <10 μU/ml.

§ For normal see Fig. 5.

|| A nonsuppressible uptake is defined as an abnormal uptake in the presence of elevated T_3 levels. Normal uptake values before or after T_3 suppression are considered as suppressible.

had hyperthyroidism as a result of thyroiditis. Patient 15 had an elevation of T_4 due to the presence of an inherited abnormal thyroxin-binding protein.

Laboratory data for these patients are tabulated in Table 3. Five patients (Nos. 1–5) had clinical and chemical evidence of hyperthyroidism at the time of the uptake test, and their trapping rates were in the hyperthyroid range. T_3 suppression tests were performed in 11 patients (Nos. 4–14). T_3 blood concentrations were significantly increased to the hyperthyroid range after T_3 ingestion, thus indicating the achievement of effective T_3 concentrations in the blood. After suppression, T_4 concentration was generally less than the T_4 level before suppression. However, such observations cannot be shown to be statistically significant by our present data.

Although the ranges of normal value for K_1 or AIU cannot be established from the number of patients that we have studied, the sensitivity of our method in distinguishing hyperthyroid from normal subjects is illustrated in Fig. 5. The combined results of K_1 and AIU of our adult and pediatric patients are plotted on log-log axes for the convenience of demonstrating the range of values obtained. The upper limit values (mean + s.d.) for K_1 and AIU illustrated in the figure for the normal population are adapted from the data of Armstrong et al. (*22*) and Alexander et al. (*25*). They are 0.03 min^{-1} and 0.04 μg/min, respectively. In the hyperthyroid subjects, K_1 and AIU were in the hyperthyroid range before and after T_3 suppression. K_1 and AIU of our patients in remission (Nos. 12–16) are in the normal range after T_3 suppression. The elevated presuppression levels for two of these patients (Nos. 13 and 15) may indicate the presence of thyroiditis or a compensation for antithyroid medication.

Of the 16 patients whose thyroid status is known

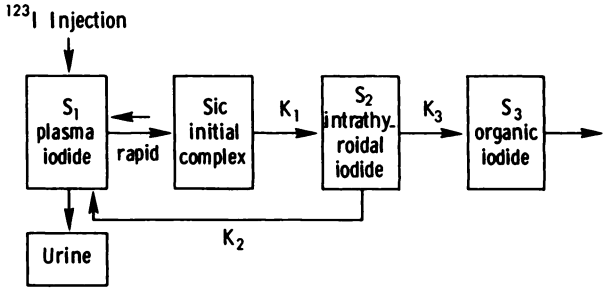

FIG. 3. Model for the analysis of early iodine-trapping kinetics.

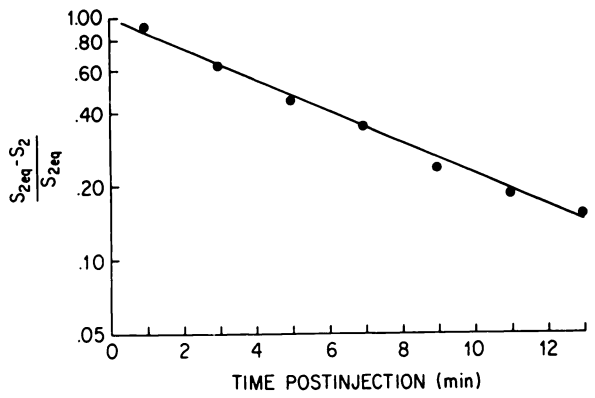

FIG. 4. Semilogarithmic plot of $\frac{S_{2eq} - S_2}{S_{2eq}}$ for the calculation of K_2.

from other clinical data, 14 had a correct prediction of clinical diagnosis based on the initial uptake or the suppression test. There were two patients (Nos. 10 and 11) who had nonsuppressible thyroid uptake and remained euthyroid when medication was discontinued. Our accuracy in predicting remission is 14/16 (87.5%). The four patients whose remission status was not ascertained were still considered hyperthyroid and were not tested.

DISCUSSION

The advantages of using I-123 coincidence counting in thyroid-uptake studies have been discussed previously by Herman et al. (*11*) and Wimmer (*12*). Our experience so far has confirmed their prediction. We have eliminated as a source of error the problems of detector position and of the variation of thyroid size. The ability to measure absolute activity, as opposed to determining activity by count rate, allows one to compare directly the activity in urine with that in the thyroid without regard for differences in geometry or an external standard phantom. Employing a scheme to study only the trapping mechanism, similar to that of Berson andYalow (*20*), we use thionamide blocking (*26*) to reduce further the absorbed radiation dose to the patient by preventing organification of iodide. Assuming a biologic halftime of 10 hr for I-123 (based on renal iodide clearance of 30 ml/min), and 25% uptake by the thyroid, we estimate the dose delivered to a 10-g thyroid gland to be 21 mrads. This is less than 1/300 of the irradiation dose of 6–13 rads delivered by conventional methods using I-131. The reduction of absorbed radiation comes from the properties of I-123 and the small doses used in the present study. Table 4 shows a detailed comparison between I-123 and I-131 (as iodides) regarding the absorbed doses to the thyroid and other target organs. The data have been abstracted from an HEW publication (*30*). The absorbed doses are given for both adult and pediatric patients, and are calculated assuming a 20% uptake of iodide (*30*). The calculated doses with the I-123 procedure for adult patients as shown in Table 4 are in agreement with our estimated dose.

The early iodide uptake is usually calculated as a percentage of the injected radioactivity after the subtraction of extrathyroidal neck activity. The kinetic analysis of the early radioiodine uptake using graphical methods has been reported, and plasma radioactivity measurements were required (*21,27*). Parameters such as "equilibrium plasma flow" and "unidirectional flow" are measures of the trapping rate. Armstrong advocated the use of the initial slope of a pertechnetate uptake as a measure of trapping rate (*22*).

By using the N_x/N_γ ratio to determine the relative depth of source in the neck tissue, we have demonstrated that an appreciable amount of activity is associated with the thyroid gland soon after $Na^{123}I$

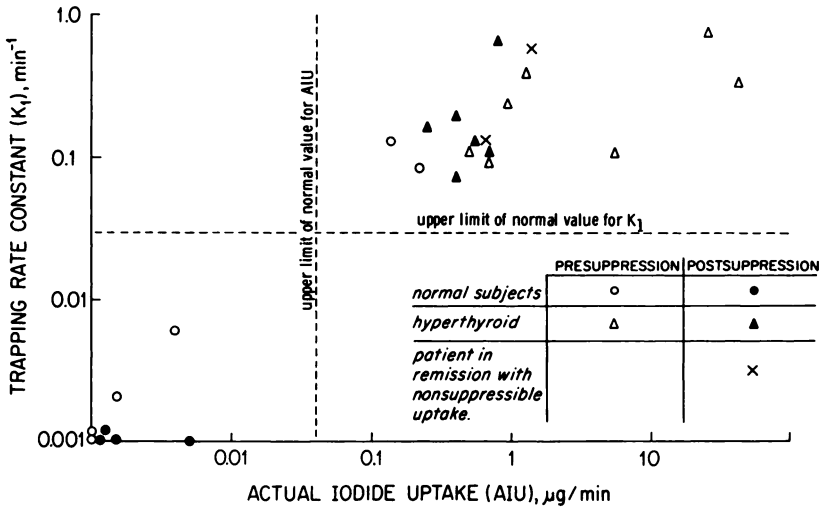

FIG. 5. Distribution of K_1 and AIU values among hyperthyroid and euthyroid individuals. The upper limit of normal values is adapted from Alexander et al. (*25*) and Armstrong et al. (*22*).

TABLE 4. COMPARISON OF ABSORBED DOSES FROM RADIOIODINE THYROID UPTAKE PROCEDURES*

Patient age	Isotope	Administered activity (μCi)	Thyroid dose (mrad)	Whole-body dose (mrad)	Gonad dose (mrad)
Adult	I-123	2	22	0.06	(0.02) (M) (0.04) (F)
	I-131	6	6600	2.6	(0.52) (M) (0.84) (F)
10 years	I-123	2	44	0.10	(0.10) (M) (0.07) (F)
	I-131	2	4400	1.6	

* Reference 30 and references therein.

is injected. This amount of activity is associated with the initial rapid phase of the uptake curve, and represents a thyroidal iodide compartment that has not been described previously. This compartment apparently: (a) equilibrates very rapidly with the plasma iodide pool; and (b) is present in all subjects with functioning thyroid tissue representing about 1–3 μg of iodide. Previous analysis of early thyroidal radioiodide uptake did not account for this compartment. The model that we propose is an attempt to incorporate this compartment into our analysis. Since the activity in S_{i_c} is probably inversely related to the plasma iodide pool, as the iodide trapping rate is, the normalization of the trapping rate by S_{i_c} to give the trapping rate constant (K_1) will eliminate the influence of the total plasma iodide pool on the trapping rate. The properties of the observed rapidly equilibrating compartment, however, would be evidence in support of our scheme. Much further work is needed to elucidate the exact relationship of these several thyroidal iodide compartments. Despite the uncertainty of our interpretation, the procedure that we follow has been shown useful in distinguishing hyperthyroidism from normal function, and the kinetic constants derived are comparable with those of Armstrong or Alexander (*22,25*).

There are four groups of hyperthyroid patients defined by suppressibility and remission status. They are:

1. those who relapse with nonsuppressible uptake;
2. those who remit with nonsuppressible uptake;
3. those who remit with suppressible uptake; and
4. those who relapse with suppressible uptake.

Alexander has found patients in each of the categories (*5*). Others have grouped their patients in different categories (*4*). We have observed patients in the first three groups in our limited series. The apparent heterogeneity of hyperthyroid patients with respect to iodide uptake and its suppression may be partly due to the criteria used for performance and interpretation in the early uptake test (*5*). If one assumes a continuous distribution of patients exhibiting values between the normal and hyperthyroid states, distinguishing between these two states may be difficult for those whose uptake values fall close to the boundary values of K_1 and AIU. However, the K_1 and AIU values of our hyperthyroid subjects differ from those of the normal by an order of magnitude, suggesting the possibility of a discontinuous distribution rather than a continuous one. The criteria for separating normal from abnormal values should have little effect on the amount of separation observed.

The coexistence of thyroiditis and Graves' disease has been recognized (*28*). Patients in Group 2 (Nos. 10 and 11)—who underwent remission from Graves' disease despite the findings of nonsuppressible uptake by T_3—may represent patients with coexistent thyroiditis. The proportion of patients with thyroiditis among patients with Graves' disease can be estimated from Alexander's finding to be about 11%, representing his ten patients who remitted with nonsuppressible uptake out of 93 patients studied (*5*), which has a 95% confidence limit of 5–18%. Our finding of two such patients out of 16 studied represents a ratio of 12.5%, which falls in the range estimated by Alexander. In those patients who remit from the disease, the observation of a T_4/T_3 ratio different from that of the normal population also supports the existence of dyshormogenesis in these patients (*29*).

In summary, I-123 injection and coincidence counting were used to study the kinetics of early iodide uptake in hyperthyroid subjects. Enhanced accuracy and significant reduction in radiation dosage are achieved. By using the N_x/N_γ ratio to determine the average depth of source in tissue, we have demonstrated the presence of appreciable amounts of activity, located at the same depth as the thyroid

gland, associated with the initial rapid phase of the thyroid-uptake curve. The kinetic analysis of the early radioiodide uptake, based on a proposed three-compartment model, has yielded results comparable to the standard techniques. This simple, safe, and accurate method should prove useful in the clinical management of hyperthyroidism, especially in pediatric patients.

APPENDIX

We assume that iodide is first localized on the thyroid gland in the compartment S_{ic}, then it is transported into an intrathyroidal iodide pool S_2 with rate constant K_1. Iodide is then either organified into S_3 with rate constant K_3, or leaked out with a diffusion rate constant of K_2 (Fig. 3).

A general differential equation can then be written as:

$$\frac{dS_2}{dt} = K_1S_{ic} - K_2S_2 - K_3S_2.$$

Since we use thionamide to block organification, $K_3S_2 = 0$. The resultant equation can be solved in the form: $S_2 = S_{2eq}(1 - e^{-K_2t})$. A plot of $\log \frac{S_{2eq} - S_2}{S_{2eq}}$ against t will yield a straight line with the slope equal to $-K_2$ (Fig. 4). Since $K_1S_{ic} = K_2S_{2eq}$ when $\frac{dS_2}{dt} = 0$, and S_{ic}, S_{2eq} and K_2 are directly measurable, all four quantities, including K_1, can be determined. K_1 and K_2 have the dimensions of min^{-1}; S_{ic} and S_2 are expressed in terms of μCi. The rate of actual iodide uptake (AIU) is determined by computing AIU (μg/min) $= K_2S_{2eq} \times$ Ku, where Ku is the ratio of I-127/I-123 in the urine.

FOOTNOTE

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