Thyroid Uptake and Imaging with Iodine-123 at 4–5 Hours: Replacement of the 24-Hour Iodine-131 Standard

John L. Floyd, Paul R. Rosen, Ronald D. Borchert, Donald E. Jackson, and Fredrick L. Weiland

Nuclear Medicine Section, Department of Radiology, David Grant USAF Medical Center, Travis AFB, California; Nuclear Medicine Department, Boston Children's Hospital, Boston, Massachusetts; Nuclear Medicine Section, Department of Radiology, and Wilford Hall USAF Medical Center, Lackland AFB, San Antonio, Texas.

A study was carried out to determine the suitability of utilizing a 4 to 5 hr interval from administration of Iodine-123 to imaging and uptake measurement as a replacement for the 24-hr standard originally established with Iodine-131. In 55 patients who underwent scintigraphy at 4 and 24 hr, there was no discrepancy between paired images. In 55 patients who had uptake measured at 4 and 24 hr and in 191 patients who had uptake measured at 5 and 24 hr, the early measurements proved equal or better discrimants of euthyroid from hyperthyroid patients. In our institutions, these findings and the logistical advantages of completing the exam in 4–5 hr led us to abandon the 24-hr study in the majority of patients.

J Nucl Med 26:884–887, 1985

The benchmark of iodine accumulation by the thyroid gland has been the "24-hour radioiodine uptake" since the post-World War II introduction of clinical thyroid investigation with reactor-produced iodine-131 (^{131}I). With the development of the rectilinear scanner by Cassen in 1951, the "24-hour uptake and scan" became the world-standard test for anatomical mapping and functional assessment of the thyroid. Iodine-131 has since been largely replaced by technetium-99m (as pertechnetate) and ^{123}I because of their lower dosimetry and optimized decay characteristics for imaging with gamma cameras. Because it provides a high target/nontarget ratio with greatly reduced patient radiation and is now widely available, ^{123}I is the preferred radioiodine for thyroid imaging. Since it reflects organification as well as trapping, it is also considered by many physicians to be the radionuclide of choice for thyroid examination (*1–3*).

Despite its physical distinctions from ^{131}I, however, the interval between administration of ^{123}I and imaging and/or uptake measurements has remained tied to the 24-hr ^{131}I standard. The inconvenience and expense often associated with a 2-day test has led many departments to use pertechnetate for imaging and utilize ^{123}I or ^{131}I only when an uptake is specifically required. Though 1-hr ^{123}I images are inferior to 24-hr scintigrams (*4*), successful thyroid imaging at 4–6 hr after oral administration of ^{123}I is possible (*5,6*). In this study, we evaluated objective and subjective parameters of early (4-hr) thyroid imaging relative to 24-hr imaging. In addition, we also evaluated the clinical utility of early (4- or 5-hr) uptake measurements as a replacement for the 24-hr measurement, hoping to establish a standard ^{123}I thyroid examination that could be completed in a single patient visit and within the usual workshift of the nuclear medicine laboratory.

MATERIALS AND METHODS

This study was carried out at a 1,000-bed (Institution A) and 300-bed (Institution B) medical center. Each center is a tertiary referral facility serving a diverse population. Because of a sex predilection for thyroid disease, the majority of patients in the study were females but the study population includes both sexes and individuals from 6 mo to 87 yr of age.

Received Dec. 27, 1984; revision accepted Apr. 16, 1985.

For reprints contact: John L. Floyd, MD, Nuclear Medicine Service, Department of Radiology (SGHR), David Grant USAF Medical Center, Travis AFB, CA 94535.

Thyroid imaging

All imaging studies were carried out at Institution A. Ten-minute images were obtained on 50 consecutive patients 4 and 24 hr after the oral administration of 200–300 μCi ^{123}I using a standard-field camera with integrated digital data processing and a pinhole collimator. A 128 × 128 matrix was utilized for acquisition, analysis, and image display. Total counts and pixel-weighted thyroid/background count ratios were determined for each 10-min image. Images were transferred to transparency film for permanent storage and subsequent interpretation. Paired 4/24-hr images were evaluated by three board-certified nuclear medicine physicians for discrepancy relative to radionuclide distribution and number and distribution of "hot" or "cold" defects.

Uptake measurements

Radioiodine uptake measurements (%RAIU) at both centers were carried out using a collimated scintillation detector with a 3-in. NaI crystal and a Picker Plexiglas neck phantom. For the 4-hr measurements, a second dosage capsule was counted at each uptake interval and used for decay correction. The 5-hr uptakes were derived by mathematically decaying the dosing capsule.

Uptake measurements on 55 consecutive patients from Institution A were obtained at 4 and 24 hr. Depending on laboratory data, clinical findings, and followup data, these patients were given the following diagnoses: (a) normal/euthyroid—34; (b) Graves' disease—9; (c) toxic nodule—2; (d) multinodular toxic goiter—1; (e) primary hypothyroidism—7; and (f) subacute thyroiditis—2.

Uptake measurements on 191 consecutive patients referred for thyroid evaluation at Institution B were performed at 5 and 24 hr. By similar criteria, these patients were given the following diagnoses: (a) normal/euthyroid—108; (b) Graves' disease—58; (c) toxic nodule—3; (d) toxic multinodular goiter—3; (e) primary hypothyroidism—13; (f) subacute thyroiditis—3; and (g) "thyrotoxicosis with low uptake"—3.

RESULTS

Imaging

The 4-hr images were consistently constructed of more total counts than the 24-hr images; 80.9k +/− 58k compared with 39.1k +/− 24k. Though background activity was higher on the 4-hr images (average 2.2% at 4 hr as opposed to 0.5% at 24 hr), it was so small at either interval as to be a subjectively imperceptible difference. The subjective review of paired images agreed with previously reported comparisons of 6- and 24-hr ^{123}I imaging; i.e. there was no discrepancy in radioiodine distribution between 4 and 24 hr in any patient. Examples of 4- and 24-hr paired images are provided in Fig. 1.

Uptake measurements

Comparative early and late percent uptake values are summarized in Table 1. Analysis of this data and review of the individual cases indicate:

a. The average, range, and estimated standard deviation of %RAIU at 4 or 5 hr in euthyroid patients demonstrate a close grouping that is well delineated from the hyperthyroid population with no overlap.

b. Though the average %RAIU at 24 hr in hyperthyroid patients is well above that for normals, there was overlap with the euthyroid range (three patients).

c. Seven of 76 hyperthyroid patients had a lower %RAIU at 24 hr relative to the early uptake; one of these fell to well within the "normal" range (54% at 4 hr to 25% at 24 hr).

d. The clinically hypothyroid patients all had %RAIUs of less than 2.3% in this series. However, it should be noted that TSH values were not available on many patients, and some of those with a normal RAIU might have had compensated early thyroid failure. Subacute thyroiditis patients also exhibited uptakes in the 0–3% range.

DISCUSSION

From the introduction of clinical studies with ^{131}I until the late 1960s, the accepted standard nuclear medicine examination consisted of a %RAIU and a rectilinear scan of the thyroid, both obtained at 24 hr postadministration of the radionuclide. The advantage of the higher percent of the administered dose concentrated within the thyroid the day after administration outweighed the small decrease in activity due to decay (8% in 24 hr). Also, it was reported that, in St. Louis, the %RAIU in hyper-, eu-, and hypothyroid patients were "not far apart at less than 8 hour" and were "greatest apart" at 24 hour (*7*). The introduction of [^{99m}Tc]pertechnetate allowed virtually immediate imaging, but its lack of physiologic identity to iodine has prevented its uniform adoption. In the 1970s, ^{123}I became widely available. Like pertechnetate, its decay characteristics were almost ideal for gamma camera imaging, and it had the added advantage of being a truly physiologic reflection of iodine metabolism and distribution within the body. Unlike ^{131}I, however, ^{123}I has a relatively short half-life of 13.3 hr, and the administered activity has diminished by 72% at 24 hr simply by decay. This more than offsets the increased percent accumulation of the dose by the thyroid at that time. The maximum thyroid counting rate by uptake probe or gamma camera should occur at about 6 hr following administration in a normal patient. A number of nuclear medicine laboratories now carry out imaging at this time interval, but they generally continue to obtain an uptake value at 24-hr.

We were unable to find a recently reported series of

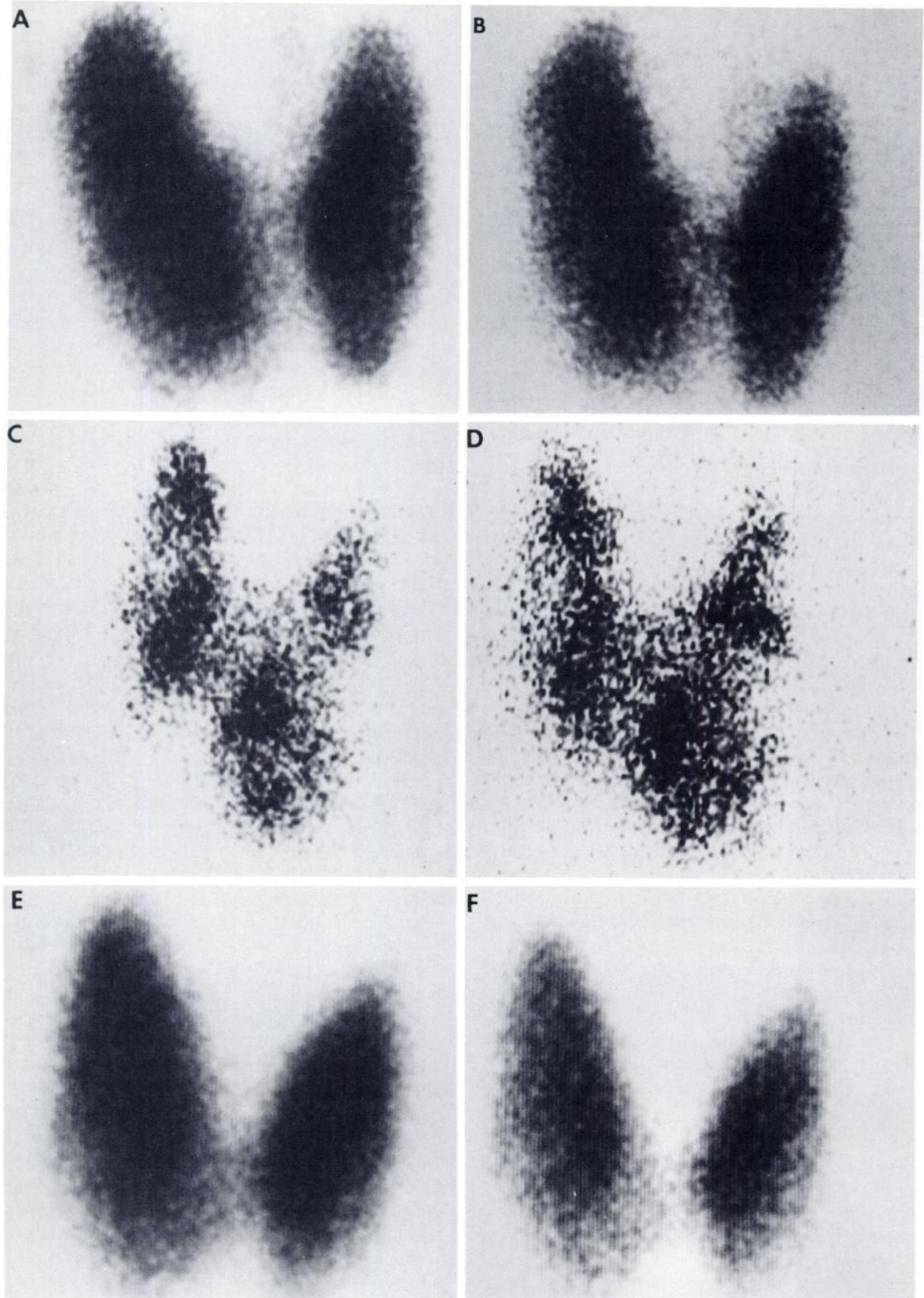

FIGURE 1
Representative pairs of thyroid scintigrams obtained 4 and 24 hr after administration of 200–300 μCi ^{123}I in three patients. A,B: Normal patient: 4-hr RAIU = 12%, 88k count image; 24-hr RAIU = 27%, 51k count image. C,D: Multinodular goiter: 4-hr RAIU = 7.8%, 66k count image; 24-hr RAIU = 23%, 44k count image. E,F: Graves' disease: 4-hr RAIU = 56%, 176k count image; 24-hr RAIU = 73%, 65k count image. There is no discrepancy in radioiodine distribution within paired images

TABLE 1
Comparison of 4- and 24-hr RAIU (% Uptake)

Time	Euthyroid (n = 142)	Hyperthyroid* (n = 76)	Hypothyroid (n = 20)
4-hr	8.7+/−3.4	64.1+/−18.4	0.85+/−0.3
	(4–16)	(38–90)	(0.6–1.8)
5-hr	10.6+/−3.3	51.5+/−21.6	1.3+/−0.4
	(4–18)	(22–93)	(0.2–1.8)
24-hr	21.3+/−7.9	73.2+/−11.5	0.88+/−0.5
	(9–52)	(25–93)	(0.1–2.2)

* Includes toxic nodules and toxic multinodular goiters.

patients in which the early %RAIU had been established in a broad range of normal and abnormal patients and related to the 24-hr %RAIU, and since "normal" uptake values have fallen over the past several decades, we felt it necessary to establish a normal "early" %RAIU prior to instituting a single-day thyroid imaging and uptake examination. Initiating the examination at 6 hr (the theoretical time of maximum count-rate from the thyroid in a normal person) requires about 7 hr of actual time from patient arrival to departure. Therefore we chose the shorter interval of 4–5 hr for imaging and uptake determinations to allow more flexibility in scheduling and completing the study within normal department working hours.

Our camera imaging results were similar to the 4- and 24-hr rectilinear scan comparison reported by Rosenthal, et. al. (*6*). We found the 4-hr images to be at least equal, if not superior in image quality, to the 24-hr study. In every case, there were substantially more net thyroid counts on the early image. Digital analysis did indicate a slightly higher background at 4 hr, but this was not subjectively detectable. The physicians evaluating the paired images found several early images to be more "pleasing" than the matching late image (presumably due to the greater count statistics), but in no case was there a discrepant distribution of radioiodine within the thyroid.

The 4-hr uptake measurement was initiated as part of the original protocol and continued throughout the study at Institution A. At Institution B, 5- and 24-hr uptake determinations were already being obtained on a routine basis when this study began; 104 patients from this population were retrospectively included and an additional 87 patients were prospectively added to the data base.

Our findings did not support earlier reports of increased overlap of normals and abnormals on early uptake measurements. Both series indicate adequate distinction between euthyroid and hyperthyroid populations by the early uptake value. The larger series actually indicates that significant overlap of these groups occurs only in the 24-hr uptake. Because of these observations, we have ceased obtaining the 24-hr uptake on a routine basis, reserving it for those patients who have an elevated 4- or 5-hr uptake and are likely candidates for therapeutic ablation with ^{131}I.

We have established an upper normal limit of 18% for the 4-hr uptake and 20% for the 5-hr uptake in our respective laboratories. Though there will be 3–4 hr of inactive time during the study, we have found most of our patients prefer this to a second trip to the hospital. An added benefit to the department is that, should a single nuclear medicine physician not be present in the department on two consecutive days for some reason such as a shared practice, a single physician will be able to initiate and complete the exam. In addition, a study may be initiated and completed on Friday without calling a physician and technician to the department on Saturday.

We believe that the diagnostic similarity in ^{123}I thyroid images obained at 4 and 24 hr in our study with gamma camera imaging confirms the findings of Rosenthal in rectilinear imaging. The %RAIU is not a primary diagnostic test for thyroid functional status, but 4-hr values have been found at least as useful as 24-hr values for diagnostic confirmation at our institutions. Iodine-131 therapeutic doses are traditionally based to some degree on the 24-hr %RAIU, therefore the 24-hr measurement is still obtained in patients with planned or potential radioiodine therapy. While not addressing the relative merits of [^{99m}Tc]pertechnetate as opposed to ^{123}I thyroid imaging, this information has allowed us to establish a 4/5 hr thyroid uptake and scintigram as the standard *radioiodine* thyroid examination in our departments.

REFERENCES

1. Wellman HN, Anger RT Jr: Radioiodine dosimetry and use of other radioiodines than I-131 in thyroid diagnosis. *Semin Nucl Med* 1:356, 1971
2. Atkins HL, Klopper JF, Lambrecht R, et al: A comparison of Tc-99m and I-123 in thyroid imaging. *AJR* 117:195, 1973
3. Goolden A, Glass H, Silvester D: The choice of a radioactive isotope for the investigation of thyroid disorders. *Br J Radiol* 41:20, 1968
4. Ryo UY, Vaidya PV, Schneider AB, et al: Thyroid imaging agents: A comparison of I-123 and Tc-99m pertechnetate. *Radiology* 148:819–822, 1983
5. Atkins HL: The thyroid. In *Freeman and Johnson's Clinical Radionuclide Imaging. 3rd ed.* Orlando, Grune and Stratton, 1984, p 1280
6. Rosenthal SL, Hofeldt FD, Verdon TA: Comparison of 4 and 24-hour thyroid scans with I-123. *J Nucl Med* 17:1050–1052, 1976
7. Brucer M: The calibration (and salvation) of thyroid uptake. In *Thyroid Radioiodine Clinical Testing.* St Louis, Mallinckrodt, Inc., 1973, p 26