COMPARISON OF ^{99m}Tc AND ^{123}I FOR THYROID IMAGING

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Thyroid images were obtained with ^{99m}Tc and ^{123}I, using a scintillation camera and pinhole collimator, from 85 patients selected from over 1,000 patients predisposed to the development of thyroid neoplasms by prior radiotherapy. In 66 of 85 patients ^{99m}Tc and ^{123}I gave essentially similar information, whereas in 19 patients some thyroid-image disparity was seen. In 11 of these 19, focal areas of increased ^{99m}Tc concentration were not seen with ^{123}I. Radioiodide images showed slightly better contrast than the ^{99m}Tc images but required a longer imaging time and usually did not provide more information; in a few cases ^{99m}Tc showed abnormalities more readily. Regardless of which radionuclide was used, oblique views were needed to define some abnormalities. Currently ^{123}I does not provide significant advantages over ^{99m}Tc for routine thyroid imaging. However, ^{123}I is preferred in patients with very poor thyroid function and in those with suspected retrosternal thyroid tissue. In addition, areas of increased ^{99m}Tc concentration should also be studied with ^{123}I.

Several radionuclides have been used to image the thyroid. Radioiodine ^{131}I and ^{125}I deliver a high radiation dose to the thyroid, and their photon energies are not optimal for imaging (Table 1). Since ^{123}I and ^{99m}Tc have much more suitable photon energies and deliver a smaller radiation dose to the thyroid, they are preferred to ^{131}I or ^{125}I. Pertechnetate is trapped but not organified by the thyroid (*1*) so that its tissue background is higher than with ^{123}I, which is both trapped and organified. Therefore, in theory ^{123}I should be preferable to ^{99m}Tc for thyroid imaging. However, adequate thyroid images can be obtained with pertechnetate (*2*), which is much less expensive and more readily available than ^{123}I in most nuclear medicine laboratories. Moreover, commercially available ^{123}I contains small amounts of other radioiodine isotopes which increase the radiation dose to the thyroid and emit high-energy photons that degrade the thyroid image (*3,4*).

The present study compares thyroid images obtained with ^{99m}Tc and ^{123}I in a group of patients specially selected to exhibit disparities between the images obtained with the two radionuclides.

METHODS

Michael Reese Medical Center is conducting a thyroid screening program for patients previously treated there with x-ray therapy for benign conditions of the head and neck (*5*). Such patients are predisposed to the subsequent development of benign and malignant thyroid tumors. Over 1,000 patients were examined clinically and thyroid scintigrams were obtained 20–30 min after 5 mCi of ^{99m}Tc-pertechnetate was administered intravenously. A Searle Radiographics HP scintillation camera and 5-mm pinhole collimator were used. Using a triple-lens Polaroid camera, 150,000 counts were imaged in 2–8 min. Most patients were either completely normal by this evaluation or had one or more readily detectable thyroid nodules. In some patients (about 10%) a repeat examination after 6 months was recommended either because an indefinite nodule was found by palpation or because a focal area of increased uptake, or an indefinite area of decreased uptake, was seen on the ^{99m}Tc image. At this repeat examination 85 of these patients again had their thyroids imaged with ^{99m}Tc; they were then given 250–400 μCi of ^{123}I (Medi-Physics, Emeryville, Calif.)

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TABLE 1. RADIONUCLIDES FOR THYROID IMAGING

Radionuclide	Half-life	Photon energy, keV (% abundance)	Dose	Radiation dose to adult (rads)*	
				Thyroid	Whole body
^{131}I	8.1 days	364 (82%) 637 (7%) 723 (1.7%)	50 μCi (oral)	75	0.22
^{125}I	60 days	35 (7%) ~28 (139%)	50 μCi (oral)	52	0.17
^{123}I	13 hr	159 (83%) 529 (1%)	200 μCi (oral)	3†	0.006
^{99m}Tc	6 hr	140 (88%)	5 mCi (intravenous)	1	0.06

* From Webster EW, Alpert NM, and Brownell GL, 1974 (Ref. 19).
† Impurities (^{124}I, ^{126}I, ^{130}I, ^{131}I), if present, will increase the radiation dose.

orally and asked to return 16–19 hr later for an ^{123}I thyroid scintigram. This was also obtained with the scintillation camera and 5-mm pinhole collimator. From 40,000 to 80,000 counts were imaged with a triple-lens Polaroid camera; this usually required 5–15 min.

If an indefinite area of abnormality was seen on the anterior image, or if a palpable abnormality was not visualized, oblique views of the area in question were obtained (*6*).

RESULTS

The 85 specially selected patients who had both ^{99m}Tc and ^{123}I thyroid scintigrams are the subject of this report. In 66 of the 85 patients (78%), the ^{99m}Tc and ^{123}I images were similar (Table 2). In 42 of these patients both thyroid images were considered normal, although in one a thyroid abnormality was palpable by two observers (Fig. 1A). In 21 patients discrete areas of decreased uptake were seen (Fig. 1B and 1C), and in three patients discrete areas of increased uptake were seen with both radionuclides.

TABLE 2. PATIENTS WITH SIMILAR ^{99m}Tc AND ^{123}I THYROID IMAGES

Thyroid image	Number of patients
Normal	42
Discrete area(s) of decreased uptake	21
Discrete area of increased uptake	3
Total	66

Nineteen patients showed some difference between the ^{99m}Tc and ^{123}I thyroid images (Table 3). Eleven of the 19 patients had a localized area of increased ^{99m}Tc but apparently normal ^{123}I uptake (Fig. 2), unchanged in appearance since the ^{99m}Tc study 5–9 months previously. Four patients had areas of decreased uptake more obvious with ^{99m}Tc than ^{123}I on the anterior images (Fig. 3); another had an area of decreased ^{123}I uptake and a normal anterior ^{99m}Tc image (Fig. 4A); another showed an area that concentrated ^{123}I but not ^{99m}Tc in addition to several areas of decreased uptake with both radionuclides (Fig. 4B). Two patients had such poor uptake that the ^{99m}Tc image was too indefinite to be of any value; the ^{123}I image, however, was much clearer. Both these patients had recently been taking thyroid hormone (Fig. 4C).

DISCUSSION

Several studies have suggested that the scintillation camera is preferable to the rectilinear scanner for thyroid imaging with ^{123}I, ^{131}I, and ^{99m}Tc-pertechnetate (*3,7,8*). The scintillation camera cannot be used to image ^{125}I because the photon energies are too low. Hurley et al (*8*) compared the scintillation camera with a rectilinear scanner having an 8-in.-diam crystal. A 3-in.-diam crystal might provide better resolution because of the longer depth of focus of the collimator but it is doubtful that a rectilinear scanner with a 3-in.-diam crystal would provide better thyroid images than a scintillation camera.

The high-energy photons from ^{123}I and its impurities can cause more loss of image resolution in a rectilinear scanning system than in a scintillation camera with pinhole collimator (*3,4*). The high-energy photons are less able to penetrate the thick walls of the pinhole collimator than the thin septa of a focused collimator. Moreover, they are less likely to interact with the thin (0.5 in.) crystal of the camera than with the 2-in.-thick crystal of the scanner.

In the present study the scintillation camera and pinhole collimator were used, and these currently provide optimal instrumentation for thyroid imaging with radionuclides. The method of selection of patients for this study excluded patients with abnormalities readily detectable by palpation or radionuclide imaging. Any difference between the ^{123}I and ^{99m}Tc thyroid images was expected to be more readily apparent in the study group than in an unselected group of patients.

Oblique views usually confirmed or excluded the presence of an abnormality in questionable areas seen on the anterior view. Oblique views were also

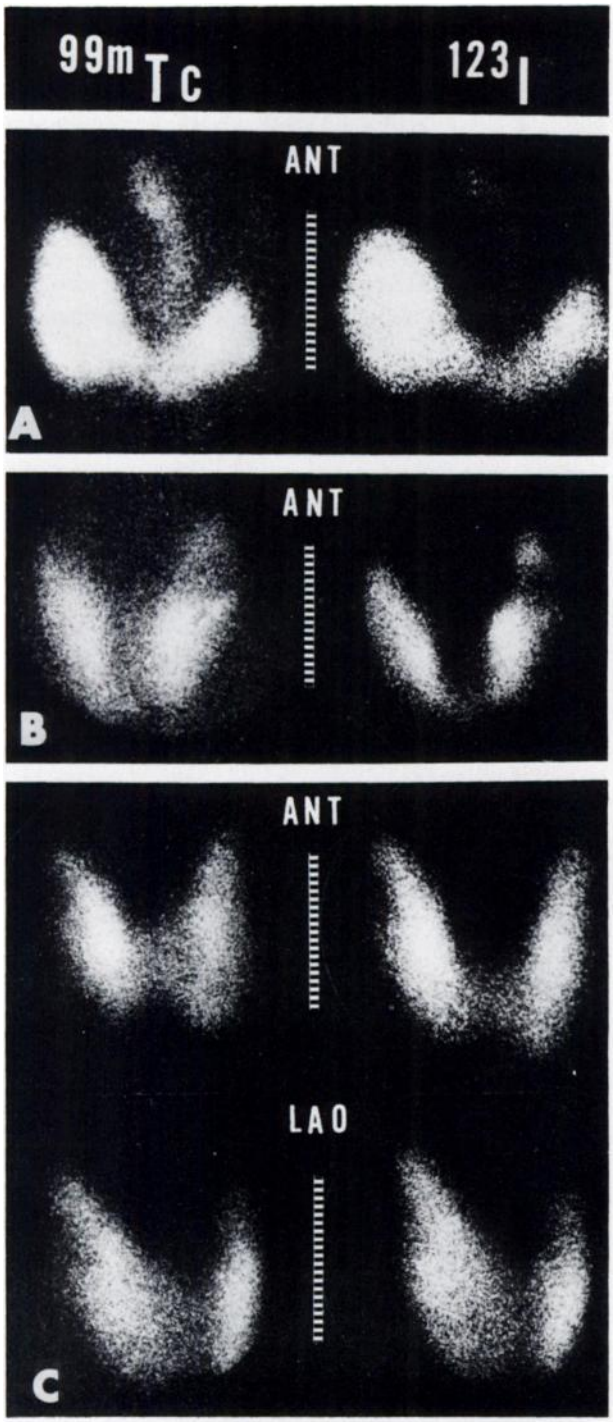

FIG. 1. Equally informative ^{99m}Tc and ^{123}I thyroid images: (A) Palpation showed abnormally firm enlarged right lobe and firm 1-cm-diam nodule to right of pyramidal lobe. Although thyroid images could be considered normal, surgical specimen showed lower two-thirds of both lobes to be replaced by papillary–follicular thyroid carcinoma. Palpable nodule above isthmus was lymph node replaced by metastatic carcinoma, which also involved five nodes in left side of neck. (B) No thyroid abnormality palpable. Area of decreased uptake in left upper pole represents 11-mm-diam papillary carcinoma, surgically proven. Although ^{123}I shows lesion more clearly, it provides no additional information. (C) No thyroid abnormality palpable. Both images show equally well area of decreased uptake below right upper pole, confirmed by RAO view and found to be 10-mm follicular adenoma immediately adjacent to 4-mm carcinoma. Small multicentric foci of carcinoma were also present throughout both lobes.

necessary to evaluate the functional status of areas that were abnormal to palpation but were not defined on the anterior view alone. The ability to perform oblique views easily is another advantage of the scintillation camera over the rectilinear scanner.

In the majority of patients ^{123}I provided no advantage over pertechnetate for thyroid imaging. The ^{99m}Tc study was unsatisfactory in two patients in whom recently administered thyroid hormone had depressed the thyroid uptake. In these two patients the ^{123}I image was acceptable because at 18 hr after dosing the body background had decreased to such an extent that it did not obscure visualization of the small amount of radioiodide concentrated by the thyroid. Equivalent ^{99m}Tc images were later obtained 6 weeks after cessation of hormone treatment. One other patient in the present series had an essentially normal anterior thyroid image with ^{99m}Tc, whereas the anterior ^{123}I image suggested an area of decreased uptake in the lower portion of the left lobe. This cold area, which was due to a 12-mm-diam mixed papillary–follicular carcinoma, was well shown in the left anterior oblique view with both ^{99m}Tc and ^{123}I (Fig. 4A). Since there was a questionable palpable abnormality at the left lower pole, an oblique view was indicated despite the apparently normal anterior ^{99m}Tc image. The cases in which ^{123}I was superior to ^{99m}Tc are partly offset by several cases in which the anterior ^{99m}Tc image was more clearly abnormal than the ^{123}I image (Fig. 3). However, these were all due to benign lesions.

A marked disparity between ^{99m}Tc and ^{123}I images was often seen when the ^{99m}Tc image showed a focal area of relatively increased concentration; often the ^{123}I image did not show a similar focus of increased activity (Fig. 2). This disparity is presum-

TABLE 3. THYROID IMAGE DISCREPANCY WITH ^{99m}Tc AND ^{123}I

Thyroid image	Number of patients
Focal area of increased ^{99m}Tc uptake not seen with ^{123}I	11
Focal area of decreased uptake more obvious with ^{99m}Tc than ^{123}I	4*
Area of decreased uptake more obvious with ^{123}I than ^{99m}Tc	1†
Area of ^{123}I concentration not seen with ^{99m}Tc	1
Insufficient ^{99m}Tc uptake for a clear image	2
Total	19

* In two of the four cases, the area of decreased uptake was detectable in an oblique ^{123}I image.

† Area of decreased uptake was visible in oblique but not in anterior ^{99m}Tc image.

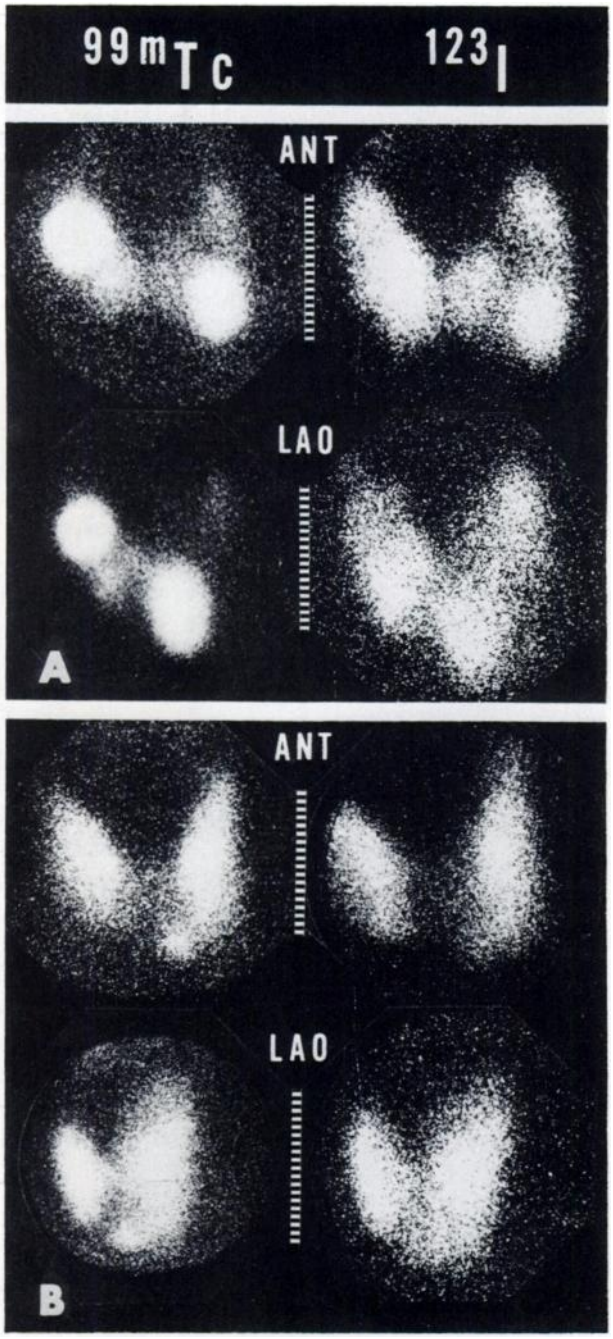

FIG. 2. Focal areas of increased ^{99m}Tc concentration not shown with ^{123}I. (No surgical specimens available.) (A) Areas of increased ^{99m}Tc concentration at left lower pole and right upper pole are not seen with ^{123}I. Area of decreased uptake in middle left lobe is shown with both nuclides. (B) Focal area of slightly increased ^{99m}Tc concentration in left lower pole anteriorly is not shown with ^{123}I. This case was the smallest focus of increased ^{99m}Tc concentration not shown with ^{123}I in present series.

ably due to focal areas which show good trapping function and hence ^{99m}Tc concentration but decreased organification and therefore decreased radioiodide concentration. That the ^{99m}Tc concentration is increased above normal could be due to a focal increase in the ratio of the total volume of functioning cells (with normal trapping function) to the volume of nonfunctioning tissue (connective tissue and follicle contents), to some functioning cells showing an absolute increase in trapping function, or to a combination of these.

The high incidence of disparity between ^{99m}Tc and ^{123}I in the present series may be due to the patient population: a highly selected subgroup of a group of previously irradiated patients. Occasional disparity between ^{99m}Tc and radioiodide thyroid images has been reported previously (*9–14*) but it is not common: it was found in only 13 of 578 combined studies taken from the literature (Table 4). In all but one of these the disparity consisted of a focal area of increased ^{99m}Tc concentration that appeared normal or cold with radioiodide. A similar finding accounted for most cases of disparity in the present series. Hence we confirm previous recommendations that nodules showing increased ^{99m}Tc concentration be reimaged with radioiodide. Such a combined study is not required frequently; only 66 of 1,000 patients had a nodule that showed increased uptake when imaged with ^{99m}Tc (*2*). We have been unable to evaluate the pathologic significance of the cases showing focal areas of increased ^{99m}Tc but not radioiodide concentration, but other workers have indicated that such disparity can be due to both benign and malignant lesions (*9,11,13*).

The disparity seen in Fig. 4B, where focal areas of relatively normal ^{123}I concentration show decreased ^{99m}Tc concentration, is very unusual. This case presumably involves areas which, relative to the remainder of the thyroid, show decreased trapping function but normal or even increased organification. Although Hashimoto's thyroiditis was found at operation, the disparity in this case is the reverse of that previously described in patients with Hashimoto's thyroiditis (*15*) and in a case of subacute thyroiditis (*13*). In those subjects the thyroidal trapping function was apparently less affected than organification since pertechnetate uptake was higher than radioiodide uptake.

Atkins et al (*12*) found ^{123}I preferable to ^{99m}Tc-pertechnetate for thyroid imaging with the scintillation camera and pinhole collimator. Their study differed from the present one in the following respects, which could account for the different findings:

1. Only 50,000 to 100,000 counts were collected on their ^{99m}Tc images, and they "usually obtained the same number of total counts with iodide-123 as with technetium-99m when possible, but in a number of instances this was not feasible." While this number of counts is often adequate, we prefer to collect 150,000 counts on the ^{99m}Tc images; this can be done in a reasonable time and, we feel, often

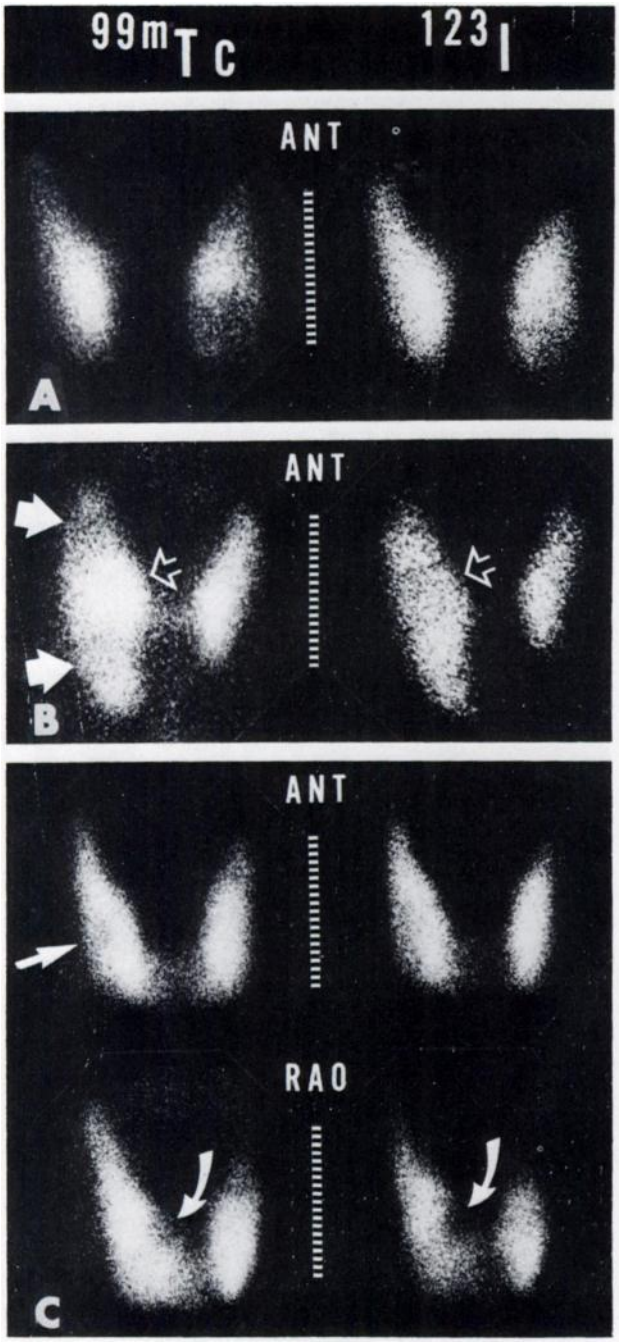

FIG. 3. Areas of decreased uptake seen best with ^{99m}Tc on anterior view. (A) Abnormal area of decreased uptake in left lower pole, due to 10-mm-diam follicular adenoma, is much less obvious with ^{123}I than with ^{99m}Tc. (B) Abnormal areas of decreased uptake adjacent to right upper and lower poles (solid arrows) are seen with ^{99m}Tc but not with ^{123}I. Midportion of right lobe shows increased ^{99m}Tc but slightly decreased ^{123}I concentration (open arrow). RAO views showed similar findings. At surgery three benign adenomatous nodules were found in right lobe, and both lobes showed changes of chronic lymphocytic thyroiditis. (C) Small area of decreased uptake in midportion of right lobe is shown only with ^{99m}Tc in anterior view (straight arrow), although shown by both radionuclides in RAO view (curved arrow). Palpation findings normal. At surgery 10-mm follicular adenoma was found.

gives a clearer image. We found it impractical to collect more than 80,000 counts for the ^{123}I image because of the excessive time this would require. For equal information density from the thyroid, Atkins et al indicated that about twice as many total counts must be accumulated with ^{99m}Tc as with ^{123}I.

2. We obtained oblique or close-up views of those areas of the thyroid that were suspected of abnormality on the standard anterior view. These often made the ^{99m}Tc study diagnostic when the anterior view alone might not have been. In such cases the slightly better image definition with ^{123}I did not provide increased diagnostic information. Usually anterior and oblique ^{99m}Tc images could be obtained in the time required for a single anterior ^{123}I image.

3. Our series did not include any cases with retrosternal extension of thyroid tissue. Radioiodide ^{123}I or ^{131}I will show poorly functioning thyroid tissue in the mediastinum more clearly than ^{99m}Tc. Not only is thyroid ^{99m}Tc uptake much less than that of radioiodide, but the adjacent blood-pool activity is much greater for ^{99m}Tc. The lower energy of ^{99m}Tc photons is an additional slight disadvantage. Hence, radioiodide is definitely to be preferred to ^{99m}Tc for delineation of substernal thyroid tissue (*2,14,16*).

For the detection of functioning thyroid metastases, imaging with ^{131}I 72 hr after dosing is more reliable than images obtained earlier (*17*). The short half-life of ^{123}I precludes its use for this purpose. Visualization of thyroid metastases can sometimes be obtained with ^{99m}Tc (*13,18*), but since these patients are usually being studied to assess their suitability for radioiodide ablative therapy, assessment with ^{131}I is to be preferred.

In most cases ^{99m}Tc and ^{123}I give thyroid images with similar diagnostic information. Therefore, despite the theoretic advantages of ^{123}I, we currently prefer pertechnetate to ^{123}I for routine thyroid imaging for the following reasons:

1. Technetium-99m is much more readily available than ^{123}I.
2. A thyroid image can be obtained in a shorter time with ^{99m}Tc than with ^{123}I, unless the dose of ^{123}I is increased well above that currently employed.
3. The imaging procedure can begin only 20–30 min after the dose of ^{99m}Tc, whereas a less convenient 4–24 hr must elapse for a ^{123}I study.
4. Technetium-99m is currently much less expensive than ^{123}I.

Radiation dose is not a deciding factor, for, although the radiation dose to the thyroid is less with ^{99m}Tc, the whole-body radiation dose is greater than with ^{123}I (Table 1).

The occasional disparity between thyroid uptake of pertechnetate and radioiodide may prove to be

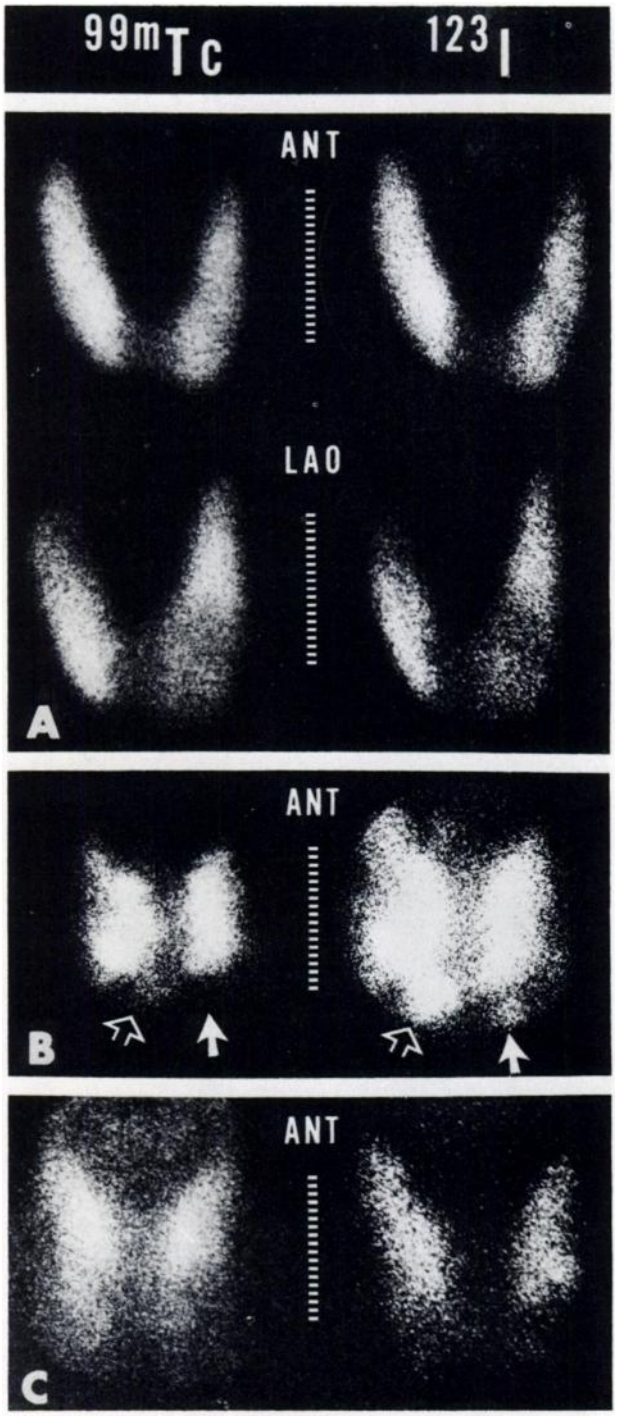

FIG. 4. Disparate ^{99m}Tc and ^{123}I thyroid images. (A) Cold area in left lower pole on anterior ^{123}I image is barely seen on anterior ^{99m}Tc image, but well seen on LAO view with both radionuclides. (B) Left lower pole shows area of apparently normal ^{123}I concentration (solid arrow) but absent ^{99m}Tc concentration. Right lower pole shows greater ^{123}I than ^{99m}Tc concentration (open arrows). Several areas of decreased uptake throughout both lobes are shown with both nuclides. Thyroid felt abnormally firm and enlarged. At operation diffuse lymphocytic thyroiditis was found bilaterally. (C) Ill-defined ^{99m}Tc image because of poor concentration. Iodide image shows abnormal foci of decreased uptake at both lower poles. Repeat ^{99m}Tc image after patient had ceased thyroid medication also showed cold areas at both lower poles. At operation lower portions of both lobes contained colloid and adenomatous nodules; also microscopic focus of occult sclerosing carcinoma was present in right lobe.

TABLE 4. INCIDENCE OF DISPARATE PERTECHNETATE AND RADIOIODINE THYROID IMAGES IN PUBLISHED SERIES

Author	Total No.	No. disparate
Sanders et al, 1968	98	0
Strauss et al, 1970	56	2*
dos Remedios et al, 1973	54	0
Atkins et al, 1973	100	3*
Shambaugh et al, 1974	204	7*
Marion et al, 1974	75	1†
Total	587	13

* All showed focal area of greater ^{99m}Tc than radioiodine concentration.

† Showed focal area of decreased technetium but not radioiodide concentration.

important in some situations in which imaging with both nuclides gives more information than that obtained with either alone. For example, in Fig. 2A the right upper pole (with no palpable abnormality) appears within normal limits on the ^{123}I image alone, whereas the ^{99m}Tc image shows a focus of increased uptake, indicating that thyroid tissue at the right upper pole differs from the remainder of the right lobe and is presumably abnormal. In turn, the ^{123}I image gives the additional information that this tissue at the right upper pole did not concentrate radioiodide; malignancy should therefore be considered, as in any thyroid lesion that appears "cold" on a radioiodine image. Pertechnetate appears to be the imaging agent of first choice to detect abnormalities similar to the foregoing example, which could have been missed by radioiodide alone, but the latter does give useful additional information in turn.

CONCLUSIONS

Pertechnetate and ^{123}I give similar thyroid-image information in most patients. We currently prefer ^{99m}Tc because it is more convenient and less expensive than ^{123}I. Radioiodide thyroid imaging, however, is preferred to ^{99m}Tc in such instances as the investigation of patients with possible retrosternal thyroid tissue or with unsatisfactory ^{99m}Tc images due to poor radionuclide concentration. If a palpable nodule shows apparently normal or increased ^{99m}Tc concentration on anterior and oblique views, an additional study with radioiodide is necessary, since occasionally such nodules will show decreased radioiodide concentration. For these circumstances ^{123}I is the preferred iodine isotope. For the study of possibly functioning thyroid metastases ^{131}I remains the nuclide of choice.

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