THYROID SCINTIPHOTOGRAPHY IN 1,000 PATIENTS: RATIONAL USE OF ^{99m}Tc AND ^{131}I COMPOUNDS

Leo V. dos Remedios, Paul M. Weber, and Ivan A. Jasko

The Permanente Medical Group, Kaiser Foundation Hospital, Oakland, California

Thyroid imaging was at first restricted to rectilinear dot scanning with ^{131}I as the imaging agent. In 1962 Harper et al (*1*) proposed ^{99m}Tc as a better scintigraphic agent than ^{131}I, and it has been widely used for this purpose (*2–8*). In 1968 Haas et al (*6*) reported the superiority of ^{99m}Tc in 2,000 patients and in 1970 Wagner's group (*8*) compared ^{99m}Tc with ^{131}I and clearly showed ^{99m}Tc to be better for rectilinear thyroid scanning. However, scanners produce a static, fragmented linear image. In 1963 Anger (*9,10*) described the gamma scintillation camera which produces images dynamically as a continuous, integrated whole. It was successfully used with ^{131}I for thyroid imaging (*11,12*) and found superior when compared with ^{131}I scanning (*13*). In 1970 ^{99m}Tc thyroid scintiphotography was reported to be better than both ^{99m}Tc and ^{131}I thyroid scanning (*14*). However, that abstract suggested that thyroid scintiphotography with the pinhole collimator was too insensitive for use with ^{131}I (*14*).

We wish to show, on the basis of our experience with the Anger Pho/Gamma III camera, (A) how to obtain optimal scintiphotos (Figs. 1, 2), (B) that for *routine* thyroid imaging, ^{99m}Tc is preferable to ^{131}I, (C) but that in special cases ^{131}I must be used to obtain interpretable scintiphotos, and (D) that this practice significantly decreases radiation exposure.

SUBJECTS

From February 1968 to February 1970, 1,000 consecutive patients referred for routine thyroid imaging were studied with ^{99m}Tc. Fifty-four selected thyroids were reimaged with ^{131}I in a comparative study (*15*). Twenty-five additional patients were reimaged with ^{131}I when the ^{99m}Tc scintiphoto was not interpretable. Except for illustrative purposes, patients with known thyroid carcinoma were usually studied with ^{131}I only and are excluded from Table 1.

PROCEDURE

The 24-hr ^{131}I thyroid uptake was measured. Some patients whose uptakes were suppressed below 3% by iodides or thyroid were asked to discontinue the drug and return in 2 weeks for ^{99m}Tc imaging.

From 1 to 3 mCi of ^{99m}Tc as sodium pertechnetate were injected intravenously. Twenty to 30 min later the thyroid was positioned below the 5-mm pinhole collimator so that its image filled the field of the cathode-ray tube display of the Anger camera. With the three lenses of the Polaroid recording camera at f/8, f/11, and f/16, the 3000 ASA film was

Received March 10, 1970; revision accepted April 18, 1971.

For reprints contact: L. V. dos Remedios, Kaiser Foundation Hospital, 280 W. MacArthur Blvd., Oakland, California 94611.

TABLE 1. QUALITY OF ^{99m}Tc THYROID IMAGE ACCORDING TO DIAGNOSIS

Image diagnosis	Image quality: Not diagnostic	Image quality: Diagnostic	Total
"Normal" thyroid (including thyroiditis)	11 (8)*	270 (5)	281
Solitary "cold" nodule	12 (9)	195 (9)	207
Multinodular goiter	22 (17)	159 (10)	181
Diffuse toxic goiter	0	97	97
Diffuse nontoxic goiter	3 (3)	69	72
Solitary "hot" nodule	5 (5)	61 (10)	66
Postoperative remnants (excluding thyroid carcinoma)	3 (3)	62	65
Toxic nodular goiter	0	31	31
Totals	56 (45)	944 (34)	1000

* In parentheses are the numbers of thyroids in each category which were reimaged with ^{131}I.

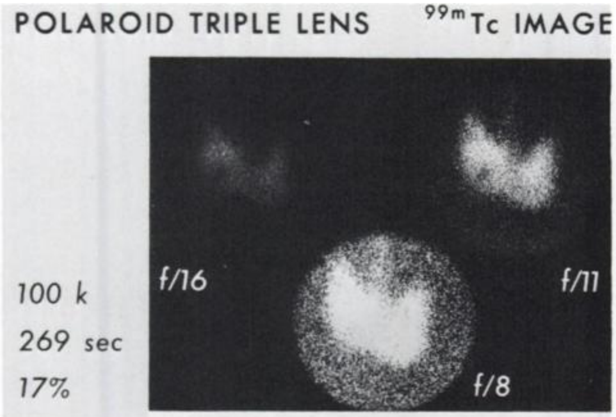

FIG. 1. Optimized scintiphoto: large thyroid image, 100K fine dots; f/11 image is made best. But triple image is always needed: pyramidal lobe, area of low activity, is well defined in f/8 overexposed image, whereas 3-mm "cold" nodule is obscured by encompassing high activity area and is best visualized in f/16 image.

exposed to obtain 100,000 high-resolution dots with the dot intensity adjusted to make the f/11 image optimal (Figs. 1 and 2A). This procedure usually took 1–6 min. Then to measure thyroid size, a sealed micropipette 30 mm long, containing about 0.5 μCi of $H_2{}^{75}SeO_3$, was taped along the thyroid without moving the patient and imaged at high intensity for 60 sec with the window set for the 260-keV gamma ray (Fig. 2B). If a thyroid nodule had been palpated, its exact location relative to the thyroid image was recorded by a 5-μCi ^{75}Se "wand" point source (Fig. 2C). When a "cold" nodule was suspected but not located, oblique views occasionally revealed its indentation on active tissue (Fig. 3). When the ^{99m}Tc image was of poor quality, 50–100 μCi of Na^{131}I, depending on the uptake, was given orally, and the thyroid was reimaged the next day (Figs. 4A′–D′ and 5A′–D′).

RESULTS

In 944 of the 1,000 patients, the ^{99m}Tc image (Figs. 1–3; 4A–D) was interpretable (Table 1). Early in the study, patients whose ^{131}I uptakes were suppressed below 3% by iodides or exogenous thyroid were nevertheless imaged, often with poor results. When the drug was stopped, 20 of 30 such patients had interpretable repeat ^{99m}Tc scintiphotos and were reassigned to the "diagnostic" category. Later, we preferred to stop these drugs if possible before imaging with ^{99m}Tc. However, an ^{131}I uptake below 10%, whether drug-suppressed or not, should not necessarily disqualify ^{99m}Tc (*8*) since 114 of 152 such patients in our series were successfully imaged (Fig. 4D).

Fifty-six of the 1,000 patients had scintiphotos that could not be made interpretable with ^{99m}Tc (Figs. 5A–D). Twenty-two of 181 multinodular goiters (Figs. 4B, 4D, 5A, 5B), some with normal ^{131}I uptakes, gave poor images (Figs. 5A, 5B). Some goiters were difficult to interpret because they were very large and/or irregular (Fig. 5A) or substernal (Fig. 5B). Of 207 scintiphotos of solitary "cold" nodules (Figs. 1–3), even though the thyroid itself was often visualized, 12 were deemed poor because reimaging with ^{131}I was required to delineate the hypoactive nodule more precisely. Reimaging with ^{131}I was also attempted in some patients with persistently poor ^{99m}Tc scintiphotos due to iodinated radiographic contrast media, thyroiditis, or after thyroidectomy.

An area in the thyroid parenchyma that appeared "hot", "cold", or normally active when imageable with ^{99m}Tc was always concordant with the corresponding area in each of the thyroids reimaged with ^{131}I (Figs. 4A–D and 4A′–D′). Therefore only 15 of 66 thyroids with a ^{99m}Tc "hot" nodule (Figs. 4C) were reimaged with ^{131}I (Fig. 4C′), whereas all probably should have been restudied with ^{131}I (*8,16*).

With only 35,000 dots (Figs. 4B′ and 4C′), 90% of the ^{131}I repeat images done when ^{99m}Tc failed were "diagnostic". By accumulating more dots over a long period, nearly all eventually became interpretable (Figs. 4A′, 4D′; 5A′–D′). The exceptions were from two patients with thyroiditis in whom the unsuppressed ^{131}I uptake was zero.

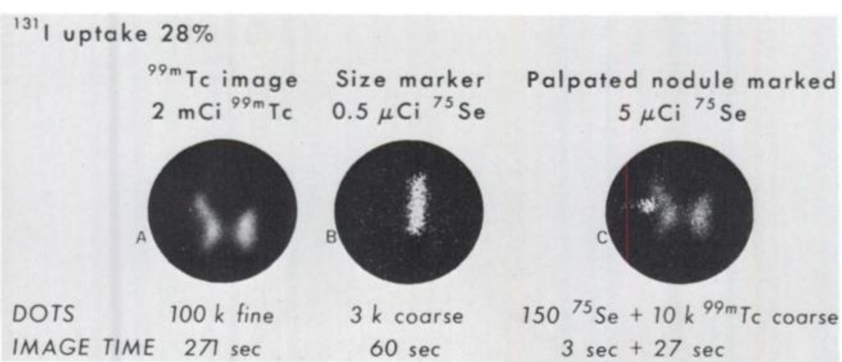

FIG. 2. 10 × 15 mm "cold" nodule proved to be 10 × 10 × 15-mm nodule of papillary carcinoma in right lobe of thyroid. Left lobe was normal. A, B, and C were imaged sequentially without moving patient.

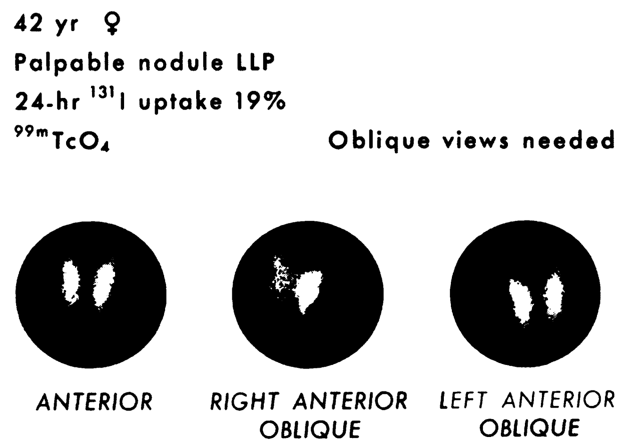

FIG. 3. "Cold" nodule is obscured by activity of underlying left lower lobe in anterior and left anterior oblique views. In right anterior oblique view its indentation is visible. Properly registered, RAO and LAO paired images may be viewed stereoscopically for a three-dimensional image.

DISCUSSION

Radiation dose. A 15-gm thyroid with a 24-hr ^{131}I uptake of 30% receives a calculated 210 rads from 100 μCi of ^{131}I given orally (*17*) and about 0.81 rad from 3 mCi of ^{99m}Tc given intravenously (*18*). The whole-body dose is about the same from either: approximately 0.040 rad (*18,19*). Small children receive a much higher thyroid dose in rad/μCi from ^{131}I (*17,19*). Since a 200-fold reduction in thyroid radiation is desirable in a routine procedure, ^{99m}Tc is preferable to ^{131}I for *routine* thyroid scintiphotography in adults, and mandatory in infants. However, when ^{131}I thyroid imaging is performed only when ^{99m}Tc imaging has failed, frequently not much of the ^{131}I is organified and/or the concentration in a large thyroid is low so that the ^{131}I radiation exposure may be 10 times less than in normal thyroids: for example, in a 15-gm thyroid with 3% ^{131}I uptake, or a 150-gm goiter with 30% uptake (*20*).

Duration of imaging procedure. Good thyroid ^{99m}Tc scintiphotos should contain 100,000 fine dots and a large thyroid image. These are usually produced in 1–6 min (Figs. 1, 2, 4A–D, 5A). Using a fairly large amount of ^{131}I (50–100 μCi), images as good as those made by ^{99m}Tc can be obtained after 24 hr with fewer but coarser, more intense dots (35,000–50,000) in 5–12 min (Figs. 4B′–D′). Therefore the routine use of ^{99m}Tc instead of ^{131}I saves time for patient and laboratory by halving both the number of visits and the imaging time.

Thyroid/neck background (T/N-B) ratio. The poor ^{99m}Tc T/N-B ratio of 1.2:1–4:1 (*15*) is due to both a normal ^{99m}Tc thyroid uptake of only 1–5% (*21*) and early imaging (after 30 min) before much free pertechnetate ion can be excreted (*22,23*). The poor ^{99m}Tc T/N-B ratio is offset by the high ^{99m}Tc gamma flux (*24*) and energy (140 keV), favorable for detection by the NaI(Tl) crystal (*25*) and collimation by the pinhole (*24*) of the Anger camera.

Because of the favorable ^{131}I T/N-B ratio (usually 4:1–50:1 after 24 hr) which offsets the low ^{131}I gamma flux, thyroid images with fewer, coarser, brighter dots can be of good quality (Figs. 4A′–D′ and 5A′–D′). Despite limiting the use of ^{131}I to ^{99m}Tc imaging failures, 90% of our ^{131}I images were "diagnostic" with only 35,000 dots (Figs. 4B′ and 4C′). By accumulating more dots for a longer period (Figs. 4A′, 4D′ and 5A′–D′), nearly all eventually became interpretable. These excellent results with ^{131}I in thyroids difficult to image are contrary to many reports (*6,8,14,21*).

Scintiphotos with ^{99m}Tc have typically a thyroid image of high resolution but with low contrast in a high activity background, whereas ^{131}I images are less well resolved but with high contrast in a low activity background.

Only ^{131}I should be selected for the postoperative management of thyroid carcinoma with or without metastasis. A large radiation dose is tolerable, so greater amounts of ^{131}I (up to 2 mCi) may be ad-

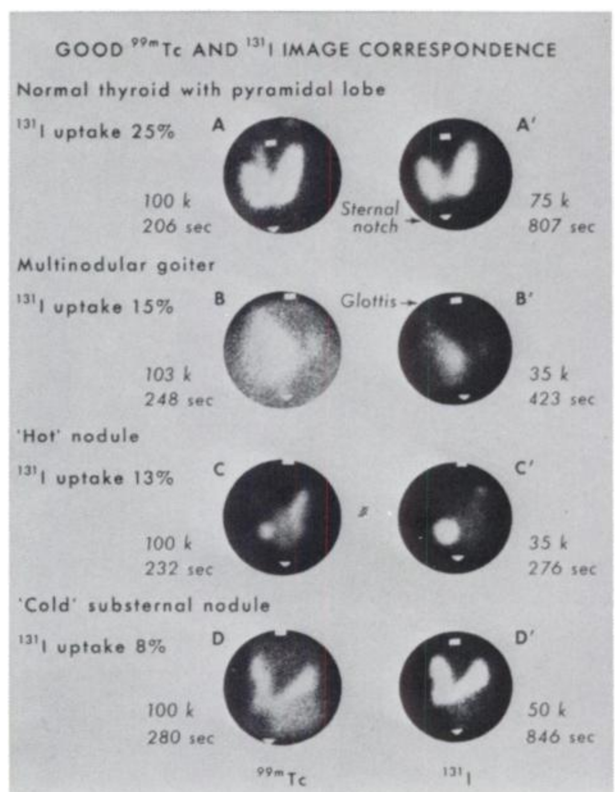

FIG. 4. A′ had 50 μCi; B′, C′, and D′ had 100 μCi ^{131}I. B had fetal adenoma removed from left lobe in 1957. Right lobe measures 45 × 55 mm. C had tracheostomy in 1962. "Hot" nodule is autonomous and does not suppress with thyroxine. In D left lobe measures 35 × 55 mm. Note that most of ^{131}I image times are much longer than those for ^{99m}Tc. Original triple images reveal much more detail than can be reproduced in single image (cf. Fig. 1).

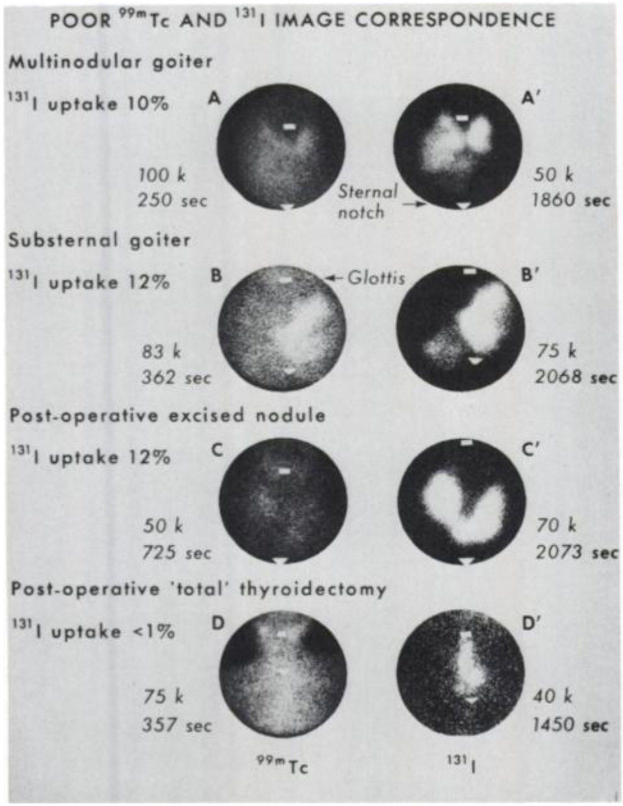

FIG. 5. A′ had 50 μCi, B′ and C′ had 100 μCi, and D 1,000 μCi ^{131}I. A: Right lobe is 25 × 50 mm. B had right lobectomy in 1957 for colloid goiter. C had benign adenoma removed from right lower lobe. D had total thyroidectomy and neck dissection for follicular carcinoma with lymph node metastases 3 months previously. After imaging, active areas subsided following treatment with 50 mCi ^{131}I. Good ^{131}I images can nearly always be obtained with very long imaging times or with administration of more activity.

ministered, and imaging delayed for 48 hr. In such cases, despite ^{131}I uptakes of 1% or less, the finest detail of the poorly functioning thyroid remnant and/or metastasis, with minimal background activity, can be attained when the imaging duration is long enough to accumulate more than 35,000 dots (Fig. 5B′). Although lingual thyroids have been detected using scanning with ^{99m}Tc (*26*), ^{131}I is a better choice because of the high salivary ^{99m}Tc concentration. Rarely, vascular anomalies in the mediastinum will pool ^{99m}Tc but not ^{131}I and could be mistaken for a substernal thyroid; therefore only ^{131}I should be used for evaluating extrathyroidal activity.

Recently, "hot" ^{99m}Tc nodules were reported to be "cold" to ^{131}I in rare instances (*8,16*). This finding apparently suggests thyroid malignancy (*16*).

Scintigraphy or scintiphotography? Unless color discrimination is used, a single scan image can record only a limited activity range. With "background erase" set arbitrarily at 10%, areas of low activity—pyramidal lobe, "cold" nodule, or thyroid remnant—will be missed (*25,27*). The high-contrast Polaroid film also has a limited density range, which helps to accentuate areas of activity from background. But "lower 10% wipeout" (*27*) inherent in single scans is obviated by the triple image scintiphoto, which simultaneously brackets the best image with an under- and over-exposed image, extending the density range four-fold (Fig. 1). The f/8 over-exposed image demonstrates low activity areas well, but a small "cold" nodule encompassed by an area of high activity is obscured. The f/16 under-exposed image does not register low-activity areas, but the "cold" nodule missed by the f/8 image is over-emphasized. The best f/11 image is a compromise. Therefore, all three images should be inspected simultaneously. Scanning lines which, blended or not, always degrade the image, are absent from scintiphotos. The gamma camera image can be magnified conveniently for even better resolution, or minified for a larger field of view. Five-millimeter "cold" nodules are readily detected (Fig. 1).

Oblique views, either alone or as a stereoscopic pair (Fig. 3), are helpful for locating a "cold" nodule (*28*).

We are exploring the dynamic potential of the Anger camera in quantifying blood flow and radionuclide concentration of ^{75}Se-selenomethionine in "cold" nodules compared with adjacent normal thyroid tissue, in an attempt to differentiate thyroid carcinoma from benign lesions.

The best method for imaging the thyroid routinely appears to be ^{99m}Tc scintiphotography (*14*).

CONCLUSIONS

When optimized, the best method for *routine* imaging of the thyroid is ^{99m}Tc scintiphotography. Its merits are: low thyroid radiation dose, technical simplicity and speed, and consistent yield of good thyroid images. Scintiphotography with ^{131}I should not be performed routinely but should be reserved for reimaging after ^{99m}Tc failure where, because of poor uptake and/or large goiter, the thyroid radiation dose may be much less than usual. Iodine-131 should also be used to evaluate all ^{99m}Tc "hot" nodules, to diagnose substernal or ectopic activity, and to define equivocal "cold" nodules. Only ^{131}I should be used for the postoperative management of thyroid carcinoma.

ACKNOWLEDGMENT

This work was supported in part by a grant from the Kaiser Foundation Hospitals.

REFERENCES

1. Harper PV, Andros G, Lathrop K: Preliminary observations on the use of six-hour Tc^{99m} as a tracer in biology and medicine. Argonne Cancer Research Hospital, *USAEC Report ACRH-18*, 1962, pp 77–88

2. HARPER PV, BECK R, CHARLESTON D, et al: Optimization of a scanning method using Tc^{99m}. *Nucleonics* 22: No. 1, 50–54, 1964

3. QUINN JL, MEHDI B: Radioisotope scanning of thyroid. *JAMA* 199: 920–924, 1967

4. DODDS WJ, MALCOLM RP: Thyroid scanning with technetium 99m pertechnetate. *Radiology* 91: 27–31, 1968

5. SANDERS TP, KUHL DE: Technetium pertechnetate as a thyroid scanning agent. *Radiology* 91: 23–26, 1968

6. HAAS JP, SCHMIDT KJ, WOLF RE: Experience with thyroid gland scintigraphy using technetium-99m. Review of 2000 cases. *Fortschr Roentgenstr* 109: 222–226, 1968

7. UMEK H: ^{99m}Tc in thyroid gland scintigraphy. *Nuclearmedizin* 7: 231–239, 1968

8. STRAUSS HW, HURLEY PF, WAGNER HN: Advantages of ^{99m}Tc pertechnetate for thyroid scanning in patients with decreased radioiodine uptake. *Radiology* 97: 307–310, 1970

9. ANGER HO: Scintillation camera. *Rev Sci Instrum* 29: 27–33, 1958

10. ANGER HO: Scintillation camera with multichannel collimators. *J Nucl Med* 5: 515–531, 1964

11. MURRAY P, THOMSON JA: The use of the gamma camera in the investigation of thyroid disorders. *Amer J Roentgen* 90: 345–351, 1963

12. WANG Y: Thyroid scanning using the gamma camera. *J Nucl Med* 7: 386, 1966

13. ROBINSON T, COLLICA CJ, CHANG S: Clinical comparison of scans and scintiphotos of the thyroid gland. *Amer J Roentgen* 103: 738–745, 1968

14. STRAUSS HW, HURLEY JH, WAGNER HN: Thyroid imaging with ^{99m}Tc pertechnetate and the pinhole camera. *J Nucl Med* 11: 403, 1970

15. WEBER PM, DOS REMEDIOS L, FISH M, et al: Thyroid imaging: ^{131}I or ^{99m}Tc, a clinical comparison. *J Nucl Med* 10: 451, 1969

16. STEINBERG M, CAVALIERI RR, CHOY SH: Uptake of technetium 99-pertechnetate in a primary thyroid carcinoma: need for caution in evaluating nodules. *J Clin Endocr* 31: 81–84, 1970

17. WELLMAN HN, KEREIAKES JG, BRANSON BM: Total- and partial-body counting of children for radiopharmaceutical dosimetry data. In *Medical Radionuclides: Radiation Dose and Effects.* Cloutier RJ, Edwards CL, Snyder WS, eds, USAEC Symposium Series 20. CONF-691212, 1970, pp 131–156

18. SMITH EM: Internal dose calculation for ^{99m}Tc. *J Nucl Med* 6: 231–251, 1965

19. SELTZER RA, KEREIAKES JG, SAENGER EL, et al: Radiation exposure from radioiodine compounds in pediatrics. *Radiology* 82: 486–494, 1964

20. PFANNENSTIEL P: Determination of radiation dose and assessment of clinical results after radioiodine treatment. In *Medical Radionuclides: Radiation Dose and Effects.* Cloutier RJ, Edwards CL, Snyder WS, eds, USAEC Symposium Series 20. CONF-691212, 1970, pp 185–206

21. ATKINS HL, RICHARDS P: Assessment of thyroid function and anatomy with technetium-99m as pertechnetate. *J Nucl Med* 9: 7–15, 1968

22. SODEE DB: The study of thyroid physiology utilizing intravenous sodium pertechnetate. *J Nucl Med* 7: 564–567, 1966

23. HARPER PV, LATHROP KA, GOTTSCHALK A: Pharmacodynamics of some technetium-99m preparations. In *Radioactive Pharmaceuticals.* Andrews GA, Kniseley RM, Wagner HN, eds, USAEC Symposium Series 6. CONF-651111, 1966, pp 335–358

24. ALEXANDER GH, JOHN GF, MCALLISTER JD: Potential resolution of the scintillation camera in thyroid studies. *Radiology* 89: 898–902, 1967

25. COLLICA CJ, ROBINSON T, HAYT DB: Comparative study of the gamma camera and rectilinear scanner. *Amer J Roentgen* 100: 761–779, 1967

26. DODDS WJ, POWELL MR: Lingual thyroid scanned with technetium 99m pertechnetate. Report of two cases. *Amer J Roentgen* 100: 786–791, 1967

27. GOODRICH JK, HARRIS CC: Imaging devices: Comparative clinical attributes (one opinion). In *Pulmonary Investigation with Radionuclides. First Annual Nuclear Medicine Seminar.* Gilson AJ, Smoak WM, eds, Springfield, Charles C Thomas, 1970, pp 146–159

28. CHARKES ND: Three-dimensional radionuclide imaging, stereoscintiphotography. *Radiology* 98: 335–339, 1971

TECHNOLOGIST SECTION
THE SOCIETY OF NUCLEAR MEDICINE
19th ANNUAL MEETING

July 11–14, 1972 **Sheraton-Boston Hotel** **Boston, Mass.**

Call for Papers: Nuclear Medicine Technologists' Program

The Technologist Section has set aside time for a nuclear medicine technologists' program at the 19th Annual Meeting in Boston, July 11–14, 1972.

The Scientific Program Committee welcomes the submission of abstracts for 12-minute papers from technologists for this meeting. Abstracts must be submitted on an abstract form similar to the form for general scientific papers available from the Society of Nuclear Medicine. The length must not exceed 400 words and the format of the abstracts must follow the requirements set down for all abstracts for the scientific program (see "Call for Abstracts for Scientific Program" in this issue). Send the abstract form and four carbon copies to:

LEONARD LOPEZ, M.D.
Mallinckrodt Institute of Radiology
Washington University School of Medicine
510 S. Kingshighway
St. Louis, Missouri 63110

DEADLINE: February 15, 1972