
SNM Practice Guideline for Parathyroid Scintigraphy 4.0*

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PREAMBLE

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The SNM will periodically define new guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients throughout the United States. Existing practice guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

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These guidelines are an educational tool designed to assist practitioners in providing appropriate care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal

standard of care. For these reasons and those set forth below, the SNM cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, there is no implication that an approach differing from the guidelines, standing alone, was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

The practice of medicine involves not only the science, but also the art, of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not ensure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

Primary hyperparathyroidism is characterized by increased synthesis and release of parathyroid hormone, which produces an elevated serum calcium level and a decline in serum inorganic phosphates. Asymptomatic patients are frequently identified by routine laboratory screening. The vast majority of cases of primary hyperparathyroidism (80%–90%) are due to a single hyperfunctioning adenoma. Multigland hyperplasia and double adenomas account for approximately 10% of cases, whereas parathyroid carcinomas occur in only

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1%–3% of cases of hyperparathyroidism. In general, parathyroid adenomas larger than 500 mg can be detected scintigraphically. Hyperplastic glands can be detected but with less sensitivity than adenomas.

II. GOALS

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of parathyroid imaging.

III. DEFINITIONS

Dual-phase or double-phase imaging refers to acquisition of early and delayed images with ^{99m}Tc -sestamibi. Dual-isotope or subtraction imaging refers to protocols using 2 different radiopharmaceuticals.

IV. COMMON CLINICAL INDICATIONS

Indications for parathyroid scintigraphy include, but are not limited to, the following:

Although no published appropriateness criteria exist for parathyroid scintigraphy, parathyroid scintigraphy is specifically designed to localize parathyroid adenomas or parathyroid hyperplasia in patients with hyperparathyroidism that is determined on the basis of elevated parathyroid hormone levels in the setting of an elevated serum calcium level (1–8).

Localization of hyperfunctioning parathyroid tissue (adenomas or hyperplasia) in primary hyperparathyroidism is useful before surgery to help the surgeon localize the lesion, thus shortening the time of the procedure. In the past when surgery involved bilateral neck exploration, parathyroid scintigraphy was controversial (1–5,9–12). However, with present-day minimally invasive parathyroidectomy, preoperative parathyroid scintigraphy may be extremely useful in reducing the duration or extent of surgical exploration. Combining intraoperative parathyroid hormone assays with minimally invasive surgery may improve success rates for complete cure.

Parathyroid scintigraphy may also be indicated for localization of hyperfunctioning parathyroid tissue in patients with persistent or recurrent disease. Many of these patients will already have had one or more surgical procedures, making reexploration more technically difficult. Also, ectopic tissue is more prevalent in this population, and preoperative localization will likely increase surgical success, in part by helping to direct the surgical approach (6,13–16).

Localization of hyperfunctioning parathyroid tissue for intraoperative localization using a γ -probe or a small camera can be helpful, particularly in patients with persistent or recurrent disease, especially those who have undergone previous surgical exploration.

V. QUALIFICATIONS AND RESPONSIBILITY OF PERSONNEL

See the SNM Guideline for General Imaging.

VI. PROCEDURE/SPECIFICATIONS OF THE EXAMINATION

A. Information pertinent to performing the procedure

An elevated level of serum calcium and parathyroid hormone should be documented. When other laboratory abnormalities are mild, documentation of increased urinary excretion of calcium is also advised. Other pertinent information includes the results of physical examination, especially palpation of the neck; the presence of concurrent thyroid disease, especially nodular thyroid disease; recent administration of iodine-containing preparations, such as intravenous contrast material or thyroid hormone, when the technique of thyroid imaging and subsequent subtraction will be used; the results of CT, MRI, or ultrasound; and whether there is a history of thyroid or prior parathyroid surgery.

B. Patient preparation and precautions

No special patient preparation or precautions are necessary. The procedure should be explained to the patient, such as the importance of preventing patient motion during the study, particularly if dual-isotope/subtraction techniques are used. Patients who are unable or unwilling to remain completely immobilized during the study may require sedation.

C. Radiopharmaceuticals

1. ^{99m}Tc -sestamibi or ^{99m}Tc -tetrofosmin

The range of intravenously administered radioactivity in adults is 740–1,110 MBq (20–30 mCi). This radiopharmaceutical localizes in both parathyroid tissue and thyroid tissue but usually washes out from normal and possibly abnormal thyroid tissue more rapidly than from abnormal parathyroid tissue. (Hyperplastic parathyroid glands generally show faster washout than most adenomas and can be more difficult to detect.)

^{99m}Tc -tetrofosmin can be used alternatively to ^{99m}Tc -sestamibi using the dual-isotope subtraction procedure (17). ^{99m}Tc -tetrofosmin localizes in both parathyroid tissue and functioning thyroid tissue, but in contrast to sestamibi, there is no differential washout between thyroid and parathyroid tissue (18).

2. ^{99m}Tc -pertechnetate

^{99m}Tc has a physical half-life of 6 h and energy of 140 keV. Pertechnetate is used for delineating the thyroid gland, since pertechnetate is trapped by functioning thyroid tissue. This image is subtracted from the ^{99m}Tc -sestamibi image, and what remains is potentially a parathyroid adenoma. The administered activity of ^{99m}Tc -pertechnetate, administered intravenously, ranges from 74 to 370 MBq (2–10 mCi).

3. ^{123}I

^{123}I has a half-life of 13 h and emits a photon with energy of 159 keV. ^{123}I is used for delineating

the thyroid gland, since ^{123}I is trapped (and organified) by functioning thyroid tissue. It has been used as a thyroid imaging agent in subtraction studies, with $^{99\text{m}}\text{Tc}$ -sestamibi. The administered radioactivity, given orally, ranges from 7.5 to 22 MBq (200–600 μCi).

D. Protocol/image acquisition

Digital data should be acquired in a 128×128 or larger matrix. Planar images of the neck and mediastinum (down to the level of the inferior margin of the heart) can be obtained with a γ -camera fitted with a high-resolution collimator. Images including the mediastinum should be obtained in all cases. Mediastinal images are particularly helpful in cases of residual or recurrent disease, where there is a much higher likelihood of ectopic parathyroid tissue. Additional pinhole or converging collimator images of the neck may be useful. If SPECT is not available, anterior oblique images may be useful. With γ -cameras that have a large field of view, magnification may be of help.

1. Dual-phase $^{99\text{m}}\text{Tc}$ -sestamibi protocol

If a dual-phase study is performed, then a high-resolution parallel-hole collimator or a pinhole or converging collimator can be used. Pinhole collimators are preferred if SPECT or SPECT/CT is not part of the imaging protocol. Early (10–30 min after injection) and delayed (1.5–2.5 h after injection) high-count images are obtained of the neck and chest. Dual-phase imaging with $^{99\text{m}}\text{Tc}$ -tetrofosmin appears not to be useful because of rapid washout from parathyroid tissue (17,18).

2. SPECT and SPECT/CT protocols

SPECT and SPECT/CT have proven useful and provide more precise anatomic localization (19–21), particularly for localizing ectopic lesions. In the mediastinum, accurate localization may assist in directing the surgical approach, such as median sternotomy versus left or right thoracotomy. A cine of volume-rendered images may be helpful. A cine of a maximum-intensity projection may be helpful in reviewing images with referring physicians, as it allows one to quickly estimate the anterior/posterior orientation of the lesions. Whether SPECT improves sensitivity is debatable; published results have been variable (22). The combination of anatomic and functional imaging, that is, SPECT/CT, provides the optimal localization for surgical planning and additional diagnostic information (19,20).

Regarding the specific procedure for SPECT/CT dual-phase $^{99\text{m}}\text{Tc}$ -sestamibi scintigraphy, the optimal approach is to acquire studies on an integrated SPECT/CT device, but software fusion (coregistration) of images obtained on separate SPECT and CT devices can be used when an integrated device is not available. The general technical guidance for

SPECT/CT is outlined in the respective SNM practice guideline (1). One must exercise extreme caution in fusing separately acquired SPECT and CT studies when dealing with coregistration of such tiny structures. Subtle changes in neck positioning may make fusion images totally misleading.

If planar images are acquired, they should be obtained first (see the specific section in this guideline for further details). These images provide information that can supplement SPECT/CT data, especially if the latter are compromised by a technical difficulty (such as patient motion or equipment failure). Anterior planar images of the neck (magnified as appropriate) to visualize the parotid glands (or angle of the jaw) cranially and extending to fully include the thyroid caudally, as well as the neck-and-chest view (no magnification, including parotid glands cranially and the inferior myocardium caudally), are obtained approximately 15 min after injection (early) and repeated approximately 120 min later (delayed). Each acquisition is typically for 10 min on a 256×256 (16-bit) matrix, using a large-field-of-view γ -camera fitted with a high-resolution low-energy parallel-hole collimator. SPECT/CT can be performed immediately after the planar imaging, at the early, the delayed, or both time points. Although 2 SPECT acquisitions can be obtained without exposing the patient to any additional radiation, the CT component exposes patients to radiation each time it is performed. Therefore, one should consider carefully whether CT should be used at both or only a single time point. One large published study found early SPECT/CT in combination with delayed planar, SPECT, or SPECT/CT to have the highest accuracy (21). Early SPECT (or SPECT/CT) may increase sensitivity because there is rapid washout of sestamibi from some parathyroid adenomas and many hyperplastic glands.

When possible, the SPECT data should be acquired over a 360° arc, using a body-contoured elliptic orbit, optimally obtaining 120 (minimum of 60) projections at 15–25 s per projection (every 3° – 6° angle), depending on the number of projections and sensitivity of the detector. The SPECT acquisition takes, on average, approximately 25 min. The images are acquired into a 128×128 (16-bit) matrix, corrected for attenuation, and reconstructed using a 2-dimensional ordered-subset expectation maximization iterative technique (at least 10 subsets and 2 iterations are typical, but the number may vary according to the manufacturer). A 3-dimensional postprocessing filter, which should be specified in detail by the manufacturer (e.g., the Hanning postprocessing filter with a cutoff frequency of 0.85 cycles/cm) is typically applied to the SPECT dataset.

The CT component of the examination is performed for lesion localization and attenuation correction. The optimal slice thickness, acquisition time, and CT parameters (mAs and kVp) should be determined by individual laboratories or suggested by the manufacturer to maximize image quality and to minimize radiation exposure to the patient. Within these parameters, the highest possible spatial resolution should be sought in setting up the imaging protocol. Although the typical parameters are a tube current ranging from 100 to 200 mAs and a voltage of 120 kVp (ranging from 100 to 140 kVp), these may vary by manufacturer and in some systems may be automatically modulated, depending on the body part imaged. Intravenous contrast enhancement is not usually applied but may be useful or justifiable in selected cases.

Optimal display of the acquired image sets includes SPECT, CT, and fusion images reconstructed in 3 standard projections (axial, coronal, and sagittal). It is preferable for all 3 sets to be coregistered so that the same body region is displayed on any one of the numbered slices of any given projection. This allows for the most reliable comparison between the image sets for anatomic and functional correlation.

3. Dual-isotope ^{99m}Tc -sestamibi/ ^{99m}Tc -pertechnetate protocol

^{99m}Tc -pertechnetate can be administered first and followed by ^{99m}Tc -sestamibi, or ^{99m}Tc -sestamibi can be administered first and followed by ^{99m}Tc -pertechnetate. When ^{99m}Tc -pertechnetate is injected first, high-count (10 min) images are obtained 30 min after radiopharmaceutical administration. ^{99m}Tc -sestamibi is then injected, and high-count (10 min) images are obtained 10 min later. If ^{99m}Tc -pertechnetate is injected after ^{99m}Tc -sestamibi images are obtained, the patient should be immobilized for 15–30 min after the ^{99m}Tc -pertechnetate injection, and then a 10-min image is acquired. In all cases, frame normalization can be performed, and computer subtraction of ^{99m}Tc -pertechnetate images from the ^{99m}Tc -sestamibi images is performed (3,8,10,12,22–24).

4. Dual-isotope ^{99m}Tc -sestamibi/ ^{123}I -iodide protocol (25)

^{123}I -iodide must be given first, followed by ^{99m}Tc -sestamibi. ^{123}I -iodide cannot be administered after sestamibi, because of its much lower administered activity and the long time needed for localization and imaging. High-count (10 min) images are obtained 4 h after ^{123}I administration. ^{99m}Tc -sestamibi is then injected, and high-count (10 min) images are obtained 10 min after injection. Both sets of images are normalized to total thyroid counts, and computer subtraction of ^{123}I -iodide images from the ^{99m}Tc -sestamibi images is per-

formed. Disadvantages of ^{123}I include cost and the long time required for localization.

None of the preceding techniques has been shown to be diagnostically superior.

5. Processing

In ^{99m}Tc -sestamibi/ ^{123}I or ^{99m}Tc -pertechnetate imaging studies, the images should be normalized and the ^{123}I or ^{99m}Tc -pertechnetate image is subtracted from the ^{99m}Tc -sestamibi image. The images for interpretation should include one in which the ^{123}I is subtracted just enough to make the thyroid disappear into the background.

E. Interpretation

1. Dual-phase ^{99m}Tc -sestamibi

If ^{99m}Tc -sestamibi is used without ^{123}I or ^{99m}Tc -pertechnetate (dual phase), the 2 sets of images (early and delayed) are inspected visually. Abnormal parathyroid tissue usually appears as an area of increased uptake on the immediate scan and becomes more prominent on the delayed images because of slower washout from parathyroid than from thyroid. However, some lesions (10%–15%) will show washout of tracer by 2–2.5 h that is as fast as that from the thyroid. Many hyperplastic glands show such a rapid washout. Washout of tracer from adenomas is variable. SPECT images may reveal lesions not seen on planar images, and SPECT/CT images may additionally provide better localization of abnormal findings.

2. Dual-isotope protocols

^{99m}Tc -sestamibi/ ^{99m}Tc -pertechnetate and ^{99m}Tc -sestamibi/ ^{123}I images should be inspected visually, as well as evaluated with computer subtraction or with rapid alternating display of images (cine). Abnormal parathyroid tissue appears as an area of relatively increased ^{99m}Tc -sestamibi uptake. Computer subtraction may be useful in cases with equivocal visual findings.

Interpretation of the images should include a complete description of the planar, SPECT, CT and fusion image sets. The primary goal is to render the opinion on the presence of abnormal parathyroid tissue, such as single or multiple parathyroid lesions. Those findings require a detailed description of the anatomic location of the lesion, including relationship to the neighboring structures (e.g., the thyroid gland, trachea, esophagus, and vessels). Incidental pathology in the imaged field also should be described (9,12,13,23,25,26).

F. Interventions

No interventions are required.

TABLE 1
Radiation Dosimetry for Adults

Radiopharmaceutical	Administered activity		Organ	Largest radiation dose			Effective dose		Effective dose		
	MBq	mCi		mGy/MBq	rad/mCi	mGy	rad	mSv/MBq	rem/mCi	mSv	rem
^{99m} Tc-pertechnetate* (no blocking agent)	75–150 intravenously	2–4	Upper large intestine	0.057	0.21	4.3–8.6	0.43–0.86	0.013	0.048	0.98–2.0	0.098–0.2
^{99m} Tc-sestamibi (rest)*	185–925 intravenously	5–25	Gallbladder	0.039	0.14	7.2–36	0.72–3.6	0.009	0.033	1.6–8.3	0.16–0.83
^{99m} Tc-tetrofosmin (rest)†	185–925 intravenously	5–25	Gallbladder	0.027	0.10	5.0–25	0.5–2.5	0.0069	0.026	1.3–6.4	0.13–0.64
¹²³ I-iodide (assuming 35% uptake)‡	7.5–20 by mouth	0.2–0.6	Thyroid	4.5	17	34–90	3.4–9.0	0.22	0.81	1.6–4.4	0.16–0.44

*ICRP publication 80, 1998 (28).

†ICRP publication 106, 2008 (27).

‡ICRP publication 53, 1987 (29), and ICRP publication 80, 1998 (28).

VII. DOCUMENTATION/REPORTING

In addition to patient demographics, the report should include the indication for the study; the procedure, including the dosage and route of administration of radiopharmaceuticals and, if more than 1 radiopharmaceutical is used, the order and the timing of administration; and the timing of image acquisition and whether the imaging is planar or SPECT (or SPECT/CT). For planar images, the projections acquired (e.g., anterior) and region imaged (e.g., neck or mediastinum) should be listed. For SPECT, the timing of acquisition after injection and the region imaged (neck or mediastinum) should be listed. For CT, the parameters to be listed include kVp, mA, pitch, beam, width, and scan length.

The report should also indicate which images demonstrated the lesions (early or late images), the location of the findings (mediastinum or thyroid bed [upper or lower pole or ectopic, and which side]; a more precise localization may be possible with SPECT and SPECT/CT); any study limitations or confounding factors (e.g., patient motion); and whether the patient underwent previous thyroidectomy.

In making the interpretation, the degree of diagnostic certainty may differ depending on the findings. This difference should be reflected in the wording of the impression. For example, if there is a single focus of increased uptake on the immediate image that becomes more prominent on the delayed image, the interpretation may say “findings are most consistent with parathyroid adenoma.” On the other hand, if the immediate image is subtly positive and the delayed image is negative, the impression may state that “findings could represent an atypical scintigraphic appearance of parathyroid adenoma or hyperplasia.”

VIII. EQUIPMENT SPECIFICATION

Any properly functioning γ -camera may be used to acquire the images in parathyroid scintigraphy. Parallel-hole collimation is the standard for imaging the neck and mediastinum, though pinhole collimation can improve resolution of the neck and allow lateral views for lesion depth estimation.

Computer acquisition is necessary for the dual-radiopharmaceutical technique with subtraction and is often helpful for qualitative visual analysis in single-radiopharmaceutical studies as well.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

See also the SNM Guideline for General Imaging.

γ -camera quality control will vary from camera to camera. Multiple spatial and energy window registration should be checked periodically if dual-isotope studies are performed. For further guidance on routine quality control procedures for γ -cameras, refer to the SNM Guideline for General Imaging.

A. Sources of error

Sources of error include patient motion, image misregistration, and findings that are more difficult to

TABLE 2

Radiation Dosimetry in Fetus/Embryo: ^{99m}Tc-Sestamibi, Rest

Stage of gestation	Fetal dose	
	mGy/MBq	rad/mCi
Early	0.015	0.055
3 mo	0.012	0.044
6 mo	0.0084	0.031
9 mo	0.0054	0.020

Dose estimates to fetus were provided by Russell et al. (30). No information about possible placental crossover of this compound was available for use in estimating fetal doses.

detect. These include adenomas or hyperplastic glands smaller than 500 mg (22), ectopic adenomas (the entire neck as well as the upper mediastinum to the level of the heart should be imaged), thyroid lesions such as adenomas and carcinomas (may be indistinguishable from parathyroid lesions), and parathyroid carcinomas (indistinguishable from other parathyroid lesions).

Recently administered radiographic contrast material or thyroid hormone (within the previous 3–4 wk) may interfere with ¹²³I and pertechnetate imaging and will therefore compromise the use of subtraction techniques; this is not a problem with dual-phase sestamibi studies. Previous thyroidectomy can be a problem, especially for precise lesion localization, mainly with the subtraction technique.

B. Issues requiring further clarification

There is now a clear consensus that imaging with ^{99m}Tc-sestamibi is superior to ²⁰¹Tl-chloride. ²⁰¹Tl-chloride should no longer be used. A few investigators have used ^{99m}Tc-tetrofosmin; however, it is not clear if this agent is comparable to ^{99m}Tc-sestamibi. There is still no consensus regarding subtraction imaging versus dual-phase imaging. There is a developing consensus that SPECT and SPECT/CT are most useful for improving the precision of anatomic localization (19–22).

TABLE 3

Radiation Dosimetry in Fetus/Embryo: ^{99m}Tc-Tetrofosmin

Stage of gestation	Fetal dose	
	mGy/MBq	rad/mCi
Early	0.0096	0.036
3 mo	0.0070	0.026
6 mo	0.0054	0.020
9 mo	0.0036	0.013

Dose estimates to fetus were provided by Russell et al. (30). No information about possible placental crossover of this compound was available for use in estimating fetal doses. Separate estimates were not given for rest and exercise subjects.

TABLE 4

Radiation Dosimetry in Fetus/Embryo: ^{99m}Tc-Pertechnetate

Stage of gestation	Fetal dose	
	mGy/MBq	rad/mCi
Early	0.011	0.041
3 mo	0.022	0.081
6 mo	0.014	0.052
9 mo	0.0093	0.034

Dose estimates to fetus were provided by Russell et al. (30). Information about possible placental crossover of this compound was available and was used in estimating fetal doses.

There is still controversy regarding the utility of this study as a preoperative evaluation in primary hyperparathyroidism patients who have not had prior surgery. However, there are now some data that these studies may shorten the operative time and reduce cost. In cases of residual or recurrent disease, these studies are clearly helpful.

There are some data emerging that ¹⁸F-FDG PET imaging may be useful in imaging parathyroid adenomas. PET studies are probably most useful in difficult cases in which ^{99m}Tc-sestamibi has failed to localize the cause for a high parathyroid hormone level. PET would generally involve the use of ¹⁸F-FDG, or possibly ¹¹C methionine outside the United States.

X. RADIATION SAFETY IN IMAGING

See also the SNM Guideline for General Imaging.

Dosimetry data are provided in Tables 1–6. It is the position of the SNM that patient exposure to ionizing radiation should be at the minimum level consistent with obtaining a diagnostic examination. Patient radiation exposure may be reduced by the administration of less radiopharmaceutical when the technique or equipment used for imaging can support such an action. Each patient procedure is unique, and the methodology to achieve minimum exposure while maintaining diagnostic accuracy needs to be viewed in this light. Radiopharmaceutical dose ranges outlined in this document should be considered a guide. Dose

TABLE 5

Radiation Dosimetry in Fetus/Embryo: ¹²³I-Nal

Stage of gestation	Fetal dose	
	mGy/MBq	rad/mCi
Early	0.020	0.074
3 mo	0.014	0.052
6 mo	0.011	0.041
9 mo	0.0098	0.036

Dose estimates to fetus were provided by Russell et al. (30). Information about possible placental crossover of this compound was available and was used in estimating fetal doses.

TABLE 6

Radiation Dosimetry in Fetus/Embryo: Dose to Fetal Thyroid

Stage of gestation	Fetal thyroid dose*	
	mGy/MBq	rad/mCi
3 mo	2.7	10
4 mo	2.6	9.6
5 mo	6.4	24
6 mo	6.4	24
7 mo	4.1	15
8 mo	4.0	15
9 mo	2.9	11

*Per unit activity administered to the mother.
The fetal thyroid takes up iodine after 10–13 wk of gestation (31).

reduction techniques should be used when appropriate. The same principles should be applied when CT is used in a hybrid imaging procedure. CT acquisition protocols should be optimized to provide the information needed while minimizing patient radiation exposure.

Parathyroid imaging is not usually indicated in children. The authors recommend that no interruption is needed for breastfeeding patients administered ^{99m}Tc-sestamibi or tetrofosmin, but a 12-h interruption time for ^{99m}Tc-pertechnetate and a greater than 3 wk interruption for ¹²³I are required.

XI. ACKNOWLEDGMENTS

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XII. APPENDIX

Parathyroid Subtraction Technique at North Shore Long Island Jewish Health System

A ^{99m}Tc-sestamibi/^{99m}Tc-pertechnetate dual-tracer protocol is used. An intravenous line is placed in the patient’s forearm before the procedure begins. Approximately 10 min after injection of 1,110–1,295 MBq (30–35 mCi) of ^{99m}Tc-sestamibi, patients undergo early imaging of the neck using a pinhole collimator. Data are acquired dynamically at 2 min/frame for 5 frames (10 min total) as 128 × 128 matrices.

Immediately after early ^{99m}Tc-sestamibi imaging, SPECT (or SPECT/CT) is performed. After SPECT (or SPECT/CT) has been completed, about 90 min after injection, pinhole imaging of the neck is repeated. Data are acquired as 128 × 128 matrices at 2 min/frame for 25 frames (50 min). For the first 10 frames, data are acquired using only residual sestamibi activity (late sestamibi image). During the 11th to 12th frames, 259 MBq (7 mCi) of ^{99m}Tc-pertechnetate are injected intravenously (through the previously established intravenous line), and imaging (thyroid) continues for the remainder of the test.

Cinematic playbacks of unprocessed early and late data are reviewed to identify and exclude frames demonstrating patient motion or other artifacts likely to affect subsequent image processing and interpretation. After frame deletion, the remaining frames are summed to create composite early and late ^{99m}Tc-sestamibi images and the composite thyroid image. The composite early and late ^{99m}Tc-sestamibi images are normalized to the composite thyroid image, and all 3 composite images then are background-subtracted. Finally, the composite thyroid image is digitally subtracted from the composite late ^{99m}Tc-sestamibi image to produce the subtraction image.

The technique of course is not useful in patients who previously underwent total thyroidectomy. False-negative subtraction images are encountered in patients with decreased thyroid uptake of ^{99m}Tc-pertechnetate due to hormone replacement, thyroiditis, or other causes. A pre-scanning questionnaire decreases the likelihood of this occurrence. Another potential problem is ^{99m}Tc infiltration; at the end of the study, an image of the injection site is obtained routinely to check for infiltration.

XIII. REFERENCES

1. Carty SE, Worsley MJ, Virji MA, et al. Concise parathyroidectomy: the impact of preoperative SPECT ^{99m}Tc sestamibi scanning and intraoperative quick parathormone assay. *Surgery*. 1997;122:1107–1114.
2. Johnston LB, Carroll MJ, Britton KE, et al. The accuracy of parathyroid gland localization in primary hyperparathyroidism using sestamibi radionuclide imaging. *J Clin Endocrinol Metab*. 1996;81:346–352.
3. Palestro CJ, Tomas MB, Tronco GG. Radionuclide imaging of the parathyroid glands. *Semin Nucl Med*. 2005;35:266–276.
4. O’Doherty MJ, Kettle AG, Wells P, et al. Parathyroid imaging with technetium-99m sestamibi: preoperative localization and tissue uptake studies. *J Nucl Med*. 1992;33:313–318.

5. Sfakianakis GN, Irvin GL III, Foss J, et al. Efficient parathyroidectomy guided by SPECT-MIBI and hormonal measurements. *J Nucl Med.* 1996;37:798–804.
6. Akram K, Parker JA, Donohoe K, Kolodny G. Role of single photon emission computed tomography/computed tomography in localization of ectopic parathyroid adenoma: a pictorial case series and review of the current literature. *Clin Nucl Med.* 2009;34:500–502.
7. Gasparri G, Camandona M, Bertoldo U, et al. The usefulness of preoperative dual-phase ^{99m}Tc MIBI-scintigraphy and IO-PTH assay in the treatment of secondary and tertiary hyperparathyroidism. *Ann Surg.* 2009;250:868–871.
8. Hindié E, Ugur O, Fuster D, et al. 2009 EANM parathyroid guidelines. *Eur J Nucl Med Mol Imaging.* 2009;36:1201–1216.
9. Harris L, Yoo J, Driedger A, et al. Accuracy of technetium-99m SPECT-CT hybrid images in predicting the precise intraoperative anatomical location of parathyroid adenomas. *Head Neck.* 2008;30:509–517.
10. Hindié E, Melliere D, Simon D, et al. Primary hyperparathyroidism: is technetium-99m-sestamibi/iodine-123 subtraction scanning the best procedure to locate enlarged glands before surgery? *J Clin Endocrinol Metab.* 1995;80:302–307.
11. Perez-Monte JE, Brown ML, Shah AN, et al. Parathyroid adenomas: accurate detection and localization with Tc-99m sestamibi SPECT. *Radiology.* 1996;201:85–91.
12. Neumann DR, Obuchowski NA, Difilippo FP. Preoperative ¹²³I/^{99m}Tc-sestamibi subtraction SPECT and SPECT/CT in primary hyperthyroidism. *J Nucl Med.* 2008;49:2012–2017.
13. Chen CC, Skarulis MC, Fraker DL, et al. Technetium-99m sestamibi imaging before reoperation for primary hyperparathyroidism. *J Nucl Med.* 1995;36:2186–2191.
14. Majors JD, Burke GJ, Mansberger AR, et al. Technetium Tc-99m sestamibi scan for localizing abnormal parathyroid glands after previous neck operations: preliminary experience in reoperative cases. *South Med J.* 1995;88:327–330.
15. Weber CJ, Vansant J, Alazraki N, et al. Value of technetium 99m sestamibi iodine 123 imaging in reoperative parathyroid surgery. *Surgery.* 1993;114:1011–1018.
16. Doppman JL, Skarulis MC, Chen CC, et al. Parathyroid adenomas in the aortopulmonary window. *Radiology.* 1996;201:456–462.
17. Wakamatsu H, Noguchi S, Yamashita H, et al. Technetium-99m tetrofosmin for parathyroid scintigraphy: a direct comparison with ^{99m}Tc-MIBI, ²⁰¹Tl, MRI and US. *Eur J Nucl Med.* 2001;28:1817–1827.
18. Fröberg AC, Valkema R, Bonjer HJ, Krenning EP. ^{99m}Tc-tetrofosmin or ^{99m}Tc-sestamibi for double-phase parathyroid scintigraphy? *Eur J Nucl Med Mol Imaging.* 2003;30:193–196.
19. Thomas DL, Bartel T, Menda Y, Howe J, Graham MM, Juweid ME. Single photon emission computed tomography (SPECT) should be routinely performed for the detection of parathyroid abnormalities utilizing technetium-99m sestamibi parathyroid scintigraphy. *Clin Nucl Med.* 2009;34:651–655.
20. Lindqvist V, Jacobsson H, Chandanos E, Backdahl M, Kjellman M, Wallin G. Preoperative ^{99m}Tc(m)-sestamibi scintigraphy with SPECT localizes most pathologic parathyroid glands. *Langenbecks Arch Surg.* 2009;394:811–815.
21. Lavelly WC, Goetze S, Friedman KP, et al. Comparison of SPECT/CT, SPECT, and planar imaging with single- and dual-phase ^{99m}Tc-sestamibi parathyroid scintigraphy. *J Nucl Med.* 2007;48:1084–1089.
22. Nichols KJ, Tomas MB, Tronco GG, et al. Optimizing the accuracy of preoperative parathyroid lesion localization. *Radiology.* 2008;248:221–232.
23. Wimmer G, Profanter C, Kovacs P, et al. CT-MIBI-SPECT image fusion predicts multiglandular disease in hyperparathyroidism. *Langenbecks Arch Surg.* 2010;395:73–80.
24. Fuster D, Torregrosa JV, Setoain X, et al. Localising imaging in secondary hyperparathyroidism. *Minerva Endocrinol.* 2008;33:203–212.
25. Eslamy HK, Ziessman HA. Parathyroid scintigraphy in patients with primary hyperparathyroidism: ^{99m}Tc sestamibi SPECT and SPECT/CT. *Radiographics.* 2008;28:1461–1476.
26. Delbeke D, Coleman RE, Guiberteau MJ, et al. Procedure guideline for SPECT/CT imaging 1.0. *J Nucl Med.* 2006;47:1227–1234.
27. International Commission on Radiological Protection. Radiation dose to patients from radiopharmaceuticals: a third addendum to ICRP publication 53, ICRP publication 106. Approved by the Commission in October 2007. *Ann ICRP.* 2008;38:1–197.
28. International Commission on Radiological Protection. Radiation dose to patients from radiopharmaceuticals: addendum 2 to ICRP publication 53. *Ann ICRP.* 1998;28:1–126.
29. International Commission on Radiological Protection. ICRP publication 53: radiation dose to patients from radiopharmaceuticals. *Ann ICRP.* 1988;18:1–4.
30. Russell JR, Stabin MG, Sparks RB, Watson E. Radiation absorbed dose to the embryo/fetus from radiopharmaceuticals. *Health Phys.* 1997;73:756–769.
31. Watson EE. Radiation absorbed dose to the human fetal thyroid. In: *Fifth International Radiopharmaceutical Dosimetry Symposium.* Oak Ridge, Tennessee: Oak Ridge Associated Universities; 1992:179–187.

XIV. APPROVAL

This practice guideline (version 4.0) was approved by the Board of Directors of the SNM on September 17, 2011. Version 1.0 was approved on January 14, 1996; version 2.0 on February 7, 1999; and version 3.0 on June 2, 2004.