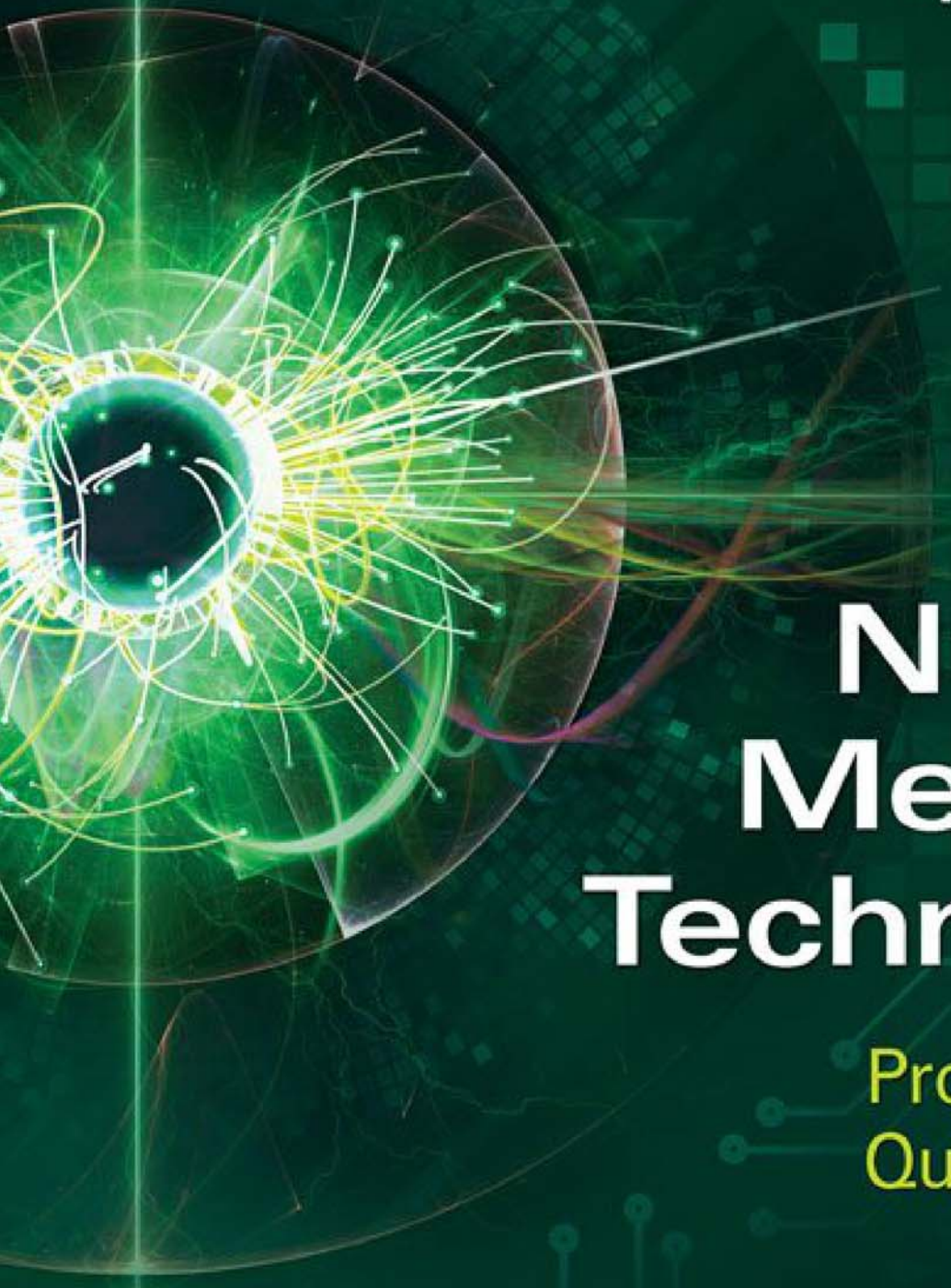
Pete Shackett



Nuclear Medicine Technology

Procedures and Quick Reference

Third Edition

Wolters Kluwer

Nuclear Medicine Technology:

Procedures and Quick Reference

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Third Edition

PETE SHACKETT, BA, ARRT[N], CNMT

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It is unimaginably saddening to lose your loved one and closest friend. That said, I would like to dedicate this third edition with all my love to my extraordinary and lovely wife.

Carolyn Sue Howe Shackett
(June 24, 1955–July 24, 2018)

In addition, I dedicate this to our past canine gatekeeper, Brandy, and to my present companion and "hunine" gatekeeper, Daisy. They have all brought and still bring home the genuine meaning of happiness and support.

In loving memory of my parents, Bertha and Wilfard Shackett

I also extend a debt of gratitude and appreciation posthumously in memory of my immediate family: Robert Shackett, Virginia Garrity, William Shackett, David Shackett, Winifred (Dolly) Duhaime, Carolyn's brother Donald Howe, and her parents, Pauline and Viley Howe.

About the Author

Photo Courtesy of Jim Tizzano Photography, St. Petersburg, FL.

Pete Shackett was born and raised in Newport, New Hampshire. He is the youngest of six children (three brothers and two sisters) with incredibly supportive parents (Bertha and Wilfard). At the age of five, one of his brothers began teaching him how to play drums and at nine, began teaching him how to play guitar. Pete spent his pre–high school and high school years immersed in music and high school band, becoming president of the band in his senior year.

In 1970, Pete received a Bachelor of Arts degree in Biology from Plymouth State College (now Plymouth State University) of the University of New Hampshire in Plymouth, New Hampshire. While studying under Dr. Mary G. Bilheimer, he received a science essay award for a treatise entitled "The Sanitary Significance of Fecal Coliforms in the Environment."

From 1970 to 1996, Pete pursued a professional career in music as a songwriter, singer, recording producer, drummer, acoustic, and electric guitarist. Most of his music was performed in and around New England until 1976; he moved to Florida to continue his music career. He released an album of all original music in 1988 entitled "Grouper Republic." The title song Grouper Republic was voted the official city song of Madeira Beach/John's Pass Village, Florida in 2012.

In 1991, having growing issues with his voice and while taking prerequisite classes at St. Petersburg Junior College, he began volunteering at Bayfront Medical Center in St. Petersburg as a patient transporter and shadowing in the nuclear medicine department. He learned very early how a department was run and how to image patients. His friend Bud, the Chief Technologist of the department at that time, in turn learned how to play guitar. In 1994, he resumed study at Hillsborough Community College in Tampa, Florida, majoring in nuclear medicine under the direction and guidance of Dr. Max Lombardi. During his tenure as a student, he wrote a disquisition entitled "^{99m}Tc-tetrofosmin: The Efficacy and Significance of a New Myocardial Perfusion Radiopharmaceutical." The paper and presentation won an award at the Florida Nuclear Medicine Technologist conference in 1996 and was accepted for publication in the *Journal of Nuclear Medicine Technology.* Pete graduated with high honors in 1996, earning the Award for Academic Excellence in Nuclear Medicine from Hillsborough Community College and elected to Who's Who Among Students at American Junior Colleges.

Lippincott Williams & Wilkins received a copy of the original manuscript for *Nuclear Medicine Technology: Procedures and Quick Reference* in 1998. The first edition of the book was published in 2000. Pete continued to assimilate information, ideas, and experience in the field of nuclear medicine during his 22 years of patient care. His second edition was released in 2008 with an update in 2013. This third edition has been the most gratifying and done in hopes of contributing to successful careers to all that may use it.

Pete Shackett presently resides, plays and writes music, and writes about nuclear medicine and other subjects out of the Tampa Bay area in Florida.

Acknowledgments

A special expression of gratitude and deepest respect to Dr. Max H. Lombardi, Director of Nuclear Medicine Technology (Retired), Hillsborough Community College, Tampa, Florida, for the opportunity of knowledge, encouragement, inspiration, and assistance. I also thank Mr. Henry (Bud) Rogers, CNMT, past Chief Technologist, Bayfront Health (formerly Bayfront Medical Center), St. Petersburg, Florida, now owner and operator of the Advanced Nuclear Imaging mobile units, for all his past and continuing to this day support. Also, thank you to the many technologists, students, nurses, and physicians who contributed opinions and information during the development of the original manual and this second edition. I also honor and thank posthumously Dr. Mary G. Bilheimer for her understanding and contributions to my education at the then-named Plymouth State College of the University of New Hampshire (now Plymouth State University).

For the first and second edition information that has endured the journey to the third edition, a special thanks lingers for the incredibly helpful radiologists of Pasadena Radiologist Associates, PA, St. Petersburg, Florida, for their many years of information (thinking out loud for me) and support (Drs. Greg Arterburn, Kit Clarke, Ronnie Pollack, and, despite his reluctance to discuss nuclear medicine, Brian Cornnell). Thanks also to Joseph Sutera, Bayfront Health, and all the teaching technologists and the many program directors who contributed ideas and opinions during the development of the first and second editions and the many people that helped develop the language translations.

For the third edition, thank you for the considerable contributions from the following: Jason Cohen (SimonMed Imaging), Heather Wharram (Charlotte Heart and Vascular Institute), Dr. Jasmin Trunzo Miller (Director of Nuclear Medicine at Keiser University, Lakeland, FL), Chantel Corbett of Fusion Physics LLC, Harold Cleveland of Cardinal Health, Whitney Green of PETNET Solutions, Karen Tinker-Emanuel and once again the "Bud-Meister." Thank you to the many students of Nuclear Medicine Technology and reviewers who contributed ideas to the first, second, and third editions of this book.

I consider and give thanks to the contributing people and institutions that chose to remain anonymous, to the many physicians, technologists, and nursing staff too numerous to mention at the various institutions for their continuing assistance, instruction, suggestions, observations, and insight. None were forgotten and all very much appreciated. At the risk of defying professional medical standards, I would like to bring to the attention of the public my appreciation for the editors and staff at Wolters Kluwer publishing company for their extraordinary support and caring during one of my most difficult times in life. Their generosity and understanding was over and beyond anything expected within the writing community. Thank you.

Disclaimer

The intention of this book since its inception in 1998 has been to allow access to an amalgamation of protocols from many institutions, technologists, physicians, and written resources. Every department has a specific method of obtaining very similar diagnostic images and results. The book serves only as a guide and to provide examples in the performance of the procedures included. The book is *not* intended to be the consummate and quintessential encyclopedia of nuclear medicine but rather a resource to be used for relatively quick access to information concerning procedures and related material. The scope of the manual covers the basic data needed for most routine imaging and includes a reference section of peripheral material utilized on a daily basis by many personnel (not only nuclear medicine) within the hospital and clinic settings. Tables, charts, and data are incorporated that are usually difficult to find quickly or in any one source bearing in mind that the values given are taken from sources with values and ranges that vary greatly from one to another. The information provided is miniscule in comparison to the available amount of material and due to size constraints, must remain so. The hope is that the readers will pursue the references used for more specific information. Institutional protocols and manufacturer's recommendations should always be followed as written when available. If ever there is a question, without question, discuss all related issues with your radiologist or nuclear physician.

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CHAPTER 1

Adrenocortical Scan

RADIOPHARMACY

Radionuclide

- ^{131}I $t_{1/2}$: 8.1 days
  Energies: 364 keV
  Type: β^-, γ, fission product

Radiopharmaceutical

- ^{131}I-6-β-Iodomethyl-19-norcholesterol (NP-59 or ^{131}I-iodocholesterol). Available for imaging since 1975 and, last known, remains under an Investigational New Drug (IND) application.

Localization

- Compartmental, blood flow, into the adrenal cortex, bound to and transported by plasma low-density lipoproteins.
- Taken up by low-density lipoprotein receptors on adrenocortical cells.
- Cholesterol is the main precursor in the production of adrenocortical steroid; NP-59 is a cholesterol analogue.

Quality Control

- Done at factory, NP-59>90%.
- Assay dosage in dose calibrator for activity.

Adult Dose Range

- 2 mCi (74 MBq).
- Some recommend 1.0 mCi (37 MBq) per 1.73 m^2 body surface area.

Method of Administration

- Intravenous slow injection over 2–3 minutes.
- Observe patient for 30 minutes after injection for reaction to injection.
- Injection may be required to be performed by a physician as per institution protocol.

INDICATIONS

- Detection and localization of adrenal glands.
- Evaluation of documented primary hyperaldosteronism (PA).
- Differentiation in PA between aldosterone-producing adenoma (APA or Conn syndrome) and bilateral adrenal hyperplasia (BAH).
- Detection and localization of abnormal adrenal function in adrenocorticotropic hormone (ACTH)–independent Cushing syndrome.
- Detection and localization of adrenal incidentalomas.
- Evaluation of adrenal lesions visualized on other imaging techniques.

- Evaluation of virilization and/or amenorrhea secondary to suspected adrenal hyperandrogenism.
- Evaluation for biopsy or surgical intervention.

CONTRAINDICATIONS

- Allergy to iodine may be a consideration, although doses are small.
- Patient taking interfering medications.
- Pregnancy or nursing. Follow institutional guidelines.

PATIENT PREPARATION

Before Day of Injection

- Physician instructs the patient to take SSKI (saturated solution potassium iodide) or Lugol solution to block free iodine uptake in thyroid. This is administered 1 drop, t.i.d., beginning the day before radiotracer administration and continuing for 10 days after injection. If there is an allergy to iodine, perchlorate may be used.
- Physician instructs the patient to take bisacodyl (e.g., Dulcolax®) 10 mg orally (PO), b.i.d. × 3 days before imaging, to reduce bowel activity. Patient may be required to take laxatives and/or enemas on afternoons before imaging days; check with radiologist.
- Physician instructs patients with atopic history (genetic disposition to hypersensitivity or allergy to medications such as iodine or steroids) to be treated with oral antihistamine (e.g., Benadryl® 50 mg) 1 hour before injection of radiotracer.

Day of Injection

- Identify the patient. Verify the doctor's order. Explain the procedure.
- Obtain signed consent from the patient and a prescription for the iodine.
- Ensure that the patient is not taking the following drugs: steroids, antihypertensives, reserpine, tricyclic antidepressants, sympathomimetics (adrenergic, stimulates release of epinephrine), and diuretics as per physician's order.

EQUIPMENT

Camera

- Large field of view

Collimator

- Medium or high energy, parallel hole

Computer Setup

Statics

- ^{131}I: 50,000 to 100,000 counts or up to 20 min/image, 10%–20% window at 364 keV

Single Photon Emission Computed Tomography (SPECT) or SPECT/CT

- 360°, 64 stops at 20 sec/stop, step and shoot or continuous

PROCEDURE (TIME: ~45 MIN/SESSION)

Single Isotope: NP-59

- Begin imaging 5 days (120 hours) after injection, followed by images on day 6 and 7 if required.
- Place the patient in supine position, with camera posterior and the kidneys centered (~12th rib).

- Collect statics to at least 100,000 counts or 5–20 minutes each.
- Obtain lateral and posterior views with markers along the spine on one of the imaging days to allow for determination of depth of each adrenal gland (5 μCi ^{131}I capsule or store injection syringe for markers until imaging is done).
- Record percent uptake using regions of interest (ROIs) for counts and correcting for depth differences. (Some processing systems have this software.)
- Determine whether SPECT images need to be taken. Check with radiologist.

Dual Isotope: NP-59 and ^{99m}Tc-DTPA

- Begin imaging 48 hours after injection and repeat at 2- to 3-day intervals until results are satisfactory.
- Place the patient in supine position, with camera posterior and renal area centered.
- Collect ^{131}I images up to 20 minutes (1200 seconds).
- Change energy window; without moving the patient, inject 5 mCi ^{99m}Tc-DTPA (diethylenetriaminepentaacetic acid) and collect 500,000–1,000,000 counts for subtraction image (computer protocol).
- Proceed with anterior views of the chest and abdomen if the adrenals are not visualized.

Procedure for Adrenocortical Scan With Suppression

- This scan differentiates bilateral hyperplasia from adenoma in hyperaldosteronism and hyperandrogenism. Unilateral visualization indicates adenoma. Bilateral visualization is indicative of hyperplasia. Dexamethasone suppresses pituitary ACTH secretion, thus embellishing NP-59 uptake into the ACTH-independent zona glomerulosa, while inhibiting NP-59 uptake into the ACTH-dependent zona fasciculata-reticularis including the ACTH-dependent, glucocorticoid-producing part of the adrenal cortex. This prevents the masking of uptake by the zona glomerulosa of the adrenal cortex, which is responsible for aldosterone production.
- Patient preparation is the same. Administer 2–4 mg dexamethasone b.i.d. beginning 2–7 days before injection of nuclide and continuing until completion of the study.
- Scan using same procedures; however, begin imaging 24–48 hours after injection.

Procedure for Adrenocortical Scan With ACTH Augmentation

- Patient preparation is the same. Administer 50 IU of ACTH IV daily beginning 2 days before radiotracer injection.
- Scan using single isotope or dual isotope procedures.

NORMAL RESULTS

- Visualization of both adrenal glands with the right slightly superior to the left.
- On posterior image, most normal patients present with the right adrenal gland showing greater intensity than the left because of the difference in depth and because the left adrenal gland is partially shielded by the kidney.
- Liver and gallbladder present brightly. If there is interference, laterals or SPECT can help localize. A fatty meal or cholecystokinin can also diminish the activity in the gallbladder.
- Colon may also visualize. Cathartics can be used to reduce colon activity.
- Dexamethasone will suppress about 50% of adrenal uptake of NP-59 that is ACTH dependent. These studies will show only faint visualization or bilateral nonvisualization by day 5. Imaging may be discontinued after the 24- or 48-hour studies.

ABNORMAL RESULTS

- In the nonsuppression study, faint visualization or nonvisualization (usually bilateral) indicates adrenal carcinoma.
- Asymmetric, bilateral, intense uptake suggests autonomous, ACTH-independent cortical nodular hyperplasia.

- Cushing syndrome produces BAH causing bilateral visual uptake of NP-59.
- Unilateral, intense uptake in the presence of known Cushing syndrome is highly suggestive of adrenal cortical adenoma.
- No uptake bilaterally in the presence of known Cushing syndrome is suggestive of carcinoma.
- In primary aldosteronism, bilateral symmetrical early visualization indicates BAH, unilateral early visualization indicates aldosterone-secreting adenoma (Conn tumor or APA), and bilateral late visualization or nonvisualization is usually nondiagnostic.
- Incidentally discovered (nonhyperfunctioning) adrenal mass lesion, with increased uptake on the same side, indicates benign nonhyperfunctioning adenoma; reduced uptake indicates a malignant lesion or infarction.
- In the suppression study, failure to suppress uptake with dexamethasone indicates adenoma if unilateral and hyperplasia if bilateral.
- In androgen excess (hyperandrogenism), also done with suppression, bilateral early visualization indicates BAH and unilateral early visualization indicates adrenal adenoma. This syndrome occurs secondary to polycystic ovarian disease and is also produced by primary adrenal cortical (zona reticularis) hyperplasia but rarely by adrenal tumors.

ARTIFACTS

- Attenuating articles in clothing.
- Images not taken for enough counts.
- Focal areas of interest usually linger over time and grow in intensity. False-positive results can be limited by delayed images and lateral views.
- Bilateral uptake in patients with unilateral disease—spironolactone and other diuretics.
- Early bilateral uptake in patients with no disease or unilateral disease—oral contraceptives. May occur even with dexamethasone suppression.

NOTE

- The adrenal cortex makes up about 90% of the adrenal gland. It contains three zones: (1) The zona glomerulosa, which is the outermost, produces aldosterone, the principal mineralocorticoid hormone. (2) The zona fasciculata produces cortisol, the principal glucocorticoid hormone. (3) The zona reticularis produces androgenic steroids, principally androstenedione.
- The adrenal medulla secretes the catecholamines epinephrine and norepinephrine.
- Secretion from the adrenal cortex is controlled by ACTH from the anterior pituitary. The exception is aldosterone from the zona glomerulosa, which is controlled by angiotensin II, blood volume, and electrolyte concentrations. Cholesterol is stored in the cortex as the metabolic precursor for the synthesis of adrenocorticosteroids, e.g., aldosterone. NP-59 uses the similarity to cholesterol for uptake into the cortex. Increased ACTH increases the uptake, occurring gradually over a period of days.
- Adrenal venous sampling (AVS) is considered the standard of reference for determining the cause of primary aldosteronism. AVS is technically difficult particularly in cannulation of the right adrenal vein which directly drains into the inferior vena cava.

PATIENT HISTORY

The patient should answer the following questions. (Or use complete patient history in reference section.)		
Do you have a history of hypertension or hypotension?	Y	N
Do you have a history or family history of cancer?	Y	N
Have you had any recent weight gain?	Y	N
Have you experienced hirsutism (abnormal hair growth)?	Y	N

Have you had any chemotherapy or radiation therapy?	Y	N
Have you had any recent examinations such as computed tomography (CT), ultrasonography (US), or magnetic resonance imaging (MRI)?	Y	N
If so, when and what facility?		
What medications are you currently taking?		
Have you had any recent blood or laboratory work done (of interest will be cholesterol levels, ACTH, aldosterone, catecholamines and metabolites, plasma renin activity, blood sugar)?	Y	N
Female patients:		
Are you pregnant or nursing?	Y	N
When was your last menstrual period?		
Have you experienced amenorrhea (suppression of menstruation)?	Y	N
Other department-specific questions:		

STUDENTS

Explain the relevancy of each of the above patient history questions to this particular scan. Can you think of others that would be helpful for the interpretation of this type of study?

SUGGESTED READINGS

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NOTES

CHAPTER 2

Adrenal Medulla

Pheochromocytoma Scan (mIBG)

RADIOPHARMACY

Radionuclide

- ^{123}I $t_{1/2}$: 13.2 hours
  Energies: 159 keV
  Type: EC, γ, accelerator
- *or* ^{131}I $t_{1/2}$: 8.1 days
  Energies: 364 keV
  Type: β^-, γ, fission product

Radiopharmaceutical

- ^{123}I- or ^{131}I-mIBG (-*meta*-iodobenzylguanidine). Both pharmaceuticals, ^{123}I-iobenguane and ^{131}I-iobenguane, are FDA (U.S. Food and Drug Administration) approved. Also known as iobenguane sulfate or AdreView™.

Localization

- Blood flow, guanethidine analogue absorbed much the same as norepinephrine into the chromaffin cells of the adrenergic tissue and stored in adrenergic granules.

Quality Control

- ^{123}I- and ^{131}I-mIBG > 90%

Adult Dose Range

- ^{131}I: 500 μCi (18.5 MBq), 1 mCi (37 MBq) for suspected metastatic pheochromocytoma
- ^{123}I: 3-15 mCi (111–555 MBq)

Method of Administration

- Intravenously injected slowly over 5 minutes, if possible followed by a 10 mL saline flush.

INDICATIONS

- Detection and localization of benign and malignant intra-adrenal and extra-adrenal pheochromocytomas (usually benign chromaffin cell tumors of the sympathoadrenal system that produce and secrete catecholamines, e.g., norepinephrine and epinephrine, producing hypertension and orthostatic [standing] hypotension). These occur within the

adrenal medulla and are frequently associated with hereditary multiple endocrine neoplasia (MEN) types 2A and 2B, neurofibromatosis, von Hippel-Lindau disease, Carney triad, and familial pheochromocytoma.
- Localization of site(s) of hormonal overproduction.
- Detection and localization of neuroectodermal (nerve tissue) tumors.
- Detection and localization of neuroblastomas (malignant hemorrhagic tumors of cells resembling neuroblasts of the sympathetic system, especially the adrenal medulla, and usually occurring in childhood).
- Detection and localization of other neuroendocrine tumors that share the property of amine precursor uptake in decarboxylation (APUD), such as
  - Carcinoid (argentaffin cells of the intestinal tract, bile ducts, pancreas, bronchus, or ovary that secrete serotonin) tumors
  - Medullary thyroid tumors
  - Paragangliomas (tumors of the adrenal medulla, chromaffin cells, and the paraganglia)
  - Merkel cell skin tumors
  - Chemodectomas (tumors of the chemoreceptor system)
  - Small cell lung carcinoma
  - Schwannoma
- Evaluation of myocardial norepinephrine receptors.
- Distinguishing neuroendocrine tumors from nonneuroendocrine tumors.
- Detection and localization of metastatic deposits from previously diagnosed pheochromocytoma.
- Staging of the disease.
- Evaluation of chemotherapy and to exclude subclinical relapse in bone marrow or bone pain.
- Evaluation of surgery.

CONTRAINDICATIONS

- Allergy to iodine may be a consideration, although doses are small.
- Patient taking interfering medications.
- Pregnancy or nursing. Follow institutional guidelines.

PATIENT PREPARATION

Before Day of Injection

- Three days prior to injection, physician may (if applicable) instruct patient to discontinue the use of certain medications including tricyclic antidepressants, antihypertensives, cocaine products, sympathomimetics, and decongestants containing pseudoephedrine, phenylpropanolamine and phenylephrine.
- Physician instructs the patient to take SSKI (saturated solution potassium iodide) or Lugol solution to block free iodine uptake in thyroid. This is administered 1 drop, t.i.d., beginning the day before radiotracer administration and continuing for 6 days after injection. If there is an allergy to iodine, perchlorate may be used.
- Physician instructs the patient to take bisacodyl (e.g., Dulcolax®) 10 mg PO, b.i.d. × 3 days before imaging, to reduce bowel activity. Patient may be required to take laxatives and/or enemas on afternoons before imaging days; check with radiologist.
- Physician instructs patients with atopic history (genetic disposition to hypersensitivity or allergy to medications such as iodine or steroids) to be treated with an oral antihistamine (e.g., Benadryl® 50 mg) 1 hour before injection of radiotracer.

Days of Injection

- Identify the patient. Verify doctor's order. Explain the procedure.
- Obtain signed consent from patient and a prescription for the iodine.

- Ensure that the patient is not taking the following drugs: steroids, antihypertensives, reserpine, tricyclic antidepressants, sympathomimetics (adrenergic, stimulates release of epinephrine),and diuretics as per physician's order. Ideally, no medications for 2–3 weeks before the examination (see Drugs to Withhold).

EQUIPMENT

Camera

- Large field of view

Collimator

- ^{131}I: High energy, general purpose, or high energy, high resolution
- ^{123}I: Low energy, all purpose, or low energy, high resolution

Computer Setup

Statics

- ^{131}I: 100,000 counts or 10 to 20 min/image, 20% window at 364 keV, 512 × 512 or 256 × 256 matrix
- ^{123}I: 500,000 counts or 10 to 20 min/image, 20% window at 159 keV, 512 × 512 or 256 × 256 matrix

Whole Body

- 5–10 cm/min, image at least head to pelvis, same setup

Single Photon Emission Computed Tomography (SPECT) or SPECT/CT

- 360°, 120 or 60 stops at 25–45 sec/stop, ^{131}I: 20% window at 364 keV, ^{123}I: 20% window at 159 keV, 128 × 128 or 64 × 64 matrix, step and shoot or continuous, circular or noncircular orbit.

PROCEDURE (TIME: ~30–60 MIN/SESSION)

- Ensure patient is off medications and has taken thyroid blocker the night before.
- Instruct patient to empty the bladder.
- Place patient in supine position.

^{131}I-mIBG: Images at 24, 48, and Possibly 72 Hours

- Acquire anterior/posterior images of the head/neck, thorax, abdomen, and pelvis.
- Set whole-body sweep slow (10 cm/min or less).
- Acquire static images of areas of interest if preferred or protocol. Statics should run at least 100,000 counts or 5–20 minutes.
- Acquire lateral views of abnormal uptake to aid in localization.
- Acquire marker images if protocol (on axillae, lower ribs, and iliac crests). Use 5 μCi ^{131}I capsule or perhaps store injection syringe for markers until imaging is done.
- Acquire SPECT images if protocol or requested.

^{123}I-mIBG: Images at 24 Hours, 40 Hours, and Possibly 72 Hours

- Same imaging procedures as above.
- Acquire statics of at least 500 k counts or 15 minutes each.
- Statics should at least include the chest, posterior mid-thorax, kidneys centered, and lumbar.

- Whole-body sweep at 10 cm/min or less, anterior/posterior, head to pelvis.
- SPECT images at 45–60 sec/stop.

NORMAL RESULTS

- Uptake occurs in the pituitary, salivary glands, thyroid, liver, and spleen.
- The gallbladder will be visualized in patients with renal failure.
- The kidneys and bladder will visualize because of the renal excretion.
- The heart is visualized in patients with normal catecholamine levels.
- Diffuse lung activity and nasal, neck muscle, and bowel activity may present in some patients.
- The normal adrenal medulla seldom visualizes (30%–40% on delayed images) and is of low intensity.
- The heart and adrenal medulla are visualized more clearly with ^{123}I-mIBG.
- There should be no skeletal uptake.
- Areas of normal uptake diminish in intensity over time.

ABNORMAL RESULTS

- Focal areas of increased activity that increase more over time occur.
- Sporadic, unilateral tumors show focal intense uptake.
- Metastatic disease is visualized in the axial skeleton, heart, lung, mediastinum, lymph nodes, and liver.
- Neuroblastomas may arise in any location of sympathetic nervous system tissue but most often are visualized as an abdominal mass, metastasizing early to bone and bone marrow.
- Images at 72 hours will provide maximal contrast between foci of activity and background.
- Localizes in pheochromocytoma, neuroblastoma, and also carcinoid, medullary thyroid carcinoma, and paraganglioma.

ARTIFACTS

- Attenuating articles in clothing.
- Images not taken for enough counts.
- Aggressive chemotherapy may hinder the visualization of some metastasis.
- False-positive results may be caused by recent surgical sites, x-ray therapy to the lungs, and bleomycin-induced pulmonary changes.
- False-negatives can be due to lesions too close to large primary or metastatic mass or tissue with high normal uptake. No or low tumor uptake related to tumor heterogeneity, ischemic necrosis in tumor mass, lack of granules, loss of tumor capacity to absorb tracer, or pharmaceutical inhibition.
- Focal areas of interest usually linger over time and grow in intensity. Limit false-positive results by delayed images (with obliques and laterals).
- Because of the nature of the disease and because they are off medications, patients may be agitated and not lie still.

DRUGS TO WITHHOLD (IDEALLY, NO MEDICATIONS 2–3 WEEKS BEFORE THE EXAMINATION)

For 3 Weeks (Affect Reuptake Mechanism Presenting With Absence of Uptake by the Salivary Glands and Heart and May Inhibit Uptake in Pheochromocytoma)

- Tricyclic antidepressants: e.g., reserpine
- Sympathomimetics: e.g., dobutamine, dopamine, norepinephrine

For 2 Weeks (Affect Depletion of Storage Vesicle)

- Amphetamines
- Angiotensin-converting enzyme (ACE) inhibitors (captopril, enalapril)
- Angiotensin receptor blockers (ARBs) (irbesartan, valsartan)
- Bretylium tosylate
- Calcium channel blockers (nifedipine, nicardipine, amlodipine)
- Cocaine
- Digoxin
- Fenoterol
- Guanethidine
- Haloperidol
- Imipramine
- Insulin
- Phenothiazine
- Pseudoephedrine (nasal decongestants)
- Phenylpropanolamine (diet-control drugs)
- Phenylephrine (nasal decongestants)
- Salbutamol
- Terbutaline
- Thiothixene
- Xylometazoline

Alpha- and beta-adrenergic blocking drugs will not affect study with the exception of labetalol (affects both reuptake and storage depletion).

NOTE

- mIBG is similar to the catecholamine norepinephrine. Epinephrine and norepinephrine are hormones that regulate smooth muscle tone, heart rate and force of contraction, and physiologic responses associated with stress. Pheochromocytomas produce excess amounts of these hormones resulting in hypertension and other symptoms associated with overabundance of catecholamines.
- Renal and skeletal imaging with ^{99m}Tc agents can be used in conjunction with this test to aid in localization. Their injections can be timed for optimal scan times at the 24- or 48-hour images with two sets of images taken by changing the energy windows to suit the radiotracer.

PATIENT HISTORY

The patient should answer the following questions. (Or use complete patient history in reference section.)		
Do you have a history or family history of cancer?	Y	N
If so, what type and for how long?		
Do you have a history of hypertension or hypotension?	Y	N
Do you have palpitations?	Y	N
Have you felt anxiety or apprehension?	Y	N
Have you experienced excessive diaphoresis (sweating)?	Y	N
Do you have headaches?	Y	N
Have you experienced a flushed face?	Y	N
Do you experience nausea or vomiting?	Y	N

Have you experienced tingling of extremities?	Y	N
Are you taking oral contraceptives?	Y	N
Have you had any recent surgery?	Y	N
If so, where and when?		
Have you had any chemotherapy or radiation therapy?	Y	N
Are there any recent or planned positron emission tomography (PET), computed tomography (CT), ultrasonography (US), magnetic resonance imaging (MRI), or nuclear medicine (NM) scans?	Y	N
What medications are you taking?		
Have you had any recent laboratory reports (with attention to adrenocorticotropic hormone, aldosterone, catecholamines, and metabolites, Na, K)?	Y	N
Female: Are you pregnant or nursing?	Y	N
Other department-specific questions:		

STUDENTS

Explain the relevancy of each of the above patient history questions to this particular scan. Can you think of others that would be helpful for the interpretation of this type of study?

SUGGESTED READINGS

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NOTES

CHAPTER 3

Bone Density

Densitometry

RADIOPHARMACY

Radionuclide

- Single radionuclide: ^{125}I $t_{1/2}$: 60.1 days
  Energies: 23–31 keV
  Type: EC, x, γ, accelerator
- *or* ^{241}Am (americium) $t_{1/2}$: 432.7 years
  Energies: 60 keV
  Type: α, γ, spontaneous fission product.
- Dual radionuclide: ^{153}Gd (gadolinium) $t_{1/2}$: 241.6 days
  Energies: 44, 100 keV (γ); 35, 70 keV (x-ray)
  Type: x, γ, neutron irradiation of ^{152}Gd

Radiopharmaceutical

- N/A

Localization

- N/A

Quality Control

- Daily calibration measurement using the supplied phantom following manufacturers' recommendations. The accuracy error percentage between the measurement and the defined standard supplied by the manufacturer should be within 5–10%.

Adult Dose Range

- N/A

Method of Administration

- Exposure to, not administration by injection.

INDICATIONS

- Detection of osteoporosis.
- Monitoring and evaluation of treatment programs for osteoporosis (e.g., estrogen, progesterone, testosterone replacement, calcitonin therapy, exercise, or pharmacologic interventions with vitamins).
- Evaluation of osteopenia (diminished bone tissue).
- Evaluation of effect of menopause and premature spontaneous menopause on bone density (for hormone therapy management).
- Evaluation for premenopausal oophorectomy.