Nuclear Medicine Protocols

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Revised 1/16/2013
INFECTION CONTROL

In order to prevent contamination with blood products, the following protocol is to be observed:

1. All personnel administering intravenous radionuclides, radiopharmaceuticals, or intramuscular injections are to wear gloves at all times.
2. All personnel performing in vitro procedures are to wear gloves at all times when blood is withdrawn and to wear gloves when handling blood containing products or their derivatives in test tubes.
3. In the unfortunate circumstance of any personnel accidentally contaminating themselves with a needle after performing a procedure on a patient they are to inform Employee Health and their supervisor. Normal hospital protocol will then be initiated.
4. All personnel are advised that the hepatitis vaccine is available.
5. Universal precautions outlined below are to be observed at all times.

Universal Precautions

Because the potential for infectivity of any patient's blood and body fluids cannot be known, blood and body fluid precautions recommended by the Centers for Disease Control (CDC) should be adhered to for all patients and for all specimens submitted to the laboratory. These precautions, called "universal precautions," should be followed regardless of any lack of evidence of the patient's infection status.

Universal precautions as enunciated by the CDC consist of the following 14 points:
1. Routinely use barrier protection to prevent skin and mucous membrane contamination with blood or body fluids of all patients and specimens.
2. Wear gloves when:
   • touching blood and body fluids, including during routine laboratory work and phlebotomy,
   • touching all laboratory specimens and tissues,
   • touching mucous membranes and nonintact skin of all patients
   • handling items contaminated with blood or body fluids, including specimen containers, laboratory instruments, counter tops, etc.,
   • performing venipuncture, arterial puncture, skin puncture, and other vascular access procedures.

Note: All skin defects (cuts, abrasions, ulcers, areas of dermatitis, etc.) should be covered with an occlusive bandage.
3. Change gloves between each patient.
4. Wear a mask and eye covering, or preferably a face shield, during procedures that are likely to generate droplets of blood or body fluids to prevent exposure of the mucous membranes of the mouth, nose, and eyes.
5. Wear a gown, apron, or other covering when there is a potential for splashing or spraying blood or body fluids.
6. Wash hands or other skin surfaces thoroughly and immediately if contaminated with blood or body fluids.
7. Wash hands immediately after gloves are removed.
8. Take extraordinary care to avoid accidental injuries caused by needles, scalpel blades, laboratory instruments, etc. when performing procedures, cleaning instruments, handling sharp instruments, and disposing used needles.
9. Place used needles, skin lances, scalpel blades, and other sharp items into a puncture-resistant biohazard container for disposal. The container should be located as close as possible to the work area. Phlebotomists should carry puncture-resistant containers with them.
10. To prevent needle stick injuries, needles should not be recapped, purposely bent, cut, broken, removed from disposable syringes, or otherwise manipulated by hand.
11. Place large-bore reusable needles (e.g., bone-marrow needles and biopsy needles) and other reusable sharps into a puncture-resistant container for transport to the reprocessing area.
12. Minimize the need for mouth-to-mouth emergency resuscitation procedures. Mouth pieces, resuscitation bags, or other ventilation devices should be used routinely.
13. Take care to minimize the formation of droplets, spatters, splashes, and spills of blood or body fluids.
14. Clean all surfaces exposed to blood and body fluids with a detergent solution followed by decontamination with an appropriate EPA-approved chemical germicide.

Laboratory workers with exudative lesions or weeping dermatitis should refrain from all patient contact and from handling patient-care equipment and patient specimens until the condition resolves.

Note: Alternative, skin lesions should be covered with an occlusive bandage to prevent contamination.

Pregnant women are not known to be at greater risk of contracting blood-borne infections than other laboratory workers. However, if HIV infection develops during pregnancy, the infant is at risk of infection by perinatal transmission. Therefore, pregnant laboratory workers should be especially aware of universal precautions.

Isolation Categories:
Implementing universal precautions eliminates the need for using the isolation category "Blood and Body Fluid Precautions" previously recommended by the CDC for patients known to be or suspected of being infected with blood-borne pathogens. Isolation precautions (e.g., enteric or acid-fast bacillus) should be used as necessary if associated conditions (e.g., infectious diarrhea or tuberculosis) are suspected or diagnosed.
INTRAVENOUS RADIO PHARMACEUTICAL ADMINISTRATION POLICY

1. **Venipuncture** - Registered Nuclear Medicine Technologists and Nuclear Medicine Student Technologists may perform venipuncture after successfully completing:
   a. Clinical supervision by the IV team in performing three (3) successful venipunctures (Clinical supervision may be performed by a designated trainer in Radiology)
   b. A technologist will not attempt venipuncture more than three (3) times on a patient.

2. **Intravenous Radiopharmaceuticals** may be administered by the Nuclear Medicine Technologist and Nuclear Medicine Student Technologist after a patient history is obtained:
   a. History of allergies to previous radiopharmaceutical administration. **If patient has a positive history, the Physician must be notified and present.**
   b. History of previous radiopharmaceutical administration
   c. Determine the appropriate amount of radiopharmaceuticals to be administered according to the Procedures Manual.

   If there are any problems with the patient, the Radiologist will be notified immediately; if problems are severe a STAT should be called and the Radiologist notified.

3. **Administering Radio pharmaceuticals through existing IV port:**
   a. Check IV site for patency and check the solution being administered for contraindications: **Never administer through a TPN or PIC line or with lipids.**
   b. Clamp off tubing at closest site to patient
   c. Inject appropriate dose of radiopharmaceutical
   d. Monitor site for infiltration
   e. Unclamp Tubing
   f. Assure proper IV flow continues

4. **Administering Radio pharmaceuticals through Heparin Lock:**
   **Do Not** use heparin flush kits on children under 1 year.
   a. Check site for patency
   b. Flush with 1 ml normal saline (use heparin flush kits)
   c. Administer appropriate dose of Radiopharmaceuticals
   d. Flush with 1 ml normal saline
   e. Flush with 1.0 ml heparinized normal saline, **a solution of 10u heparin per 1 ml normal saline.** (Neonate concentration: 30u heparin/10 ml. of non-bacteriostatic normal saline = 3u/ml. Volume not to exceed 1 ml.)

5. **Administering Radio pharmaceuticals through Central Line:**
   a. Check site for patency; if capped off check for blood return
   b. Flush line with 10cc normal saline
   c. Inject Radiopharmaceutical
d. Flush line with 10cc normal saline
e. Flush line with 2.5cc heparinized saline

6. Administering Radio pharmaceuticals through Portacath:
Portacath must have access to an external connection with a "t" connector; if not, call IV therapy nurses for assistance. **Must use 12 cc syringe for injection.**

**Must use strict hand washing prior to beginning procedure.** The connection should be cleansed with Betadine or alcohol.

a. Check for blood return
b. Flush line with 5cc normal saline
c. Flush line with 2.5cc heparinized saline
d. Flush line with 10cc normal saline
e. Inject Radiopharmaceutical
f. Flush 4.5cc heparinized saline (1cc/1000u in 10ml sterile saline), withdrawing syringe while infusing last 1cc.

7. Use of Multidose Vial:

a. Commercially prepared multidose vials must be dated when opened. The expiration date should be noted and the unit discarded when expired.

b. Any opened multidose vial that is not dated should be discarded immediately.

c. Multidose vials of saline or water that does not contain preservatives should be discarded after single use.

d. Multidose vials of substances containing preservatives should be kept at room temperature or refrigerated according to label and discarded after one month.

8. Discontinuing IV

If IV is not functioning, it may be discontinued and removed. The nurse caring for the patient should be notified.

9. IV Pump Alarms

Always check pump when alarm sounds, determine problem and correct it.
Call Radiology Nurse for assistance whenever possible, i.e.:
- Battery low - plug in
- Infusion Complete - increase volume by adding twice the set rate, ensuring there is enough solution (Call Nurse to verify infusion amount).
- Air in line - determine location of air and try to aspirate it out.

**Infection Control Policy: Injection of Blood Products**

**Intravenous Administration of Radiopharmaceuticals/Blood or Blood Products**

1. All personnel administering intravenous radionuclides, radiopharmaceuticals, or blood/blood products are to receive proper training and routine in-service education on infection control procedures.
2. All doses and syringes are to be examined for proper identification and radioassayed before injection.

3. All syringes are to be labeled with appropriate information: patient name, medical record number, radiopharmaceutical, dosage, assay time, and the initials of dose preparer.

4. Blood used in the preparation of indium-labeled white cells is to be drawn from and reinjected into the patient by the same person to verify the correct patient administration.

   If the same person is not available for the reinjection of the labeled white cells, two persons will be present to cross-check all labeling of the product to be injected, the prescription, and patient identification.

5. When red blood cells are tagged for nuclear procedures, both the mixing vial or syringe and the lead shielding container are to be labeled with a printed label. The Radiopharmacy is to furnish a duplicate prescription label for this purpose.

   The same procedure described in (4) applies to the injection of tagged red blood cells.

6. All injection procedures are to be documented. Documentation must include the date, name, amount of radiopharmaceutical, the route of administration, identification of the administering person, and the time of administration. This information is to be recorded on the nuclear medicine requisition and the report of exam in the patient record.

7. An administration error must be reported immediately to supervisory personnel. Departmental and hospital protocol will then be initiated.

OSHA GUIDELINES FOR BLOOD AND BODY FLUIDS

In March 1992, a federal law was passed to protect employees from unnecessary exposure to Blood and Body fluids. These standards will be monitored by OSHA. Vanderbilt and all of its employees must comply with all aspects of this law. Failure to comply will result in Vanderbilt being fined up to $15,000 per occurrence. We must recognize that there is an increase in Hepatitis B and HIV in healthcare workers and take all precautionary steps to prevent transmission of diseases.
The application of "Universal Precautions" is not an option. They are required by law and it is the responsibility of all employees to observe them.

*** COMPLIANCE PROTECTS YOUR LIFE. ***

The following requirements are mandatory for all Staff and Physicians at Vanderbilt:

Designated work areas must be defined - these areas mean that **no one** may **eat, drink, apply lip balm, or remove/insert contact lenses** in the work area. Designated work areas are defined with a border of Yellow tape. All staff must be aware of the hallway in Special Procedures and not cross the yellow line with food or drinks.

Personal Protective Equipment (PPEs) will be stored in a designated area in every exam room. PPEs include gowns, gloves, goggles, and masks. Supplies should be replaced as needed by the staff in the exam room. If you have special needs for PPEs (e.g. powderless gloves or glove lines, proper sizes - contact your supervisor) PPEs must be **REMOVED BEFORE LEAVING THE WORK AREA.** (No boots, hats, masks around the neck may be worn in cafeteria or out of immediate work area)

It is **imperative** that if you feel you may be splashed or exposed to blood or body fluids that you have protective equipment on. One-piece shields are available that will serve as mask and goggles. Masks and goggles must be worn **whenever** there is a possibility of a splash - you may not wear only goggles. ( Masks by themselves may be worn only for respiratory preventions)

**HANDWASHING** is **crucial** after removing PPEs. Please remember that **HANDWASHING** is the **best** prevention for transmission of infections. This should be done whenever you remove your PPEs and gloves.

Steps to take if you are exposed to:

**Blood or infectious materials**
1. Must remove contaminated clothing (soiled uniform should be placed in a yellow linen bag and hand walked to the linen department located in B704 VUH. The bag should have the employee's name and department. The employee will be contacted by the Linen Department to pick up the uniform.
2. Wash/rinse area thoroughly
3. Report work injury - Notify supervisor, complete the Tennessee Work Injury Report, Call Occupational Health and explain the exposure within 2 hours of exposure (if after hours, call the ER - you must still notify Occupational Health for a follow up visit).

*If the exposure is to a positive source of HIV - you will be offered the drug AZT.* The medical records generated by an occupational exposure incident and vaccination records must be kept confidential for the duration of employment plus 30 years.

**Blood spills**
1. Wear gloves.
2. Blot blood with absorbent material.
3. Discard material in a "RED" biohazard bag.
4. Use disinfectant on the Area.
   Proper disinfectants are: Clorox - fresh solution 2 parts water and 1 part Clorox, ORCS spray and the germicide towelettes.

**All infectious wastes and PPEs must be placed in the disposable Red bags. All contaminated linens must be placed in the linen bag. Gloves should be worn whenever handling infectious wastes. Place linens in a leak proof bag if soaking is likely.**

NEVER RECAP NEEDLES WITH 2 HANDS!! There are special needle holders available in exam rooms to allow for the recapping of needles when necessary. All sharps must be placed in a Red Sharps container. They must be as close as possible to the point of use and should not be full. Gloves should be worn whenever handling sharps. Needles should not be recapped and the sharps must be placed in needle box immediately after use.

Hepatitis B vaccinations are offered to all employees that are at risk to exposure to blood or body fluids. This is obtained at Occupational Health on a walk in basis, free of charge.

Proper cleaning of all imaging equipment must not be neglected. Cassettes, exam tables, lead aprons, lead gloves, gonad shields, restraint devices and positioning tools should be cleaned whenever contaminated with body fluids and on a frequent basis.

We must all remember that compliance is mandatory and will be effective at prevention of unwanted diseases.
URINARY CATHETER CARE FOR PATIENTS WHILE IN NUCLEAR MEDICINE

1. Always check to see if a patient has a catheter. Many times, they are covered up and not visible to the technologists.
2. Take care not to pull catheter out when moving patient from wheelchair or stretcher to scanning table.
3. Once patient is on scanning table be sure the bag is hung beneath the table, but not too far as to cause pulling, making the patient uncomfortable.
   Note: Should catheter either come unplugged (disconnection between bag and catheter) or pulled out of the bladder completely, notify the nuclear medicine physician and then call the floor notifying the charge nurse, who will in turn call the intern or residents assigned to the particular patient.
4. Take care when assisting patient back to wheelchair or stretcher. Make sure bag goes with patient.
5. Make sure that the catheter bag is always kept below the level of the bladder to prevent backflow of urine from the bag into the patient's bladder.

Policy for Pregnant Patients

1. All Nuclear Medicine procedures should be scheduled during the first 10 days after last menstrual period in childbearing age women, if possible.
2. If a pregnant patient is scheduled for a Nuclear Medicine procedure, the patient should be immediately referred to the Nuclear Medicine physician. The risks and benefits of the procedure will be discussed with the referring physician and the patient, and a decision to perform the study will be made in the best interest for the patient.
3. A written informed consent should be obtained from all female patients under age 55 and above age 12 as per the following form.
NUCLEAR MEDICINE WARNING CERTIFICATE

The following is to be read by all female patients over age 11 when scheduled for Nuclear Medicine scans.

"Diagnostic scans taken during pregnancy may pose some risk to the unborn child. You are asked to inform the Nuclear Medicine Technologist if there is ANY possibility that you may be pregnant. Please sign the statement below if you are not pregnant and not currently breastfeeding. Radioisotopes may be excreted into the new mother's milk and thus present some risk to the breast-fed infant."

"I CERTIFY THAT, TO THE BEST OF MY KNOWLEDGE, I AM NOT PREGNANT AND I AM NOT BREAST FEEDING AS OF THIS DATE."

________________________________________
Date                                                    Signature of Patient

MRN of Patient __________________

Technologist: _________________________________ CNMT

Radiology
OF HUNTSVILLE
PEDIATRIC RADIOPHARMACEUTICAL DOSES

Pediatric radiopharmaceutical doses used by D.L. Gilday, M.D., at the Hospital for Sick Children are determined from the table below.

The standard adult dose used in the hospital is listed as 100%, and the body weight in kilograms is plotted on the curve that results in a dose per body surface area.

(Approximate weight in kg. = 2 x age + 8)
## VUMC Radiopharmaceutical Doses

<table>
<thead>
<tr>
<th>Organ</th>
<th>Scan</th>
<th>Agent</th>
<th>VUMC dose activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bone</td>
<td>Bone Scan</td>
<td>$^{99m}$Tc-HDP</td>
<td>20-25 mCi</td>
</tr>
<tr>
<td></td>
<td>Bone marrow</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>8-12 mCi</td>
</tr>
<tr>
<td>2. Brain</td>
<td>Brain scan</td>
<td>$^{99m}$Tc-glucoheptonate</td>
<td>25 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-Ceretec (HMPAO)</td>
<td>18-22 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-Neurolite (ECD)</td>
<td>18-22 mCi</td>
</tr>
<tr>
<td>3. CSF</td>
<td>Cisternogram</td>
<td>$^{111}$In DTPA</td>
<td>0.45-0.55 mCi</td>
</tr>
<tr>
<td></td>
<td>Shuntogram</td>
<td>$^{99m}$Tc-DTPA</td>
<td>1.3-1.7 mCi</td>
</tr>
<tr>
<td>4. Kidney</td>
<td>Profile</td>
<td>$^{99m}$Tc-DTPA-GFR</td>
<td>0.8-1.1 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-DTPA-bolus</td>
<td>15-20 mCi</td>
</tr>
<tr>
<td></td>
<td>DMSA scan</td>
<td>$^{99m}$Tc-DMSA</td>
<td>4-6 mCi</td>
</tr>
<tr>
<td></td>
<td>DTPA flow</td>
<td>$^{99m}$Tc-DTPA</td>
<td>15-20 mCi</td>
</tr>
<tr>
<td></td>
<td>Tc$_{04}$</td>
<td>$^{99m}$Tc$_{04}$</td>
<td>15-20 mCi</td>
</tr>
<tr>
<td></td>
<td>Gluco Renogram</td>
<td>$^{99m}$Tc-Gluco</td>
<td>15-20 mCi</td>
</tr>
<tr>
<td></td>
<td>MAG$_3$</td>
<td>$^{99m}$Tc-MAG$_3$</td>
<td>6-11 mCi</td>
</tr>
<tr>
<td>5. Thyroid</td>
<td>Cystogram</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>0.45-0.55 mCi</td>
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<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc 0$_4$</td>
<td>5-16 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{123}$I Na I</td>
<td>0.2-0.5 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{131}$I Na I</td>
<td>80-110 microCi</td>
</tr>
<tr>
<td></td>
<td>Thyroid uptake</td>
<td>$^{131}$I Capsule</td>
<td>10-30 microCi</td>
</tr>
<tr>
<td></td>
<td>Parathyroid</td>
<td>$^{99m}$Tc sestamibi</td>
<td>15-25 mCi</td>
</tr>
<tr>
<td>6. Lung</td>
<td>Perfusion/venogram</td>
<td>$^{99m}$Tc-MAA</td>
<td>2-6 mCi</td>
</tr>
<tr>
<td></td>
<td>Ventilation</td>
<td>$^{99m}$Tc-DTPA aerosol</td>
<td>30-40 mCi</td>
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<tr>
<td></td>
<td>DVT</td>
<td>$^{99m}$Tc-apcitide</td>
<td>25-30 mCi</td>
</tr>
<tr>
<td>7. Liver</td>
<td>Liver/spleen scan</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>3-6 mCi</td>
</tr>
<tr>
<td></td>
<td>Hepatobiliary</td>
<td>$^{99m}$Tc-Disida (PRIDA)</td>
<td>2-5 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-mebrofenin</td>
<td>2-5 mCi</td>
</tr>
<tr>
<td></td>
<td>Hepatic perfusion</td>
<td>$^{99m}$Tc-MAA</td>
<td>3-5 mCi</td>
</tr>
<tr>
<td>8. Esophagus-stomach</td>
<td>Gastric reflux</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>0.3-0.6 mCi</td>
</tr>
<tr>
<td></td>
<td>Gastric emptying</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>0.3-0.6 mCi</td>
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<tr>
<td>9. GI</td>
<td>GI blood</td>
<td>$^{99m}$Tc-RBCs20 mCi</td>
<td>20-25 mCi</td>
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<td>10. Meckel's diverticulum</td>
<td>Meckel's</td>
<td>$^{99m}$Tc$_{04}$</td>
<td>5-11 mCi</td>
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<tr>
<td>11. Abscess</td>
<td>Gallium scan</td>
<td>$^{67}$Ga citrate</td>
<td>5-11 mCi</td>
</tr>
<tr>
<td></td>
<td>$^{111}$In leukocytes</td>
<td>$^{111}$In-WBC</td>
<td>0.3-0.7 mCi</td>
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<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc- HMPAO-WBC</td>
<td>20-27 mCi</td>
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<td>12. Scrotal scan</td>
<td>scrotal scan</td>
<td>$^{99m}$Tc$_{04}$</td>
<td>15-21 mCi</td>
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<td>13. Lymphangiography</td>
<td>sentinel node Dx</td>
<td>$^{99m}$Tc -SC filtered</td>
<td>0.3-0.6 mCi</td>
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<td></td>
<td></td>
<td>$^{99m}$Tc -SC filtered</td>
<td>0.2-0.8 mCi</td>
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<td>14. Heart</td>
<td>myocardial infarct</td>
<td>$^{99m}$Tc-pyrophosphate</td>
<td>15-21 mCi</td>
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<td>Perfusion</td>
<td>$^{201}$TI chloride</td>
<td>3-5 mCi</td>
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<tr>
<td></td>
<td>RVG</td>
<td>$^{99m}$Tc 0$_4$</td>
<td>15-25 mCi</td>
</tr>
<tr>
<td></td>
<td>Perfusion</td>
<td>$^{99m}$Tc sestamibi</td>
<td>7-30 mCi</td>
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<tr>
<td></td>
<td>Perfusion</td>
<td>$^{99m}$Tc tetrofosmin</td>
<td>7-30 mCi</td>
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<tr>
<td></td>
<td>Viability</td>
<td>$^{18}$FDG</td>
<td>8-11 mCi</td>
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<td>15. Schilling</td>
<td>Schilling</td>
<td>$^{57}$Co</td>
<td>0.3-0.9 microCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{58}$Co</td>
<td>0.1-1.5 microCi</td>
</tr>
<tr>
<td>16. Blood volume</td>
<td>Red cell mass</td>
<td>$^{51}$chromium</td>
<td>30 microCi</td>
</tr>
<tr>
<td></td>
<td>Plasma volume</td>
<td>$^{125}$I HSA</td>
<td>10 microCi</td>
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<tr>
<td>17. Tumor imaging</td>
<td>Octreoscan</td>
<td>$^{111}$In-octreotide</td>
<td>5-7 mCi</td>
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<tr>
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<td></td>
<td>$^{99m}$Tc sestamibi</td>
<td>20-27 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{201}$TI chloride</td>
<td>3-5 mCi</td>
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<tr>
<td>Thyroid</td>
<td>$^{131}$I Na I</td>
<td>2-10 mCi</td>
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<td></td>
<td>$^{131}$I MIBG</td>
<td>0.3-1.0 mCi</td>
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<tr>
<td></td>
<td>$^{67}$Ga citrate</td>
<td>7-11 mCi</td>
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<tr>
<td>Lymphoma</td>
<td>$^{111}$In Zevalin</td>
<td>4-6 mCi</td>
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<td>Prostate</td>
<td>$^{111}$In ProstaScint</td>
<td>4-7 mCi</td>
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<tr>
<td>Myeloma</td>
<td>$^{166}$Ho DOTMP</td>
<td>25-35 mCi</td>
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<tr>
<td>Lymphoma</td>
<td>$^{131}$I Bexxar</td>
<td>4-6 mCi</td>
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</tr>
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<td>18. Therapy</td>
<td>Hyperthyroidism</td>
<td>$^{131}$I Na I</td>
<td>6-60 mCi</td>
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<td>Thyroid cancer</td>
<td>$^{131}$I Na I</td>
<td>29-330 mCi</td>
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<tr>
<td>Bone mets</td>
<td>$^{90}$Strontium</td>
<td>3-5 mCi</td>
<td></td>
</tr>
<tr>
<td>Bone mets</td>
<td>$^{153}$Samarium</td>
<td>10 mCi</td>
<td></td>
</tr>
<tr>
<td>Myeloma</td>
<td>$^{32}$P sodium phosphate</td>
<td>3-7 mCi</td>
<td></td>
</tr>
<tr>
<td>Various</td>
<td>$^{32}$P chromic phosphate</td>
<td>0.1-16 mCi</td>
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</tr>
<tr>
<td>Myeloma</td>
<td>$^{166}$Ho DOTMP</td>
<td>1200-2200 mCi</td>
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<tr>
<td>Lymphoma</td>
<td>$^{131}$I Bexxar</td>
<td>50-120 mCi</td>
<td></td>
</tr>
<tr>
<td>Lymphoma</td>
<td>$^{90}$Y Zevalin</td>
<td>0.3-0.4 mCi/kg (&lt;33 mCi)</td>
<td></td>
</tr>
<tr>
<td>Liver neoplasm</td>
<td>$^{90}$Y SirSpheres</td>
<td>30-90 mCi</td>
<td></td>
</tr>
</tbody>
</table>
NUCLEAR MEDICINE QUALITY CONTROL PROCEDURES

Detailed procedures are described in the QC logs associated with each instrument and also are located in the office of the Technical Supervisor.

1. Scintillation Camera
   A. Daily - Follow automated protocol for automatic tuning, peaking, and extrinsic uniformity measurement.
   B. Monthly - Follow automated protocol for spatial resolution and linearity measurement.
   C. Monthly - Follow automated protocol for checking center-of-rotation.

2. Thyroid Uptake Probe
   A. Daily - Execute automated protocol for calibration and perform constancy check.
   B. Quarterly - Perform automated Chi-square and energy resolution measurements.

3. Bone Mineral Analysis System
   A. Daily - Execute automated protocol for checking entire system and standard values.

4. Dose Calibrator
   A. Daily - Perform background measurement and constancy check.
   B. Quarterly - Perform linearity check.
   C. Annually - Perform accuracy check.

5. Surveys for Contamination
   A. Daily - Check all work areas with a survey meter.
   B. Weekly - Perform wipe testing of all work areas.

Note: Dose calibrator measurements and radiation surveys are monitored by Radiation Safety Office.

6. Leak Testing of Sealed Sources
   A. Quarterly - Performed by Radiation Safety Office staff.

Section Revised 1/3/2007
THE SKELETON
Revised 1/3/2007

BONE SCINTIGRAPHY

The value of the bone scan lies in its ability to provide clinicians with the information necessary to make early diagnoses of disease and institute appropriate therapy. In some diseases, notably carcinoma of the breast, the bone scan findings can completely reorient the therapeutic approach; in other entities, notably osteomyelitis, the bone scan makes diagnoses earlier than is possible with alternative diagnostic modalities, thus permitting earlier, more appropriate therapy. Invariably, in multi-focal disorders, there is greater involvement on the bone scan than can be seen on conventional radiographs; while in the arthritides and in certain metabolic disorders, the stage of the pathologic process and its activity can be delineated most accurately by the bone scan.

The precise mechanism of action for the technetium bone scanning agents has yet to be determined. Basically, it appears that these agents adhere to the hydroxyapatite crystal of bone by a process known as chemisorption. Blood flow plays a major role in tracer delivery and distribution, while reaction bone formation also significantly affects the appearance of the scan. Bone images are obtained 2-4 hours after the injection of the radiopharmaceutical. If clinically indicated, the injection may be made with the patient positioned under the gamma camera so that a radionuclide angiogram and blood pool images can be obtained (three phase bone scan). Single photon emission computed tomography (SPECT) can be performed on selected areas of the body to improve resolution and help to detect and/or better localize the lesions.

Clinical Indications:

(1) METASTATIC DISEASE
Bone scanning should be the primary imaging modality employed in the search for osseous metastatic disease, with the conventional radiographic skeletal survey relegated to study those areas on the bone scan considered suspicious for disease or nonspecific in nature. The bone scan has an overall false negative rate of about 2% for metastatic disease, while the skeletal survey has false negative rates that in certain tumors can approach 50%. Most primary tumors, (with the exception of most primary intracranial malignancies) can and do metastasize to bone.

(2) PRIMARY BONE NEOPLASMS
In osteogenic sarcoma, distant osseous metastases at presentation are relatively rare. Since the advent of adjuvant chemotherapy however, a significant number of patients (15%) are noted to develop bone metastases prior to, or in the absence of lung metastases. In these patients, serial bone scanning can be invaluable in establishing the
early diagnosis of osseous metastases. Also, in those centers utilizing limited amputation as part of their protocols, the bone scan can aid the surgeon in selecting the precise level of amputation. There is a greater chance of osseous metastatic disease at time of presentation in patients with Ewing's sarcoma (12%). Also, about one third of the patients with this disease will develop bone metastases during follow-up, often prior to, or in the absence of, lung metastases. The bone scan is therefore useful both in the initial work-up and subsequent follow-up.

(3) TRAUMA
Early changes may be apparent on the bone scan as early as 24 hours post-trauma. The initial finding is mild, diffuse increased accumulation of tracer noted at the fracture site. Over the next few days, this uptake becomes more focal and intense. In uncomplicated fractures, scans that were positive will revert to normal in about two years. In children, it may only take 6-18 months, while in older, debilitated patients, the scan may take several years to revert to normal. Fractures that are under continuous stress will stay positive indefinitely.

(4) OSTEOMYELITIS
Typically, the bone scan is positive at the time of clinical presentation. This is in contrast to conventional radiography where even subtle findings may not be evident for a week to ten days after the onset of symptoms. A three-phase bone scan can help to differentiate osteomyelitis from soft tissue infection or degenerative bone disease. A gallium scan can be valuable in following patients with osteomyelitis, as it appears to reflect more accurately than the bone scan the response of the inflammatory process of therapy.

(5) AVASCULAR NECROSIS
Absence of blood flow with subsequent devitalization of the bone can occur in a variety of conditions. The most commonly affected site in both the adult and pediatric patient is the femoral head. Initially, there is loss of blood flow but the bone remains structurally intact. At this time, the disorder can be diagnosed by skeletal scintigraphy, but not by conventional radiography. The bone scan depicts an area of photon deficiency corresponding to the avascular skeletal part.

(6) BENIGN BONE TUMORS
Skeletal scintigraphy is not used in making the initial diagnosis that is usually a function of conventional radiography. Rather the scan is valuable in establishing the multi-focal nature of the entity. The selection of potential sites may also be influenced by scan findings.

(7) ARTHRITIS
The bone scan is better than conventional radiographs in delineating the extent and activity of arthritic processes.
(8) METABOLIC DISEASES AND MISCELLANEOUS ENTITIES
In Paget's disease, scan findings correlate with the clinical course of the disease, as opposed to conventional radiographs that best delineate end-stage osseous changes. Other entities that have been evaluated by skeletal scintigraphy include fibrous dysplasia, primary and secondary hyperparathyroidism, pulmonary osteoarthropathy and myositis ossificans.

(9) PEDIATRIC USE
Although the package inserts from the commercial kits do not indicate the use of bone radiopharmaceuticals in children, many of the disease processes previously mentioned occur in the pediatric population. It is well established in the medical literature that the risk of morbidity and mortality from these disease processes is much greater than the risk from the radiation exposure. Therefore, bone scintigraphies are performed in children and the radiopharmaceutical dose is calculated according to body weight (see chart).
**PROCEDURE: Bone scintigraphy**

The patient will be injected in his/her room on the floor unless flow and blood pool (3 phase) imaging is requested. The bone scan is performed approximately 2.5-4 hours after the injection and requires 30-60 minutes to complete.

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc MDP or HDP is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 20 mCi
3. Child Dose: Per body weight (see chart). Minimum 1.5 mCi
4. Route: Intravenous
5. Time interval between administration and scanning:
   a. Immediately for dynamic flow study
   b. 2.5-4 hours for delayed bone images
   c. Occasionally 24 hours for “fourth phase” images
6. Scanning time required: 30-60 minutes.

**Patient Preparation:**
1. Check that the patient is not pregnant or breastfeeding.
2. Encourage drinking of fluids prior to scan.
3. Have patient empty bladder just prior to scan.
4. Explain the procedure and check for metal objects in the FOV
5. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

**Machine Set-up Instructions (LFOV):**
1. LEHR Collimator
2. Photopeak and window settings predetermined for $^{99m}$TC (140 keV, 15-20%)
3. Dynamic flow images: 4 sec/frame for 64 sec.
4. Immediate static image: 500k counts or 300 sec/image
5. Delayed images: 6 min/image
   • 250k or 600 sec for distal extremity spot views

**Scanning Instructions:**
1. Place patient supine on imaging table with the area of interest in the field of view.
2. For the dynamic flow study (if indicated), the radiopharmaceutical is injected rapidly through a butterfly followed by a flush of 10 ml normal saline with a 3-way stopcock. Images are recorded at 4 sec/frame for 64 seconds, followed by 1 static image of 500K counts or 300 sec.
3. For the delayed images, acquire whole body images for 6-min/image.
4. In patients with knee prosthesis, a lateral view of both knees will be obtained. 300k counts or 600 seconds.

5. If calvarial abnormalities are recognized, obtain both laterals of skull.

6. A SPECT scan of the lumbar spine will be performed on all patients evaluated for low back pain and who have normal planar images.

7. For foot complaints: FOD and lateral views should be obtained of both extremities, 300k counts or 600 seconds.

8. For hand/wrist complaints: HOD and occasionally pinhole views should be obtained, 300k counts or 600 seconds.

9. For pediatric patients, 3-5 mm pinhole collimation is sometimes required, 200-300k/view.

10. Archive the images to PACS.

11. Mark the right side on all patients!

SPECT Instructions (if indicated):

1. LEHR parallel - hole collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 360 degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction
6. Reconstruct the images in the transverse, coronal and sagittal plane (see computer instructions)
8. Archive the images to PACS.

PROCEDURE: Bone Marrow Scintigraphy

The patient is injected in Nuclear Medicine department. Pictures are taken 30 minutes after injection and require 45 minutes to complete.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid
2. Adult Dose: 8-10 mCi
3. Child Dose: Per body weight (see chart)
   Minimum 1.0 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: 30 minutes post injection
6. Scanning time required: 45 minutes

Patient Preparation:
1. Check that the patient is not pregnant or breastfeeding.
2. Explain the procedure and check for metal objects in the FOV.
3. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

Machine Set-up instructions (LFOV):
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%). Use 10% window if $^{111}$In has been administered within the past 24-36 hours.
3. Preset time: 5 min/image

Scanning Instructions:
1. Place patient supine on imaging table
2. Acquire whole body images in anterior and posterior projection
3. If being compared to an $^{111}$In leukocyte scan, acquire same views as used for the $^{111}$In images.
4. Archive the images to PACS.
Conventional Brain Scintigraphy

The functional basis of conventional brain scanning is that most intracranial lesions will alter the blood brain barrier so that an administered radiopharmaceutical will leak out of the capillaries and into or around the lesion. The abnormality appears as a "hot spot," an area of increased radionuclide concentration that stands out from the normal low background of normal brain. The current preferred radionuclides are technetium labeled DTPA, glucoheptonate, or alternatively, technetium pertechnetate. In addition, the radionuclide brain scan offers the opportunity for sequential dynamic imaging of the bolus of radionuclide as it perfuses the brain. This study consists of rapid sequence of one second images during which time the major vessels, carotids, anterior and middle cerebral arteries, [the brain substance], and the venous sinuses are visualized in sequence.

Clinical Indications:

(1) BRAIN DEATH
Brain death is a clinical diagnosis taking into account both cerebral and brainstem function. Confirmatory list such as electroencephalography and imaging studies assessing blood flow to the brain gives evidence for or against the clinical impression. With the widespread use of brain metabolic suppressive therapy, cerebral blood flow studies are a more accurate assessment of irreversible neurological loss than is electroencephalography. The guidelines published in the Journal of the American Medical Association in 1981 recommend a test of cerebral blood flow for confirming brain death. Radionuclide blood flow imaging is noninvasive, a major advantage over angiography.

(2) HERPES ENCEPHALITIS
The importance of this diagnostic modality is a result of specific therapy for Herpes Encephalitis with ARA-A. (Adenine Arabinoside, Whitney. New Engl J Med 297:289 11 Aug 1977.) In nine encephalopathic patients studied at Vanderbilt Medical Center, the radionuclide brain scan became positive days before the CT brain scan showed any abnormality. Kim confirmed these results in 10 patients with documented Herpes Encephalitis (Radiology 132:425 Aug 1979). The most specific sign of Herpes Encephalitis is focal temporal lobe uptake on brain scan, but focal uptake in this location is only found in 50% of patients. The remainder of patients had more diffuse frontal or parietal abnormalities. Only one patient in 12 with non-herpetic disease had a focal abnormality and this was frontal and not temporal in location.

The most important points in brain scanning are that both dynamic and delayed images should be performed. Images delayed up to 4 hours may sometimes be necessary in a few instances, particularly encephalitis. Sequential imaging at two or more time periods may be required for specific diagnosis.
(3) PRIMARY BRAIN TUMORS, METASTATIC DISEASE, ABSCESS, ARTERIOVENOUS MALFORMATION
For the diagnosis of neoplastic disease, brain scanning is 80 to 85% sensitive as well. It is interesting to note that the two studied together are 95% sensitive for neoplastic disease.

(4) CEREBRAL VASCULAR DISEASE AND CEREBRAL INFARCTION
Where the diagnosis of cerebral vascular disease is a consideration, at least 75% of all cerebral vascular accidents will be positive on brain scan at three weeks following the event. During the first week, only 17% of ischemic strokes show a positive finding on the static brain scan and most cerebral vascular accidents will return to negative three months after the initial event.

(5) CEREBRAL SUBDURAL HEMATOMAS AND CONTUSIONS
The brain scan is also helpful in the diagnosis of subdural hematoma. A totally negative dynamic and static brain scan excludes subdural hematoma. During the first few days after acute subdural hematoma, the only abnormality may be a cold area on the dynamic angiogram; therefore, the early dynamic study is essential for the diagnosis of subdural hematoma, at this time. After ten days almost all chronic subdural hematomas will have membrane formation and a positive peripheral rim of increased activity will appear in the static brain scan.

(6) PEDIATRIC USE
Although the package insert from the glucoheptonate commercial kit (Glucoscan, NEN medical product) does not indicate the use in children, the radiation dose to different organs is in the same range as with pertechnetate. There is no concentration of glucoheptonate by the choroid plexus, a definite advantage compared to pertechnetate. The pediatric dose is calculated according to body weight (see chart).

PROCEDURE: Brain scintigraphy and dynamic flow study

99mTc ECD (ethylenediylbis-cysteine diethyl ester or bicisate or Neurolite) is a stable lipophilic chelate tracer of cerebral perfusion that can cross the normal blood brain barrier. It has a high extraction efficiency and is taken up in the brain in proportion to blood flow remaining stable within the brain for 6 hours after uptake. Excretion is renal.

Clinical Indications:
1. Confirmation of clinically suspected brain death.
2. Localization of CVA in conjunction with MR/CT.

The patient is injected in Nuclear Medicine department for the Flow Study. The Brain Flow only takes 15 minutes with static images to follow.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: 99mTc ECD (ethylenediylbis-cysteine diethyl ester or Neurolite,) is the preferred agent and is prepared according to the radiopharmacy procedure manual or acquired from a commercial pharmacy. Preparation requires 35 minutes; QC by TLC requires 30 minutes [99mTc HMPAO (Ceretec) can be used as an alternative if ECD
cannot be obtained and is prepared according to the radiopharmacy manual. Lastly, Tc99m Pertechnetate can be used if either HMPAO or ECD is not available.

2. Adult Dose: 25 mCi
3. Child Dose: Per body weight (see chart) - Minimum 2.5 mCi
4. Route: Intravenous bolus
5. Time interval between administration and scanning:
   a. Immediately for dynamic flow study
   b. 10-30 minutes post injection of bolus for static images

**Patient Preparation:**
1. Note on the requisition the location of any known lacerations or deformities.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%)
3. Set parameters for dynamic acquisition: 2 sec/frame for 64 sec.
4. Static images: 400,000 cts/image

**Scanning Instructions:** (start camera before or at same time you inject, not after)
1. For the dynamic flow study, the radiopharmaceutical is injected rapidly through a 19-gauge butterfly, followed by a flush of 20 ml saline using a 3-way stopcock.
2. Images are recorded on the computer at 2 sec/frame for 64 seconds. 10-20 minutes post-injection, a static anterior and a single lateral view of the head should be acquired for 400,000 counts each.
3. Collect the routine delayed views with a head tourniquet if practical
   a. Anterior view with marker on right side.
   b. Lateral view with marker on anterior.
   c. Oblique views as requested by physician.
   d. SPECT imaging as requested by physician.
   e. If there are poor count statistics, QC may be checked by acquiring an anterior view of the neck, thorax, and abdomen.
4. Archive the images to PACS.

Revised 1-3-2007.
CERETEC SPECT - BRAIN SCINTIGRAPHY

$^{99m}$Tc-hexamethylpropylene amine oxine ($^{99m}$Tc-HMPAO=exametazime=Ceretec) is a new lipophilic chelate tracer of cerebral perfusion. It has a high extraction efficiency, it is taken up in the brain in proportion to blood flow, and offers to dynamic SPECT the advantages of $^{99m}$Tc as a radionuclide. There is a very stable pattern of uptake within a few minutes and slow or no washout of tracer. Cerebral uptake of $^{99m}$Tc-HMPAO correlated well with labeled microspheres determinations of cerebral blood flow up to 200 ml/100gr/min.


Clinical Indications:

1. **Evaluation of stroke**
   Stroke zone appears as regions of decreased flow acutely and chronically.

2. **EPILEPSY (ictal or interictal)**

3. **Dementia**

4. **Trauma**

5. **Evaluation of cerebral perfusion during balloon test-occlusion of an internal carotid artery.**

6. **Evaluation of AVM "steal phenomenon before and after embolization"**
7. Evaluation of therapeutic balloon angioplasty for arterial spasm due to SAH

8. Evaluation of cerebral distribution of Amytal during WADA test

9. Evaluation of cerebral perfusion reserve following Diamox administration

PROCEDURE: Ceretec SPECT brain scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-HMPAO or ECD
2. Adult Dose: 20 mCi (see memo for ictal scans)
   Ictal SPECT Brain scan:
   --Prepare the dose at 30 mCi
   --Prescribe the dose: 15-25 mCi
   Children Dose: Per body weight (see chart)
   Minimum: 5.0 mCi
3. Route: Intravenous
4. Time interval between administration and scanning: 10 minutes - 2 hours post injection.
5. Time required: 1 hour scanning time, 1 hour processing time.

Patient Preparation:
1. The patient should be calm, quiet and in darkened room upon injection, free from distraction. If the patient is injected in the angiographic suite, the patient's eyes may be covered and the quiet state maintained for 2 minutes following injection.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.
4. Patients undergoing acetazolamide challenge: see contraindication below.
Special Investigational Indications:

1. When Ceretec or ECD SPECT scan is performed as an adjunct to interventional angiographic procedure (carotid artery balloon occlusion test, AVM embolization, therapeutic balloon angioplasty). [A written informed consent is obtained from each patient.] The intravenous injection of 20 mCi of $^{99m}$Tc-HMPAO or ECD is performed in the angiographic suite. The patient is then transported to nuclear medicine and imaged as above.

2. When the study is performed as an adjunct to a WADA test, [a written informed consent is obtained from the patient]. 1 mCi of $^{99m}$Tc-HMPAO or ECD is mixed with Amytal and injected in the carotid artery in the angiographic suite by a neurovascular radiologist. The patient is then transported to nuclear medicine and imaged as above.

3. When the study is performed to evaluate cerebral perfusion reserve, written informed consent is obtained from the patient for a Diamox (acetazolamide) SPECT brain scan. Diamox SPECT Brain Scan:

   --Contraindications: Within 3 days of TIA, migraine history, allergy to sulfonamides, serum sodium or potassium, renal dysfunction, hepatic dysfunction, adrenal gland failure, hyperchloremic acidosis, glaucoma, risk of steal phenomena with AVM

   --Procedure:
   Administer 1 gram acetazolamide in 50 ml D5W over 2 minutes under physician supervision
   Wait 30 minutes
   Administer 20 mCi Tc-$^{99m}$-Ceretec or ECD
   Wait 15 minutes
   Acquire SPECT scan of the brain

SPECT Camera Instructions:

1. Positioning: Supine with the cantho-meatal line perpendicular to the floor. Head fixation with tape is needed. Pillow under knees recommended. Instruct patient to remain motionless during study.

2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).

3. LEHR collimator

4. 3 degrees per step

5. 30 seconds/frame

6. 360 degree rotation

7. 128 x 128 x 16 pixel matrix for reconstruction
Data Computer Processing:
- Reconstruction filter: Metz 3.8
- Slice thickness: 0.52 cm = 3 pixels if no zoom
- Reorient transverse and coronal slices straight
- Reorient sagittal slices along AC-PC line

Comments:
1. Symmetrical ROIs should be placed about the cortical rim. Large regions should be placed within each cerebellar hemisphere.
2. Ratios of each region to the corresponding contralateral region and mean cerebellar activity should be calculated.
3. Generally accepted guidelines for normalcy are L/N of 0.85-1.15 and Cortex/Cerebellum >0.85. These are crude guidelines and ROI analysis is not a substitute for thorough visual assessment.
4. Interventionsal studies such as balloon test occlusion or Diamox challenge test generally produce abnormality in a particular vascular region, trace ROIs are the preferred method. The usual ratio tests often do not apply in these patients due to baseline abnormality. A baseline study is needed if the interventional study is anything other than "cold normal". The baseline study is then compared to the interventional study to determine the progression of deficit due to the intervention.
5. Coronal and sagittal views are constructed by interpolation, and are therefore inferior to transverse images for quantitation. They are useful for visual interpretation, but correlation should be made with the transverse data to insure that the findings are real.
6. Archive the images to PACS.
Cisternography

The cerebrospinal fluid (CSF) flow can be easily studied by intrathecal injection of radiopharmaceuticals. The knowledge of CSF dynamics helps in the diagnosis of several diseases.

Clinical Indications:

1. **CSF Leakage**

2. **Hydrocephalus**

3. **Shunt Patency (Shuntogram)**
The radiopharmaceutical used to perform a shuntogram is $^{99m}$Tc-DTPA because the radiation dose to the patient is lower than with $^{111}$In-DTPA and delayed imaging beyond 24 hours is not necessary.

   

4. **Pediatric Use**
Although the package inserts from the commercial kits $^{111}$In-DTPA do not indicate use in children, many of the disease processes previously mentioned occur in the pediatric population. It is well established in the medical literature that the risk of morbidity and mortality from these diseases processes is much greater than the risk from the radiation exposure. Therefore, cisternography is performed on children and the radiopharmaceutical dose is 0.5 mCi of $^{111}$In-DTPA or 0.5 mCi of $^{99m}$Tc-DTPA as described in the procedure.


**PROCEDURE: Cisternography**

Patient is brought to Nuclear Medicine department, lumbar puncture is done on patient, and isotope injected. Images are taken 4-6 hours after injection. 24 hour delayed views are required.

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{111}$In-DTPA from Mediphysics.
2. Adult Dose: 0.5 mCi
3. Child Dose: Per body weight (see chart) Minimum 0.2 mCi
4. Route: Lumbar puncture (a written informed consent is obtained, see form included).
5. Time interval between administration and scanning: immediate to assess the quality of the subarachnoid injection, then images over the head are obtained at 4-24 and 48 hours.
6. Additional information: $^{111}$In-DTPA must be ordered 24 hours in advance.
7. Intervals of imaging may vary with time and isotope distribution or disease process.

**Patient Preparation:**
1. Check that the patient is not pregnant or breast feeding.
2. Explain the procedure and check for metal objects in the FOV.
3. No clinical suspicions for increased intracranial pressure should be present.
4. If study done for CSF leak, make appointment with ENT clinic for pledgetts placement 2 hours after administration of the radiopharmaceutical.

**Technical Procedure for CSF Leaks:**
1. Obtain an immediate image over the lower back to assess the quality of the injection.
2. For evaluation of a CSF leak, maintain the patient in the supine position between the injection and actual imaging time so as to pool the radiopharmaceutical in the basal regions. Orientation of the patient into position that contributes to the leak may be helpful.
3. Make the patient wait for 90 min on a stretcher.
4. If the suspected site of the leak is along the spine, take posterior images of the entire spine and head (anterior, posterior and both laterals) at 90 minutes, then every hour during working hours that day, then at 24 hours, or at the direction of the staff physician.
5. If the site of the suspected leak is in the nose or ears, send the patient to ENT clinic for placement of cotton pledgetts (should be 2 hours after administration of the radiopharmaceutical) of 1 sq cm and absorptive capacity of 0.5 ml (or 1/4 pledgett). A technologist or resident needs to stay with the patient.
6. Immediately after placement of the pledgetts, a blood sample should be drawn (2 ml) in tube with dry heparin and be labeled with patient's name and time. It should be done at the time of pledgett placement, so avoid any delays.
7. Leave the pledgetts in place for 4 hours and the patient supine, then obtain images of the head in anterior and lateral projections.

8. Remove the pledgetts and place in preweight test tube (from in vitro laboratory) and draw another venous blood sample (2 ml) in a tube with dry heparin and label with patient's name and time.

9. Send pledgetts and the 2 blood samples appropriately labeled with patient's name and time of withdrawal to in vitro laboratory.

10. Obtain images of the head and abdomen at 24 hours. SPECT as necessary.

11. **In vitro laboratory:**
    - Dry pledgetts weights _______________ and has absorptive capacity of 2 ml
    - Weight the pledgetts.
    - Centrifuge blood samples.
    - Count each pledgett, and 0.5 ml of each plasma sample in gamma well counter.
    - Calculate ratio:

\[
\text{pledgett activity x (pledgett weight after removal-pledgett weight before placement in gm)}
\]

Average of the activity in the two plasma sample

Normal pledgett/plasma radioactivity ratios do not exceed 1.3.

12. Obtain images of the head in the anterior and both lateral projections, as well as an anterior and posterior image of the abdomen at 24 hours to check activity in kidneys and colon, if the pledgetts counts are inconclusive.

**Ref.**


**Technical Procedure for CSF dynamics:**

1. Obtain immediate image over the lower back to assess the quality of the injection.
2. Obtain 4 hours delayed images over the head in anterior, posterior and both lateral projections.
3. Obtain 24 hours delayed images over the head in anterior, posterior and both lateral projections.
4. Obtain 48 hours delayed images over the head in anterior, posterior and both lateral projections.
Machine Set-up Instructions:

1. Medium energy collimator
2. Photopeak and window setting for $^{111}\text{In}$ (172 keV-20%, 262 keV-20%).
3. Preset counts for 100K/image or time for 10 minutes/image.
4. Archive the images to PACS.

Updated 1/3/2007 by D. Johnson
**PROCEDURE:** Shuntogram

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc-DTPA (Pentetate) is prepared according to the radiopharmacy procedure manual and millipore-filtered for sterility.
2. Adult Dose: 1.5 mCi
3. Pediatric Dose: 0.5 mCi
5. Time interval between administration and scanning: Immediate
6. Additional information: The injection is performed by the neurosurgeon and a lumbar puncture tray is needed for procedure.
7. Scanning time required: 1 hour

**Patient Preparation:** Check that the patient is not pregnant or breast feeding. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions (LFOV):**
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset time for 60 seconds/image.

**Scanning Instructions:**
1. For V-A-shunt, obtain dynamic images for 60 seconds over the heart. After injection, place patient in supine position.
2. Image in the anterior and lateral projections of the head at 5, 10, 15 and 30 minutes.
3. Continue to image isotope into the ant. abdomen or chest projection.
4. If no migration after 30 minutes, rescan sitting.
5. If no migration sitting, rescan after neurosurgeon pumps the reservoir valve.
6. Archive the images to PACS.

The physiologic basis for studies of the kidney depends upon the particular renal function that is to be measured. There are high resolution imaging agents such as $^{99m}$Tc glucoheptonate and "DMSA" which are bound through the renal tubules. In addition, there are agents that effectively measure the glomerular filtration rate such as $^{99m}$Tc DTPA, and agents that are effective measures of renal plasma flow such as iodohippurate that is known as $^{131}$I Hippuran, and $^{99m}$Tc mertiatide known as $^{99m}$Tc MAG$_3$. 

Revised 01/03/2007
1) **Radiopharmaceuticals**

1.1) \(^{99m}\text{Tc}-\text{Diethylenetriaminepentaacetic acid (DTPA)}

This agent is cleared almost entirely by glomerular filtration. In the plasma 2-6% is bound to protein. The plasma clearance half-time is 25 minutes. \(^{99m}\text{Tc}-\text{DTPA}\) reaches a peak of concentration in the kidneys 3-4 minutes after injection, and 3-4% of the administered dose remains in the kidneys 1 hour after intravenous administration. Approximately 50% of the injected dose is eliminated in the urine in the first 2 hours and 35% at 24 hours.

\(^{99m}\text{Tc}-\text{DPTA}\) is an excellent agent to measure GFR, to assess renal perfusion and to visualize the pelvocalyceal collecting system and ureters.

1.2) \(^{131}\text{I}-\text{Orthoiodohippurate (hippuran)}

Iodohippurate is an analog of paraamino-hippurate. After intravenous administration, 80% is cleared by tubular secretion and 20% by glomerular filtration. The plasma clearance half-time is 30 minutes. \(^{131}\text{I}-\text{iodohippurate}\) reaches a peak of concentration in the kidneys 3-6 minutes postinjection, and is gradually eliminated over the next 30 minutes (2). Since most of hippuran is extracted during a single pass, the rate of excretion can be employed as a measure of renal plasma flow. It is employed principally to evaluate renal tubular function. The renal extraction efficiency exceeds that of the \(^{99m}\text{Tc}\)-labeled agents. Therefore, it is the better agent to evaluate kidneys with impaired function.

1.3) \(^{99m}\text{Tc} - \text{Mertiatide (}\(^{99m}\text{Tc-\text{MAG}}\)_3\)

\(^{99m}\text{Tc} - \text{MAG}_3\) is a new radiopharmaceutical for renal imaging which combines the advantages of high renal extraction with a proper energy emission for gamma camera imaging. Although \text{MAG}_3\) is highly bound to plasma protein, the binding is reversible and the tracer is rapidly excreted by active tubular secretion and glomerular filtration and is a suitable radiopharmaceutical to replace \(^{131}\text{I}-\text{iodohippurate}\). The renogram curves are similar with \text{MAG}_3\) and iodohippurate. \text{MAG}_3\) has also the advantage to be suitable for dynamic flow studies.


1.4) \(^{99m}\text{Tc} - \text{Dimercaptosuccinic acid (DMSA)}

This agent behaves similarly to chloromerodrin, binding to the proximal tubules of the kidney. In the plasma 70-90% is bound to protein. The plasma clearance half-time is approximately 60 minutes. Renal retention is 24% of the dose 1 hour after injection and a maximum retention of...
50% occurs 3-6 hours post injection. In the presence of renal failure the activity is shifted to the liver, gallbladder and gut. Because of the long retention time of DMSA in the renal tubular cells, it is a good agent to evaluate the morphology of the renal cortex and to calculate accurate differential renal function.

1.5) $^{99m}$Tc-Glucoheptonate (GH)

This agent is excreted both by glomerular filtration (50%) and tubular excretion (50%). Protein binding in the plasma is 50-75%. The plasma clearance half-time is similar to that of DTPA. Renal retention is 10-20% of the dose 1 hour after injection. Urinary excretion is 70% in 24 hours. This agent is often used as a multipurpose radiopharmaceutical. A fraction of the injected dose is promptly excreted in the urine enabling visualization of renal blood flow and the collecting system. A smaller amount localizes in the renal tubular cells and the retention time is sufficiently long to permit evaluation of cortical morphology on delayed images. However, this agent has the disadvantage of not measuring a single renal function.


1.6) Pediatric Use

Although the package inserts from the commercial kits do not indicate use of renal radiopharmaceuticals in children, many of the renal diseases occur in the pediatric population. It is well established in the medical literature that the risk of morbidity and mortality from these diseases is much greater than the risk from the radiation exposure due to renal radiopharmaceuticals listed above. Therefore, all the renal scintigraphic procedures described below are performed on children and the radiopharmaceutical doses are calculated according to body weight (see chart).
3) **Renal perfusion scintigraphy (dynamic flow study)**

Renal blood flow is evaluated following intravenous administration of $^{99m}$Tc-DTPA or $^{99m}$Tc-GH or $^{99m}$Tc-pertechnetate or $^{99m}$Tc MAG$_3$ with rapid, sequential dynamic imaging. Images are obtained every 2-4 seconds for 60 seconds following bolus injection.

Computer acquisition allows for generation of time-activity curves and quantitation of parameters such as kidney/aorta blood flow ratios and relative differential kidney perfusion.

**Clinical Indications:**

1. Evaluation of bilateral renal perfusion
2. Evaluation of renal transplant perfusion
3. Evaluation of pancreatic transplant perfusion
4. Evaluation of liver transplant perfusion
PROCEDURE: Renal dynamic flow study

Radiopharmaceutical Administration:
1. Radiopharmaceuticals
   a. $^{99m}$Tc-DTPA (Pentetate) or
   b. $^{99m}$Tc- MAG$_3$

All the radiopharmaceuticals are prepared according to the Radiopharmacy procedure manual or obtained from a commercial vendor.

2. Adult Dose:
   a. 15 mCi $^{99m}$Tc-DTPA or
   b. 10 mCi $^{99m}$Tc- MAG$_3$ (bilateral study)
   7.5 mCi $^{99m}$Tc- MAG$_3$ (transplant study)

3. Child Dose: Per body weight (see chart) Minimum 1.5 mCi

4. Route: Intravenous

5. Time interval between administration and scanning: Immediate

6. Scanning time required: 15 minutes

Patient Preparation: Check that the patient is not pregnant or breastfeeding.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV 15-20%)
3. Set dynamic acquisition parameters: 2 sec/frame for 64 sec.

Scanning Instructions:
1. The patient is supine on the table.
2. With the camera view under the table to take posterior views for a bilateral study. Anterior views are obtained for transplant study.
3. The radiopharmaceutical is injected rapidly through a 19-gauge butterfly and is followed by a flush of 20ml normal saline with a 3 way stopcock. (Do not rinse syringe).
4. Images are recorded on computer at 2 sec/frame for 64 seconds.

Computer processing: (see Computer Instructions)
1. A region of interest is drawn around the kidney, aorta and background.
2. Time-activity curves are plotted.
3. Archive the images to PACS.

Pancreatic transplant perfusion: Calculation of indexes:
1. Acquisition:
   Use predefined study #1
2. Processing:
In frame #61 regions of interest are drawn around the following areas:
   a. aorta (avg. cts.)
   b. pancreas (avg. cts.)
   c. bkg (avg. cts.)
   d. partial pancreas (from part not overlaying iliac artery) (avg. cts.)

3. Compute the TI two ways:

\[
\text{TI}_1 \text{ (whole pancreas)} = \frac{B-C}{A-C} \quad \text{TI}_2 \text{ (partial pancreas)} = \frac{D-C}{A-C}
\]

4) **BILATERAL RENAL SCINTIGRAPHY**

The tubular function of the kidneys can be evaluated following intravenous administration of 0.2 mCi of $^{131}$I-iodhippurate, or 10 mCi of $^{99m}$Tc-GH or 10 mCi of $^{99m}$Tc- MAG$_3$. Sequential images of the kidneys are obtained in the posterior projection for 30 minutes. If the bladder is not in the field of view, an image of the bladder is obtained at the end of the study.

Kidney time activity curves are called renograms and can be generated from data stored in the computer. Cortical uptake should peak by 5 minutes after injection and then gradually decrease over the next 20 minutes. Relative differential renal function can be estimated from early cortical uptake (first 2 minutes) before activity is present in the collecting system. Inaccuracy results from asymmetrical position or function of the kidneys.

In neonates, a DTPA renogram is substituted until the tubular function is fully developed.

**Clinical Indications:** Evaluation of renal function, renogram curves and differential renal function.
PROCEDURE: Bilateral MAG₃ renogram

Radiopharmaceutical Administration:
1. Radiopharmaceutical: ⁹⁹mTc-MAG₃ prepared according to the Radiopharmacy procedure manual or obtained from a commercial vendor.
2. Adult Dose: 10 mCi
3. Child Dose: Per body weight (see chart) Minimum 1.0 mCi
4. Route: Intravenous, as a bolus
5. Time interval between administration and scanning: Immediately
6. Scanning time required: 45 minutes

Patient Preparation: Check that the patient is not pregnant or breastfeeding.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for ⁹⁹mTc (140 keV 15-20%)
3. Preset time: 15 sec/image for 30 minutes

Scanning Instructions:
1. The patient is supine on the table with the camera under the table to take posterior views.
2. Start camera and computer 30 seconds before injection of isotope.
3. Collect serial images for 30 minutes.
4. Data must also be collected on computer for curve generation.
5. If Foley catheter is in place, collect a 5-minute image of Foley bag after completion of renogram.
6. If the bladder is not in the field of view, collect a 5-minute image on the bladder after completion of renogram.

Additional Information:
If a diuretic renogram is indicated, the patient will be injected with Lasix (40 mg or 0.5-1.0 mg/kg) and images collected for an additional 20 minutes.

Computer processing: (see Computer Instructions)
1. Display images for 2 min/images
2. Regions of interest are drawn around the kidneys (excluding the renal pelvis) and around the background.
3. Time-activity curves are generated.
4. Splits renal function are calculated on the first image (0-2 minutes data).
5. For the Lasix portion of the study, region of interest are drawn around the kidney including the renal pelvis, and around the background.
6. Time activity curves are generated.
7. Half time emptying of each kidney is calculated.
8. Archive the images to PACS.
Interpretation of Lasix curves:

T1/2  < 20 minutes: normal
      10 - 20 minutes: equivocal
     > 20 minutes: obstruction
5) Transplant Renal Scintigraphy

The patient comes to Nuclear Medicine Department. The patient is injected and serial picture images are acquired for 30 minutes. A flow study is usually requested along with patient’s first renogram and those patients with possible rejection.

**PROCEDURE: Transplant renal MAG₃ renogram**

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: \(^{99m}\text{Tc- MAG}_3\) prepared according to the Radiopharmacy procedure manual or acquired from a commercial vendor.
2. Adult Dose: 7.5 mCi
3. Child Dose: Per body weight (see chart) Minimum 0.5 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately
6. Scanning time required: 31 minutes

**Patient Preparation:** Check that the patient is not pregnant or breastfeeding.

**Machine Set-up Instructions:**
1. LEHR collimator
2. Photopeak and window settings predetermined for \(^{99m}\text{Tc} (140 \text{ keV 15-20%})
3. Computer: Select predefined study of MAG₃ transplant renogram. Data collection parameters are 1 frame/2 sec for 64 sec for flow and 1 frame/15 sec for 30 minutes for renogram images.

**Scanning Instructions:**
1. The patient is supine on the table and anterior images are obtained. Be sure positioning of kidney and bladder included in field of view.
2. Start camera and computer 30 seconds before injection of isotope.
3. Injection must not be performed in arm or leg with shunt--ask patient for location of shunt, or check point.
4. Collect serial images for 30 minutes.
5. Data must also be collected on computer for curve generation.
6. If Foley catheter is in place, collect a 5-minute static image of Foley bag after completion of renogram.

**Additional Information:**
If a diuretic renogram is indicated, the patient will be injected with Lasix (20 mg or 0.5-1.0 mg/kg) and images collected for an additional 20 minutes.

**Computer Processing: (see Computer Instructions)**
1. Display images for 2 min/image.
2. Regions of interest are drawn around the kidneys (excluding the renal pelvis) and around the background.
3. Time-activity curve is generated.
4. Lasix portion of the scan is processed as for a bilateral renogram.
5. Archive the images to PACS.
6) **CAPTOPRIL RENOGRAPHY**

Renovascular hypertension is defined as high blood pressure caused by renal artery stenosis and which improves or resolves following percutaneous or operative renal artery revascularization. Renal artery stenosis per se is relatively common in the elderly nonhypertensive population and may be an incidental but nonetiologic finding in a significant proportion of the hypertensive population. Although renovascular hypertension may affect only 0.5-3% of an unselected hypertensive population, it accounts for 15-45% of patients referred for refractory hypertension. The use of angiotensin converting enzyme inhibitors in conjunction with radionuclide renography enhances the sensitivity and specificity for detection of patients with renovascular hypertension who would benefit from renal artery revascularization.

Renovascular hypertension depends on secretion of renin from the juxtaglomerular apparatus of the stenotic kidney due to a reduced perfusion pressure distal to the stenosis. The elevated renin results in high local concentrations of angiotensin II, which preferentially constricts the efferent arteriole, which tends to maintain the GFR in the stenotic kidney despite the reduced perfusion pressure. By blocking the production of angiotensin II, ACE inhibitors reduce the constriction of the postglomerular arteriole, thus lowering the transcapillary forces that maintain glomerular filtration. The reduction in GFR leads to decreased urine flow in the renal tubules and delayed washout of tubular radiopharmaceuticals such as MAG3 and OIH.

The most specific diagnostic criterion for renovascular hypertension is a captopril-induced worsening (CIW) of the renogram. the overall accuracy of ACEI renography is high with reported sensitivities and specificities approaching 90%, but it is critical that all variable in the protocol be strictly controlled, i.e., degree of hydration, concurrent medications, timing of administration of the radiopharmaceutical, acquisition parameters, and processing of the data. For instance, peak blood levels of captopril occur 60 minutes after ingestion, but the presence of food in the GI tract may decrease absorption by 30-40%; a solid meal should not be eaten within 4 hours of captopril renography. Furosemide is used to washout the MAG3 from the collecting system without affecting cortical retention in order to improve the accuracy of cortical ROI determination. Bilateral symmetrical changes in the renogram after ACE inhibition may be related to salt depletion, insufficient hydration, a distended bladder, or hypotension occurring during the study.

Test results should be interpreted as indicating high (>90%), low (<10%), or intermediate probability of disease. Unilateral cortical retention of MAG3 after ACEI is high probability for renovascular hypertension. Significant retention is defined as a change in the "Grade" of the cortical curve of >1 or a change in the 20-minute to maximum ratio (normal <0.3) of >0.15 (a change of 0.1-0.15 is borderline). Other criteria are (1) a delay in excretion of the tracer into the renal pelvis >2 minutes after ACEI, (2) an increase in the Tmax by >2 minutes or 40% after ACEI, and (3) a change in the differential uptake by >10% (50/50 to 60/40) after ACEI.

PROCEDURE: Captopril renogram

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-MAG$_3$
2. Adult Dose: 10 mCi
3. Route: Intravenous, as a bolus
4. Time interval between administration and scanning: Immediately
5. Scanning time required: 30 minutes

Patient Preparation:
1. Patient should be off any ACE inhibitor for 48 hours prior to test.
2. The patient should be able to tolerate hydration 10 ml/kg water p.o.
3. The patient should be on clear liquids only for 4 hours prior to captopril administration.
4. Check that the patient is not pregnant or breastfeeding.

Captopril Study (First day):
1. Hydrate with water 10ml/kg po.
2. Start IV normal saline to run at 4ml/min (240 ml/hr).
3. Take and record blood pressure.
4. Captopril 50mg po.
5. Blood pressure every 15 minutes for 1 hour. May increase the IV rate for significant drop in blood pressure. Notify physician if this occurs.
6. Void immediately before MAG$_3$ injection.
7. Inject 10 mCi MAG$_3$ IV.
8. Lasix (40mg IV) is given immediately after MAG$_3$ injection. (May start imaging and then give Lasix).
9. Patient may have orthostatic drop in blood pressure so do not discontinue IV until study is complete and patient is able to stand without a significant drop in blood pressure.
10. Imaging and processing is as per flow study and MAG$_3$ bilateral renogram.
11. Archive the images to PACS.

Baseline Study (48 H later):
1. Hydrate with 10ml/kg water po and 4ml/min IV ns
2. Void immediately before MAG$_3$ injection.
3. Inject 10 mCi MAG$_3$ IV.
4. Lasix (40 mg IV) is given immediately after MAG$_3$ injections (may start imaging and then start Lasix).
5. Imaging and processing is as per flow study and MAG$_3$ bilateral renogram.
6. Archive the images to PACS.

Name ___________________ MRN ___________________ Date ____________

CAPTOPRIL RENOGRAM PROTOCOL WORKSHEET
"Day 1": Ensure patient is off any ACE inhibitor, angiotensin receptor antagonist, or calcium channel blocker at least 48 hours prior to test and record any antihypertensive (HBP) medications that the patient is presently taking.

<table>
<thead>
<tr>
<th>Generic name</th>
<th>Trade name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE inhibitors</td>
<td></td>
</tr>
<tr>
<td>Benazepril</td>
<td>Lotensin, Lotrel</td>
</tr>
<tr>
<td>Captopril</td>
<td>Capoten, Capozide</td>
</tr>
<tr>
<td>Enalapril</td>
<td>Vasotec, Vaseretic, Lexxel</td>
</tr>
<tr>
<td>Fosinopril</td>
<td>Monopril</td>
</tr>
<tr>
<td>Quinapril</td>
<td>Accupril</td>
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<tr>
<td>Ramipril</td>
<td>Altace</td>
</tr>
<tr>
<td>Lisonopril</td>
<td>Prinivil, Prinzide, Zestril, Zestoretic</td>
</tr>
<tr>
<td>Perindopril</td>
<td>Aceon</td>
</tr>
<tr>
<td>Moexipril</td>
<td>Univasc/Uniretic</td>
</tr>
<tr>
<td>Trandolapril</td>
<td>Mavik, Tarka</td>
</tr>
<tr>
<td>Valsartan</td>
<td>Diovan</td>
</tr>
<tr>
<td>Losartan</td>
<td>Cozaar, Hyzaar</td>
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<tr>
<td>Irbesartan</td>
<td>Avapro, Avalsde</td>
</tr>
<tr>
<td>Candesartan</td>
<td>Atacand</td>
</tr>
<tr>
<td>Telmisartan</td>
<td>Micardis</td>
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<tr>
<td>Calcium blockers</td>
<td></td>
</tr>
<tr>
<td>Bepridil</td>
<td>Vascor</td>
</tr>
<tr>
<td>Diltiazem</td>
<td>Cardizem, Cartia, Dilacor, Dilita, Tiazac</td>
</tr>
<tr>
<td>Nifedipine</td>
<td>Procardia, Adalat, Nifedical</td>
</tr>
<tr>
<td>Verapamil</td>
<td>Calan, Isoptin, Verelan, Covera, Tarka</td>
</tr>
<tr>
<td>Nicardipine</td>
<td>Cardene</td>
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<tr>
<td>Isradipine</td>
<td>DynaCirc</td>
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<td>Amlodipine</td>
<td>Norvasc, Lotrel</td>
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<tr>
<td>Felodipine</td>
<td>Plendil, Lexxel</td>
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<tr>
<td>Nimodipine</td>
<td>Nimotop</td>
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<tr>
<td>Nisoldipine</td>
<td>Sular</td>
</tr>
</tbody>
</table>

1. Over 20 - 40 min, hydrate patient with 5 ml/lb. water orally using calculations from Step 2 on Day 2.
2. Start IV Normal Saline to run at 4 m/min (240 ml/hr) and continue for 60 minutes.
3. Take and record Baseline blood Pressure below. **Vol IV Saline Administered** __________ml.
4. Give Captopril 50 mg orally.
5. Record Blood Pressure every 15 minutes for one (1) hour after Captopril administration.
6. Have patient void bladder completely, immediately before imaging.
7. Perform Renogram using 10 mCi TcMAG3 (adult) one hour after taking Captopril.
8. Inject 40 mg Lasix (adult) immediately following injection of TcMAG3.

BP

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>45 min.</th>
<th>15 min.</th>
<th>60 min.</th>
<th>upright post-scan</th>
</tr>
</thead>
</table>

**HBP MEDICATIONS**

1. 
2. 
3. 

48 HOURS LATER: "DAY 2"

1. Ensure patient is off any ACE inhibitor or angiotensin receptor antagonist 48 hours prior to test.
2. Hydrate patient with 5 ml per lb. water orally.

<table>
<thead>
<tr>
<th>lb.</th>
<th>5 ml</th>
<th>total ml</th>
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</table>

<table>
<thead>
<tr>
<th>lb.</th>
<th>total ml</th>
<th>total ounces (5 oz - 150 ml)</th>
</tr>
</thead>
</table>

3. Start IV Normal Saline to run at 4 ml/min (240 ml/hr) and continue for 60 minutes.
4. Perform Renogram using 10 mCi TcMAG3 (adult). **Vol IV Saline Administered** ______ml
5. Inject 40 mg Lasix (adult) immediately following injection of TcMAG3.
DIURETIC (LASIX) RENAL SCINTIGRAPHY

$^{99m}$Tc-DTPA is a good agent to visualize the pelvocalyceal collecting system and ureter because of the lack of cortical retention and rapid urinary excretion. Serial images can be obtained every 30 minutes following intravenous injection of 15 mCi of $^{99m}$Tc-DTPA. However, the collecting system can also be evaluated with $^{131}$I-iodohippurate or $^{99m}$Tc-GH or $^{99m}$Tc- MAG$_3$ renal scintigraphy, which also evaluates the tubular function of the kidney. If abnormal pelvocalyceal retention occurs, a diuretic such as furosemide (Lasix) can be administered intravenously and additional images obtained for 20 minutes. The dose administered is 40mg for a bilateral renogram, 20mg for transplant renogram and 0.5-1.0mg/kg in children. If the mechanical obstruction is not complete, Lasix will cause rapid emptying of the collecting system. If indicated, a Foley catheter will be placed and a catheter tray should be prepared (see next page).


Clinical Indications:
Evaluation of obstructive uropathy.
PROCEDURE: Bilateral pediatric renogram protocol

Patient Preparation:
1. If patients are at least one month of age the likelihood of immature renal function is reduced.

Hydration:
1. Fluids should be pushed beginning two hours prior to test. Parents are to be instructed one day prior to test.
2. Infusion of IV fluids, normal saline or half-normal saline, should be initiated 15 minutes prior to an injection of the radiopharmaceutical. The infusion rate will equal 15 ml. per kg. over 30 minutes and intravenous fluids will be maintained for the remainder of the study at a rate of 200 ml./kg per protocol.

Bladder Catheterization:
1. To ensure total emptying of the bladder, the patient will be catheterized prior to beginning the study and remain catheterized throughout the study.
   a. With hydrenephrosis (HN), a Foley catheter (balloon retention) or a straight catheter (without balloon) may be used. If hydrouretheronephrosis (HUN) is present, a straight catheter is used to avoid occluding an ectopic urethral orifice.
   b. If the catheter is unable to adequately empty the bladder as seen on the persistence scope image, then it should be repositioned and/or aspirated by syringe.

Renogram Technique:
1. Radiopharmaceutical: Tc-99m MAG3
   Dose: 50 uCi/kg or use chart of % adult dose (Minimum dose: 1 mCi)
2. Patient is placed in supine position with heart, kidneys, ureters, and bladder in the field of view. Magnification may be useful with LFOV cameras.
3. Acquisition protocols are 1 frame/2 sec for 64 sec for flow and 1 frame/15 sec for sequential renogram images.

Diuresis Phase:
1. The diuretic, furosemide (Lasix), is injected intravenously in a dosage of 1 mg/kg. It is injected 1 minute into the second renogram. Collection parameters should be the same.
2. In the present of marked HN, the patient may be placed briefly in the sitting or prone position to help distribute the radioactivity more uniformly prior to diuretic phase.
3. If the scintigram images suggest that the pelvis or ureter are incompletely drained at the termination of the diuretic phase, patient should be placed in the prone position for an additional image to determine if drainage is positional.

Data analysis:
1. **Regions of Interest:**
   a. The ROI for the initial renogram should include the entire kidney, including the dilated renal pelvis.
   b. The background ROI should be 2 pixels wide around the outer perimeter of the entire ROI for the kidney.
   c. In HN, the ROI for the diuretic renogram should include only the renal pelvis and the collecting system.
   d. In HUN, the ROI is placed around the dilated pelvis and separate ROI is placed around the ureter to the ureterovesical junction.
   e. For the diuretic phase, the background ROI should be a semilunar area adjacent and lateral to lower pole of the dilated system.

2. **Percent Differential Renal Function:** total counts of the renogram curve for each kidney minus bkgd. during the interval between 60 seconds and the appearance of radioactivity in calyces.

3. **Percent Differential Cortical Renal Fxn:** count rates from the cortical area of each kidney are recorded in the interval between 60 sec. to initial calyceal appearance.

4. **Twenty Minute to Peak Ratios:** counts obtained from the bkgd. subtracted renogram curves are used to calculate percent 20 min/peak ratios for the entire kidney and the kidney cortex for both kidneys.

5. **Renogram Time Activity Curve Patterns:** normal, immature, stasis, obstructive or poor function.

6. **Diuretic Phase Curve Patterns:** no obstruction, indeterminate, or obstruction.

7. **Determination of Clearance Halftime for diuretic Response Analysis.**

8. **Archive the images to PACS.**
8) CORTICAL RENAL SCINTIGRAPHY

Because of the long retention time of DMSA and glucoheptonate in the renal tubular cells, both the agents are used to evaluate the morphologic appearance of the renal cortex and to measure accurate relative differential renal function.

Clinical Indications:
1. Evaluation of size and shape of the kidney.
2. Evaluation of space-occupying lesions.
4. Evaluation of trauma.
5. Evaluation of pyelonephritis.
PROCEDURE:  

99mTc-DMSA Renal Scintigraphy

Patient injected on the floor with isotope. 2 to 4 hours later the patient is brought down to the department for pictures.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: 99mTc-DMSA is prepared according to the Radiopharmacy procedure manual and injected between 15-30 minutes after preparation.
2. Adult Dose: 5 mCi (0.5 mCi for renal profile.
3. Child Dose: Per body weight (see chart)  
   Minimum 0.5 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: 2-4 hours post injection.
6. Scanning time required: 30 - 60 minutes

Patient Preparation: Check that the patient is not pregnant or breast feeding.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for 99mTc (140 keV 15-20%).
3. Preset counts for 750k/image if the dose is 5 mCi and 50k/image if the dose is 0.5 mCi.

Scanning Instructions:
1. Check patient records for BUN and Creatinine clearance. This will determine time interval for imaging.
2. Collect a 750K image posterior and both obliques.
3. All patients with normal planar images should have a SPECT acquisition. In the uncooperative child, posterior pinhole views of each kidney may be substituted at the discretion of the physicians.
4. Archive the images to PACS.

SPECT Instructions (if indicated)
1. LEHR parallel-hole collimator
2. 3 degrees per stop
3. 30 seconds/frame
4. 360 rotation
5. 64 x 64 x 16 pixels matrix for reconstruction.

Computer processing: (see Computer Instructions)
1. Regions of interest are drawn around the kidneys (excluding the renal pelvis) and around the background.
2. Splits renal function are calculated.
PROCEDURE: $^{99m}$Tc glucoheptonate renal scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-GH (gluceptate) is prepared according to the Radiopharmacy procedure manual
2. Adult Dose: 15 mCi
3. Child Dose: Per body weight (see chart) Minimum 1.5 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately
6. Scanning time required: 45 minutes

Patient Preparation: Check that the patient is not pregnant or breast feeding.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV 15-20%)
3. Preset time for 5 minutes/image or 750K

Scanning Instructions:
1. The patient is supine on the table with the camera under the table to take posterior views.
2. Start camera and collect 5 minute images in the posterior LPO and RPO projections.
3. If Foley catheter is in place, collect a 5 minute image of Foley bag after completion of renogram.
4. If the bladder is not in the field of view, collect a 5 minute image on the bladder after completion of renogram.
5. All patients with normal planar images should have SPECT of the kidneys performed. In the small child, posterior pinhole views of each kidney may be substituted for SPECT at the discretion of the physicians.
6. Archive the images to PACS.
9) CYSTOGRAPHY

Clinical Indications:
Evaluation of vesicoureteral reflux. Direct radionuclide cystography is more sensitive for detecting vesicoureteric reflux than the traditional conventional roentgenographic procedure. Although the use of sulfur colloid or pertechnetate is not specified for this indication in the package insert, the method is simple, reliable and gives less radiation dose to the gonads than the standard radiographic technique (0.5 mR vs. 24-309 mR).

PROCEDURE: Cystography

Radiopharmaceutical Administration:
1. Radiopharmaceutical:
   a. $^{99m}$Tc sulfur colloid is prepared according to the Radiopharmacy procedure manual. or
   b. $^{99m}$Tc pertechnetate
2. Adult Dose: 2-3 mCi
3. Child Dose: 0.5 - 0.7 mCi
4. Route: Through catheter into bladder. Flush with sterile water.
5. Time interval between administration and imaging: Immediately
6. Additional Information:
   Physician should be present when injection is made and bladder being filled.

Patient Preparation:
1. A Foley catheter must be in place before study begins.
2. An infant feeding tube may be used for small children.
3. Check that the patient is not pregnant or breast feeding.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV 15-20%)
3. Preset time for 60 sec/image
4. Be sure to cover scanning bed and camera with appropriate shielding to prevent contamination. Also wear gloves while injecting and removing catheter.

Scanning Instructions:
1. Patient must be in supine position with camera under the scanning bed (to avoid contamination).
2. The dose is administered through catheter into bladder via a 3-way stopcock. Flush well with sterile water.
3. Continue filling the bladder with saline by gravity until patient feels full with slight discomfort. Record volume and image.
4. Begin taking images as bladder fills up. Take continuous images until catheter is removed from patient and bladder is empty. Write volume on different images.
5. Place bedpan under patient and obtain voiding image.
7. Archive the images to PACS.
The physiologic basis for the functional evaluation of the thyroid is that iodide is actively accumulated in the normal functioning thyroid gland where it is incorporated into thyroid hormones and stored within the thyroid follicles. Most recently $^{123}$I is preferred to $^{131}$I because the radiation does to the patient is lower than the $^{131}$I. Alternatively, $^{99m}$Tc-pertechnetate which accumulates in the thyroid gland because its chemical similarities to iodide is an excellent thyroid imaging agent as well. This pertechnetate is trapped within the gland for a brief period but is not made into thyroid hormone.

Thyroid nodules that are "cold" and do not take up pertechnetate or iodine are potentially thyroid cancer and require further investigation. The overall probability in a patient without previous neck radiation of a "cold" thyroid nodule being malignant is approximately 15%. If a single thyroid nodule is "cold," then the malignancy may be further evaluated by an ultrasound study to see if this is a true cyst. If the nodule has a relatively normal iodide content then it is also unlikely to be malignant.

Clinical Indications:
1. Functional assessment of thyroid nodules.
2. Evaluation of thyroid size position and qualitative function as well as the differential diagnosis of masses in the neck, base of the tongue, or mediastinum.
3. Diagnosis of functioning metastatic lesions in patients with known thyroid carcinoma.
TABLE. INTERFERING FACTORS IN THYROID IMAGING

<table>
<thead>
<tr>
<th>Factor</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Iodide</strong></td>
<td></td>
</tr>
<tr>
<td>Lugol’s, SSKI</td>
<td>1-3 wk</td>
</tr>
<tr>
<td>X-ray contrast agents</td>
<td>1-3 wk</td>
</tr>
<tr>
<td>Intravenous pyelogram, angiogram</td>
<td>2-3 wk</td>
</tr>
<tr>
<td>Gallbladder agents</td>
<td>mos</td>
</tr>
<tr>
<td>Bronchogram</td>
<td>yrs</td>
</tr>
<tr>
<td>Myelogram</td>
<td></td>
</tr>
<tr>
<td><strong>Antithyroid Drugs</strong></td>
<td></td>
</tr>
<tr>
<td>(PTU, methimazole, Tapazole(^a), Perchlorate)</td>
<td>72 hrs</td>
</tr>
<tr>
<td><strong>Thyroid Hormones</strong></td>
<td></td>
</tr>
<tr>
<td>L-thyroxine (Synthroid(^a),Levothroid(^a), Levoxyl(^a), Thyrolar(^a))</td>
<td>4-6 wk</td>
</tr>
<tr>
<td>Triiodothyronine (Cytomel(^a))</td>
<td>2 wk</td>
</tr>
<tr>
<td><strong>Thyroid Diseases</strong></td>
<td></td>
</tr>
<tr>
<td>Thyroiditis acute phase</td>
<td>transient</td>
</tr>
<tr>
<td>Hypothyroidism (primary, secondary, tertiary)</td>
<td>permanent</td>
</tr>
<tr>
<td>Congenital and migrational problems of the thyroid</td>
<td>permanent</td>
</tr>
</tbody>
</table>

\(^a\)Brand names

(From Ashkar FS, Clin Nucl med 6(105):83, 1981)
Thyroid Information Sheet  Huntsville Hospital

Patient Name: ____________________________________________

Patient MRN: ____________________________________________

Date of Exam: ____________________________________________

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>If Female:</strong> Are you pregnant or nursing?</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td><strong>If Female:</strong> Are your menstrual periods regular?</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>If Female:</strong> Are you any of the following:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-Menopausal:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-Hysterectomy:</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Do you take thyroid medications such as Synthroid, Levoxyel, Levothroid, Cytomel, PTU, Tapazole or Methimazole?</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Do you use iodine-containing medicines such as Vitamins, Kelp, SSKI, Lugol’s Solution, Amiodarone (Cordaron, Pacerone), Organidin, Diabetes Pills or Betadine?</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Do you take Interferon?</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Have you had thyroid surgery or received radioactive iodine therapy?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Have you had a thyroid scan or ultrasound examination before?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When:</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Have you had any X-ray contrast studies (CT, IVP, Arteriogram, Cardiac Cath) in the last month?</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Did you have radiation treatment to your face or neck as a child?</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Have you received any Thyrogen injections?</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Please indicate if your thyroid blood tests are high, low or normal:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High:</td>
<td>Low:</td>
</tr>
<tr>
<td>11.</td>
<td>Any additional thyroid history?</td>
<td></td>
</tr>
</tbody>
</table>

Patient Signature:_________________________________   Date:_______________

Interviewing Technologist: _____________________________, CNMT  Revised 01/03/2007
PROCEDURE: $^{131}$I Uptake

Radiopharmaceutical Administration:
1. Radiopharmaceutical: Oral $^{131}$I NaI
2. Adult or Child Dose: 5-16 microCuries
3. Route: Oral
4. Time interval between administration and scanning: 4 and 24 hours
5. Dose must be ordered 24 hours in advance. Not available on Fridays.

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Instruct patient on times to return for uptake counts.
3. Avoid iodinated medications (Organidin, amiodarone) and iodinated contrast agents for 6 weeks prior to procedure. Certain thyroid medications interfere with this study. Synthroid, Levoxyl, and Levothroid should be discontinued for 6 weeks prior to the study; Cytomel ($T_3$) should be discontinued for 2 weeks. PTU, methimazole, and Tapazole should preferably be discontinued for 3 days. An uptake for a patient taking these medications may be clinically warranted in special circumstances.
4. Clear liquids only for 4 hours before and one hour after radioiodine administration.

Machine Set-up Instructions:
1. Use single probe uptake detector and calibrate uptake probe according to manual for unit (see insert "Uptake Probe in Service").
2. Photopeak and window settings predetermined for $^{131}$I (364 keV, 35%).

Scanning Instructions:
1. Patient may be either supine or sitting.
2. Standard fixed distance pointer used to obtain fixed geometry.
3. Take a 1-minute neck and thigh background count if patient had recent $^{131}$I studies.
4. Uptake at 4 and 24 hours--1 minute count of neck and thigh.
5. Five minute count of standard capsule in Lucite phantom.
6. Fill in sheet for uptakes and calculate percent uptake.

\[
\frac{\text{[gross cpm over neck] - [thigh cpm] \times 100}}{\text{[gross cpm administered] - [room cpm] \times 100}}
\text{(standard capsule)}
\]

Interpretation:
Normal RAIU (4 hours): 5-15%
Normal RAIU (24 hours): 10-25%
I. Calibration Procedure
1. Push power button on hard drive, monitor and printer. (If hard drive was off, allow 30-minute warm-up)
2. Select Captus 2000
3. Select Autocalibrate
   a. Select Autocalibrate (done weekly)
   b. Place Cs\textsubscript{137} source, press OK
   c. Place Eu\textsubscript{152} source, press OK
   d. Select Constancy (done daily)
   e. Place Cs\textsubscript{137} source, press OK
   f. Select Chi Square (done bi-weekly)
   g. Place Cs\textsubscript{137} source, press OK
   h. Print immediate results
   i. Done

II. Thyroid Uptake Procedure
1. Select Thyroid Uptake
   a. To add a new patient:
      1) Select ADD
      2) Enter patient data (must be completed)
      3) Enter dosage data (must be completed)
      4) Done
   b. Select Administer
      1) Enter date dose was given to patient
      2) Enter time dose was given to patient
      3) Done
   c. Select Count
   d. Select Start Procedure
      1) Acquire room bkg for 60 seconds
      2) Accept data - yes
      3) Acquire sample activity in phantom for 60 seconds: measure appropriate separation with distance bar
      4) Accept data - yes
      5) Exit
   e. Select Count
   f. Select Start Procedure
      1) Acquire patient bkg: position probe over patient thigh for measurement
      2) Accept data - yes
      3) Acquire neck counts: position probe over patient thyroid
      4) Accept data - yes
      5) Exit
6) Print selected patient
7) Done

g. At 24 hours:
1) Select correct patient from patient list
2) Standard will not be counted (auto decay correction)
3) Select Count
4) Select Start Procedure:
   acquire patient bkg and neck counts as before
5) Exit
6) Print selected patient
7) Done
PROCEDURE: $^{123}$IODINE UPTAKE

Radiopharmaceutical:
1. Radiopharmaceutical: $^{123}$I sodium iodine
2. Dose: 300 uCi
3. Route: oral
4. Time interval between administration and procedure: 6 hrs. and 24 hrs. Uptake to be performed at 4-6 hours and 24 hours with scan to be performed @ 6 hours if requested.
5. Standard: $^{123}$I sodium iodine, 100 uCi
6. Calibrate the dose and the standard and note the time of calibration
7. Note the time of administration

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Avoid iodinated medications (Organidin, amiodarone) and iodinated contrast agents for 6 weeks prior to procedure. Certain thyroid medications interfere with this study. Synthroid, Levoxyl, and Levothroid should be discontinued for 6 weeks prior to the study; Cytomel ($T_3$) should be discontinued for 2 weeks. PTU, methimazole, and Tapazole should preferably be discontinued for 3 days. An uptake for a patient taking these medications may be clinically warranted in special circumstances.
3. Clear liquids only for 4 hours before and one hour after radioiodine administration.

Camera Set-up:
1. LFOV camera, LEHR or LEAP collimator
2. 64 x 64 matrix
3. 159 keV (20%)

Uptake Instructions:
If thyroid probe is unavailable, uptake may be performed as follows:
1. Maintain distance from the camera to the patient and to the standard the same
2. Acquire a five-minute anterior image of the neck 24 hrs post-administration at a fixed distance from the skin surface and note time of imaging
3. Acquire an image of the standard in a neck phantom at 24 hrs using the same fixed distance and imaging duration
4. Acquire an image of the anterior thigh at 4 hrs and 24 hrs using the same fixed distance and imaging duration; the patient should void prior to imaging the thigh and the bladder must be completely out of the field of view
5. Complete worksheet; remember to correct the standard counts for decay
5. Perform standard thyroid scan at 4-6 hours if ordered.

Processing Instructions:
1. ROI of thyroid activity
2. ROI (circumferential) of thigh background activity
3. ROI of standard
4. Calculate % uptake: \[
\frac{(\text{thyroid counts}) - (\text{BG counts})}{(\text{std counts})} \times 100
\]
Interpretation:
Normal: 5-15% at 4-6 hrs and 10-25% at 24 hrs.


2.) Floyd JL et al. Thyroid uptake and imaging with $^{123}$I at 4-5 hours; Replacement of the 24-hour $^{131}$I standard. J Nucl Med 1985; 26:884-887.
Rev 01-03-2007
PROCEDURE: $^{123}$I thyroid scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{123}$I NaI
2. Adult Dose: 0.2 - 0.3 mCi
3. Child Dose: Per body weight (see chart)
   Minimum 0.1 mCi
4. Route: Oral
5. Time interval between administration and scanning: no earlier than 6 hours
   because organification start at 4 hours
6. Dose must be ordered 24 hours in advance. Not available on Fridays.
7. Scanning time required: 1 hour

Patient Preparation:
1. Same as for $^{99}$Tc pertechnetate thyroid imaging. Certain thyroid
   medications interfere with this study. Synthroid, Levoxyl, and Levothroid should
   be discontinued for 6 weeks prior to the study; Cytomel (T$_3$) should be
   discontinued for 2 weeks. PTU, methimazole, and Tapazole should preferably be
   discontinued for 3 days. Imaging a patient taking these medications may be
   clinically warranted in special circumstances.
2. Check that the patient is not pregnant or breast feeding.
3. All thyroid patients must be examined by a nuclear physician.
4. Assist the patient in completing the thyroid information sheet.

Machine Set-up Instructions:
1. Pinhole collimator
2. Photopeak and window settings predetermined for $^{123}$I (159 keV, 30%).
3. Preset counts for 50k/image
4. Mark the sternal notch with a $^{57}$Co marker.

Scanning Instructions:
1. The patient is supine under the pinhole with the neck extended
2. Collect static images of thyroid for 50K
3. Standard views are:
   a. Anterior close up
   b. Anterior standard distance with SSN marked
   c. LAO and RAO
   d. Anterior with nodule marked and centered in field of view and
      additional views as directed by physician.
4. Archive the images to PACS.
PROCEDURE:  $^{99m}$Tc thyroid scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc Pertechnetate
2. Adult Dose: 15 mCi
3. Child Dose: Per body weight (see chart) Minimum 2 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: 20 minutes
6. Scanning time required: 1 hour

Patient Preparation:
1. Certain thyroid medications interfere with this study. Synthroid, Levoxyl, and Levothroid should be discontinued for 6 weeks prior to the study; Cytomel ($T_3$) should be discontinued for 2 weeks. PTU, methimazole, and Tapazole should preferably be discontinued for 3 days. Imaging a patient taking these medications may be clinically warranted in special circumstances.
2. Iodine-based X-ray contrast agents and iodine-containing medications will interfere with this study. A 4-6 week interval is usually necessary.
3. Check that the patient is not pregnant or breast feeding.
4. All thyroid patients must be examined by a nuclear physician.
5. Assist the patient in completing the thyroid information sheet.

Machine Set-up Instructions:
1. Pinhole collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset counts for 200k/anterior image. Use same time for LAO and RAO and record the counts.
4. Mark the sternal notch with a $^{57}$Co marker.

Scanning Instructions:
1. The patient is supine under the pinhole with the neck hyperextended.
2. Collect static images of thyroid for 200k counts.
3. Standard views are:
   a. Anterior-close up
   b. Anterior-standard distance with SSN marked
   c. LAO and RAO
   d. Anterior with nodule marked and centered in field of view and additional views as directed by physician.
4. Archive the images to PACS.
PROCEDURE: 201Tl and 131I whole body scintigraphy

Whole body 131I scintigraphy should be preceded by a whole body 201Tl scintigraphy. Tl201 whole body scintigraphy should reserved for those patients in whom residual thyroid carcinoma is suspected and have had a negative 131I. Currently, FDG-PET is likely the preferred method for this situation.

1. 201Tl Whole body Scintigraphy

   Radiopharmaceutical Administration:
   1. Radiopharmaceutical: 201Tl
   2. Adult Dose: 3.5 mCi
   3. Route: IV
   4. Time interval between administration and scanning: 10 min
   5. Dose must be ordered 24 hours in advance.
   6. Scanning time required: 1 hour

   Patient Preparation:
   1. Check that the patient has not been on thyroid medication or had contrast studies, if the 201Tl scan is to be followed by 131I scan.
   2. Pregnancy is a contraindication to the study.
   3. The patient must discontinue breast feeding.
   4. Assist the patient in completing the thyroid information sheet.
   5. Discontinuance of thyroid medications and avoidance of iodinated materials is not necessary for a Tl scan per se.
   6. These patients must all be seen by the interpreting physician.

   Machine Set-up Instructions (LFOV):
   1. LEHR or LEAP collimator
   2. Photopeak and window settings predetermined for 201Tl (80 keV, 20%).
   3. Preset time for spot views 10 minutes/view.

   Scanning Instructions:
   1. The patient is supine on scan table.
   2. Image whole body anteriorly and posteriorly.
   3. Acquire spot view anteriorly on head, neck, thorax and abdomen.
   4. Archive the images to PACS.
2. **131I Whole Body Scintigraphy**

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: 131I NaI
2. Adult Dose: 2-5 mCi
3. Route: oral
4. Time interval between administration and scanning: 24-72 hours
5. Dose must be ordered 24 hours in advance.
6. Scanning time required: 1 hour

**Patient Preparation:**
1. Check that the patient has not been on thyroid medication or had contrast studies.
2. **Females must have a negative pregnancy test. Pregnancy and breast feeding are contraindications to the study.**
3. Clear liquids only for 4 hours before and one hour after radioiodine administration.
4. Patient may remain on thyroid hormone therapy and be scanned using recombinant human TSH (Thyrogen) administration as follows:
   - Monday Day 1 (0 hr) Thyrogen, 0.9 mg, IM buttock
   - Tuesday Day 2 (24 hr) Thyrogen, 0.9 mg, IM buttock
   - Wednesday Day 3 (48 hr) I-131, at least 4 mCi, by mouth
   - Friday Day 5 (96 hr) Scan as below and draw serum thyroglobulin level
   - Adverse events reported with Thyrogen: nausea (11%), headache (7%), asthenia (3%), vomiting (2%), urticaria or rash (<1%)
5. If the patient has not been given thyrogen, document the patients TSH as being>30 prior to I131 administration on the thyroid information sheet.
6. Assist the patient in completing the thyroid information sheet.

**Machine Set-up Instructions (LFOV):**
1. Medium, high, or ultra-high energy collimator
2. Photopeak and window settings predetermined for 131I (364 keV, 35%)
3. Preset time for 5 minutes/images

**Scanning Instructions:**
1. The patient is supine on scan table.
2. Image total body anteriorly and posteriorly for at least 30 minutes (140,000 cts)
3. Acquire spot view of neck anteriorly and other views as indicated with appropriate markers on chin, SSN, and shoulders (10-15 min and/or 60,000 cts)

Archive the images to PACS.
3. **$^{123}$I Whole Body Scintigraphy**

$I^{123}$ has several advantages over $I^{131}$ for thyroid cancer follow-up: Better dosimetry, images, and no threat of stunning are the primary benefits.

**Radiopharmaceutical Administration:**

1. Radiopharmaceutical: $^{123}$NaI
2. Adult Dose: 3-6 mCi
3. Child Dose: Per body weight (see chart) Minimum 1 mCi.
4. Route: oral
5. Time interval between administration and scanning: 24-48 hours
6. Dose must be ordered 24 hours in advance.
7. Scanning time required: 1 hour

**Patient Preparation:**

1. Check that the patient has not been on thyroid medication or had contrast studies.
2. Clear liquids only for 4 hours before and one hour after radioiodine administration.
3. Patient may remain on thyroid hormone therapy and be scanned using recombinant human TSH (Thyrogen) administration as follows:
   - Monday Day 1 (0 hr) Thyrogen, 0.9 mg, IM buttock
   - Tuesday Day 2 (24 hr) Thyrogen, 0.9 mg, IM buttock
   - Wednesday Day 3 (48 hr) $I^{123}$, at least 3 mCi, by mouth
   - Thursday Day 4 (72 hr) Scan as below and draw serum thyroglobulin level
4. Adverse events reported with Thyrogen: nausea (11%), headache (7%), asthenia (3%), vomiting (2%), urticaria or rash (<1%)
5. **If the patient has not been given thyrogen, document the patients TSH as being>30 prior to $I^{123}$ administration on the thyroid information sheet.**
6. Assist the patient in completing the thyroid information sheet.

**Machine Set-up Instructions (LFOV):**

1. Low energy high resolution and pinhole collimator
2. Photopeak and window settings predetermined for $^{123}$I (159 keV, ± 10%)
3. Preset time for 10 minutes per step.

**Scanning Instructions:**

1. The patient is supine on scan table.
2. Image total body anteriorly and posteriorly for at least 30 minutes (140,000 cts)
3. Image time may be reduced to 20 minutes for a 6-hour scan
4. Acquire spot view of neck anteriorly and other views as indicated with appropriate markers on chin, SSN, and shoulders (10-15 min and/or 60,000 cts) using a pinhole collimator for the neck view. SPECT at 24 hrs as needed for localization with or without
CT transmission images. 48-hour spot images as needed to resolve equivocal findings.

5. Archive the images to PACS.


Revised 10/1/2004
PROCEDURE: Low dose $^{131}$I therapy

Clinical Indication:
Hyperthyroidism

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{131}$I NaI
2. Doses can be calculated according to the thyroid gland size and uptake using the following formula:

$$0.08 \text{ to } 0.100 \text{ mCi/gm } \times \text{ gland weight (gm)}$$
$$24 \text{ hour - uptake}$$

with a maximum of 29.9 mCi as outpatient and in consultation with the referring physician.

Doses can also be given on a more empiric basis based upon underlying pathology. In general, Grave’s patients get treated with between 10-20 mci if their uptake is significantly elevated. Multinodular goiter patients typically get treated with > than 20 mci (but less than 29.9mci). It should be noted that the vast majority of patients will be on synthroid within 6 months to one year after therapy. Older patients, multinodular goiter patients, younger patients, and autonomously functioning nodule patients all have increased rates of retreatment.

3. Route: Oral

4. Additional Information:
   a. A signed requisition must be approved by the nuclear medicine physician before isotope is ordered.
   b. Females must have a negative pregnancy test within 24 hours. Pregnancy and breast feeding are contraindications to the study. All females in child bearing age (11-60 years old) scheduled for I-131 thyroid therapy:
      1. Must have a negative pregnancy test within 24 hours before treatment.
      2. Exceptions include hysterectomy or tubal ligation and menopause.
      3. Document pregnancy test results (or tubal ligation/hysterectomy/menopause) on the thyroid information sheet
   c. Informed consent should be signed by patient.
   d. Dose amount should be remeasured and confirmed by technologist.

Patient Preparation
1. Check that the patient has not been on thyroid medication or had contrast studies for the past 6 weeks.
2. Females must have a negative pregnancy test. Pregnancy and breast feeding are contraindications to the study.
3. Make the patient aware of possible side effects:
a. Radiation thyroiditis and sialoadenitis.
b. Exacerbation of hyperthyroidism.
c. Bone marrow depressions (rare).
d. Long-term hypothyroidism.
e. Advise avoidance of pregnancy for 6-12 months.

4. Make the patient aware that $^{131}$I is eliminated by the saliva, sweat glands, and kidneys, and that his/her urine will be radioactive for a few days.
5. Advise the patient to avoid close contact with small children for a few days, and to discontinue breastfeeding.
6. Make sure that the patient will be followed up by the referring physician.
7. Clear liquids only for 4 hours before and one hour after radioiodine administration.

7. Obtain a written informed consent.
8. Give patient the hyperthyroidism information sheet. Have them sign a copy for our records. Answer any questions they may have. If the technologists is unable to answer any questions the patient may have, contact the radiologist to do so. **Document pregnancy test results on the thyroid information sheet.**
Procedural Specifics of I-131 Therapeutic Administrations

1. A copy of the prescription should be available at the time the dose is administered, and
2. All therapeutic doses should be double-checked at the time of administration (two technologists or a tech plus an MD).

3. The technologist and the physician(s) are ultimately responsible for administering the proper radiopharmaceutical at the PRESCRIBED dose.
**Radioiodine (I-131) Therapy for Hyperthyroidism**

Radioiodine is absorbed from your stomach into your bloodstream and then concentrates in your thyroid gland, where it gradually destroys thyroid tissue. This occurs over 4-10 weeks, by which time your thyroid function should improve. Some radioactive iodine is excreted in your urine, and a little is excreted in your saliva and perspiration, requiring some precautions to avoid spreading any significant radiation to by-standers. Most patients experience no side effects from this treatment, and only one in ten to one in twenty require a second treatment. After thyroid function becomes normal, nearly all patients will later go on to develop an underactive thyroid, requiring life-long thyroid hormone pills for replacement; your physician will check for this periodically. If any tenderness of the gland develops in the week after treatment, aspirin, ibuprofen or Tylenol will usually provide sufficient relief; if not, call your physician. Follow the radiation protection instructions below.

**Food and Fluids:** It is preferable to not eat for four hours before and for one hour after radioiodine treatment to enhance absorption from your stomach. Following therapy, drink at least 2 quarts of liquids (8 glasses) per day for the first three days to hasten excretion of the radioiodine.

**Time and Distance:** For two days, you should minimize the length of time in contact with others and try to maintain a prudent distance from them in order to reduce their exposure to your radioactivity. Specific instructions are as follows:
1. Sleep in a separate bed (at least 6 feet separation) for the first two (2) days after your treatment.
2. Avoid close personal contact (kissing, sexual contact) for three (3) days.
3. Avoid close contact (3 feet) with other people for two (2) days.
4. Remain at least six (6) feet away from children and pregnant women for two (2) days.
5. Do not nap with children or hold an infant or child for more than several minutes (<30 min/day) for 14 days.
6. If your sleeping partner is pregnant, do not sleep with her for 14 days.
7. Discontinue breast feeding at the time of radioiodine administration. Radioiodine is secreted into the breast milk and can damage the infant’s or child’s thyroid gland.
8. Avoid becoming pregnant for 6-12 months.

And for three (3) days after therapy, please do the following:
1. Have the sole use of a bathroom; if not possible, wipe the seat of the toilet after each use.
2. Sit while urinating and flush the toilet twice with the lid down after each use.
3. Wash hands frequently including after each toilet use, and shower daily.
4. Rinse sink and tub with water after using them.
5. Use separate eating utensils, dishes, and glasses, and wash them separately.

The dose you were administered on _____/_____20___ was _____ mCi. If you have plans to use commercial transportation over the next several weeks, you may need to present this note. If you have any questions or concerns after therapy, please contact Huntsville Hospital’s Radiologist and ask to speak with the Radiologist in Nuclear Medicine.

**Follow-up:** It is important that you see your physician within the first 4-8 weeks after treatment and regularly thereafter in order to evaluate your response to your radioiodine therapy. It is your responsibility to arrange an appointment.

Patient: ___________________________ Witness: ___________________________ Date: _______

Revised 10/1/2004
**The parathyroid gland**

**Clinical Indications:**
Evaluation of parathyroid adenoma

\(^{99m}\text{Tc}\)\(^{201}\text{Tl}\) subtraction scintigraphy is based on the fact that the thyroid traps \(^{99m}\text{Tc}\) and \(^{201}\text{Tl}\) and that parathyroid adenomas take up \(^{201}\text{Tl}\). The accumulation of \(^{201}\text{Tl}\) in a parathyroid adenoma is non-specific and is most likely related to the cellularity and/or vascularity of the lesion.


The double-phase sestamibi study is based on the time dependence of localization within the thyroid and parathyroid tissue. An initial image represents the "thyroid phase" and is used mainly as an anatomical reference for the delayed image. Over time, there is decreased uptake in the thyroid gland and persistent uptake in parathyroid adenomas.

**Table 1 From Radiographics: Vol 4 #24**

**Pearls and Pitfalls in Parathyroid Scintigraphy**

**Pearls**
85% of patients with primary hyperparathyroidism have a solitary parathyroid adenoma

Parathyroid carcinoma can demonstrate increased uptake and retention of the tracer

A "cold" center implies cystic degeneration or necrosis

Small or deep parathyroid lesions can be identified and localized with Tc-99m MIBI or TETR SPECT;
SPECT is helpful in precisely directing the surgeon
Ectopic parathyroid adenomas may be overlooked at initial or repeat surgery without imaging guidance

Ectopic localization of the tracer in the lateral aspect of the neck raises the possibility of metastatic thyroid carcinoma

Thyroid-selective imaging is essential in postoperative patients and is often helpful in those with goiter

Thyroid activity and a sternal notch marker serve as anatomic landmarks for localization

Hyperparathyroidism should be confirmed with biochemical testing to minimize false-positive or falsenegative study results

Rarely, thyroid cancer appears "hot" at thyroid-selective Imaging

Retention of the tracer does not always occur in parathyroid adenomas at dual-phase imaging
Small parathyroid adenomas may be overlooked with planar imaging alone.

Ectopic parathyroid adenomas can be overlooked at imaging performed with a field of view limited to the neck.

Asymmetric activity in the submandibular glands can be mistaken for an ectopic parathyroid adenoma.

Long-term regimens of some medications may result in nonvisualization of the thyroid at Tc-99m MIBI or TETR imaging.

In general, scintigraphy has a lower sensitivity for parathyroid hyperplasia than for parathyroid adenoma.

PROCEDURE: $^{99m}$Tc-$^{201}$Tl subtraction scintigraphy

This is no longer the procedure of choice for parathyroid localization.

Radiopharmaceutical Administration:
1. Dose: In sequence:
   a. $^{99m}$Tc-pertechnetate: 2 mCi
   b. $^{201}$Tl: 2 mCi ordered from vendor (cut-off time for ordering is 3:00 p.m. for next day delivery).
2. Route: Intravenous
3. Time interval between administration and scanning: Immediately
4. Scanning time required: 30 minutes
5. Additional Information: The patient should be able to remain still for 30 minutes.

Patient Preparation: Check that the patient is not pregnant or breast feeding.

Instrumentation Setup:
1. Scintillation camera
   a. High resolution collimator
   b. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%) and $^{201}$Tl (80 keV, 30%).
   c. Preset time for 5 minutes.
2. Computer
   a. 64 x 64 word mode data acquisition
   b. Two 5-minute static frames followed by twenty 1-minute dynamic frames.

Data Acquisition:
1. Inject patient with 2 mCi of $^{99m}$Tc.
2. Wait 10 minutes.
3. Position patient for anterior view with $^{99m}$Tc peak and window settings. Center thyroid in field of view.
4. Collect a 5-minute $^{99m}$Tc image on the camera and computer.
5. Change peak and window settings to that for $^{201}$Tl.
6. Collect 5-minute scatter image on imaging device and computer.
7. Inject patient with 2 mCi of $^{201}$Tl.
8. Collect 20-minute $^{201}$Tl images at 60 seconds/image on the computer and four 5-minute images on the camera. Dynamic mode of data collection is used so that the data still may be salvaged even though patient movements may occur. The patient must not move between steps 3 and 8.

Data Processing:
1. Reformat the $^{201}$Tl data into four 5-minute images. Frames degraded due to patient motion may be eliminated at this time.
2. Smooth all images (9-point smoothing) to reduce the effects of statistical variations.
3. Subtract the $^{99m}$Tc scatter image from each of $^{201}$T1 images.
4. Examine the images carefully and select a region of thyroid that is comparable in the $^{99m}$Tc and $^{201}$T1 images. Using a region of interest over this area, determine average count in this area for each image.

5. Determine a normalization factor from the average counts obtained in step 2. Each data pixel in the $^{99m}$Tc image is then multiplied by this factor so that the comparable regions then have the same average count.

6. Subtract the normalized $^{99m}$Tc image from each of the $^{201}$T1 images.
7. Photograph the $^{99m}$Tc, $^{201}$T1, and difference images.
8. Archive the images to PACS.
PROCEDURE: $^{99m}$Tc Sestamibi (Cardiolite) double-phase study

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-sestamibi
2. Adult dose: 20-25 mCi
3. Route: intravenous
4. Time interval between administration and scanning: 15 minutes and 2 hours

Patient Preparation: Check that the patient is not pregnant or breast feeding.

Equipment set-up instructions (LFOV):
1. LEHR parallel hole collimator
2. Photopeak and window settings for $^{99m}$Tc (140 keV, 15-20%)
3. Preset time for 10 minutes/image

Interventions:
1. In highly selected cases of persistent or recurrent post-operative hyperparathyroidism in which routine MIBI imaging is negative, repeat scintigraphy using calcitonin as a stimulus may be performed.
   • Side effects include nausea, vomiting, flushing, hypotension
   • Anaphylactic allergic reactions are rare, but a history of atopy is a relative contraindication.
2. Miacalcitonin should be injected IM at a dose of 4 units/kg 3 hrs. prior to initiation of imaging.
3. When calcitonin is utilized, the following imaging protocol should be used:
   a. anterior planar imaging at 15, 45 and 120 minutes post-injection of MIBI
   b. SPECT imaging at 60 minutes p.i.

Scanning Instructions:
1. At 10-15 minutes post-injection, acquire digital images: view of neck and upper chest with head and neck extended. Anterior oblique and lateral views when necessary.
2. At 2-3 hours post-injection: acquire similar images.
3. If planar 10-15 minute images are normal, SPECT imaging is recommended. Show studies you feel are negative on the 10-15 minute images to Nuclear Medicine Physician, SPECT will likely be required.
4. Archive the images to PACS.

SPECT Instructions:
1. LEHR parallel hole collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 180 degree rotation
5. 128 x 128 pixel matrix for reconstruction
**Image Processing:**

1. Calculation of parathyroid adenoma/normal thyroid tissue uptake ratio on both early and delayed images may sometimes be useful.
   a. Draw ROI around area of persistent increased uptake corresponding to parathyroid adenoma.
   b. Draw ROI around normal thyroid tissue.
   c. Calculate ratio.

2. Normal values for parathyroid adenomas:
   - Early images: 1.24 +/- 0.23
   - Delayed images: 1.46 +/- 0.20
Procedure: $^{99m}$Tc-MIBI Parathyroid Scan for Minimally Invasive Parathyroidectomy

**Indications:** localization of parathyroid adenoma(s) preoperatively.

Most of these patients will be scheduled to go directly to the operating room immediately following completion of the delayed images, and the surgeon will need copies of films to go with the patient to the OR; parathyroidectomy is performed unilaterally via a 2.5 cm incision without general anesthesia.

Timing is important; the patient will undergo radioguided parathyroidectomy using a hand held probe, ideally 2.5 hours after injection; at 4 hours post-injection, activity is often insufficient to permit radioguidance.

SPECT and/or images delayed more than 2.5 hours will only rarely be necessary.

**Radiopharmaceutical:**
1. Radiopharmaceutical: $^{99m}$Tc sestamibi
2. Dose: 20 mCi (or 0.3 mCi/kg for obese patients)
3. Route: IV
4. Time interval between injection and procedure: 10-15 minutes

**Patient Preparation:**
1. Notify radiopharmacy ASAP that a dose is required early A.M.
2. Check that the patient is not pregnant or breast feeding.
3. Patient must be positioned for all views with head straight and a roll under the shoulders to extend the neck.

**Camera Set-up:**
1. Collimator: LEHR
2. Matrix: 128 x 128
3. Energy window: 140 keV +/- 10%
4. Magnification: 1.6 x

**Scanning Instructions:**
1. Acquire 4-5 images early and 3-4 delayed images, each at 8 cm; 5 minutes minimum and at least 500,000 counts for initial image, and then acquire for identical time on subsequent images
   - early: anterior, anterior w/markers, anterior mediastinum, 31° LAO, and 31° RAO.
   - delayed: anterior, anterior mediastinum, 31° LAO, and 31° RAO.
   - anterior mediastinum view should be at the superior border of the heart.
   - markers on thyroid cartilage, sternal notch, and one of the lateral border of each sternocleidomastoid muscle 4 cm apart as a distance guide.
   - if the mediastinum is included on the anterior view, no need to do a separate acquisition; need separate view only with small FOV camera.
2. Timing: Early images at 15 minutes; delayed images at 90-105 minutes.
· if adenoma is apparent in the neck on the early views, the delayed anterior mediastinal view is unnecessary.
· if adenoma is apparent on the early images, begin the delayed views at 50 min.
Dual Phase Parathyroid scan (I123and Tc99m sestamibi)

Radiopharmaceutical:
1. Radiopharmaceutical: $^{123}$I sodium iodine
2. Dose: 300uCi
3. Route: po
4. Time interval between ingestion and procedure: 4 hours
5. Radiopharmaceutical: $^{99m}$Tc sestamibi
6. Dose: 15-20 mCi
7. Route: IV
8. Time interval between injection and procedure: 5 minutes

Patient Preparation:
1. Check that patient is not pregnant.
2. Avoid thyroid and iodinated medications (Organidin, amiodarone) and iodinated contrast agents for 6 weeks prior to procedure, and antithyroid medications (PTU and methimazole) for 4-6 days prior. Procedure may be performed regardless of medications after consultation with nuclear medicine physician.

Camera Set-up:
1. LFOV camera, LEHR and pinhole collimators
2. 128 x 128 matrix
3. Simultaneous dual-isotope acquisition
4. 140 keV +/- 7% (130-150 keV); 159 keV =10%, -4% (153-175 keV)

Scanning Instructions:
1. Acquire "both" images for every projection.
2. First, acquire a five minute 1 M count anterior image of the neck and mediastinum with a LEHR collimator.
3. Then, acquire a 10-minute image of the thyroid region with a pinhole collimator.
4. Acquire lateral views as indicated.

Processing Instructions:
1. Film the $^{123}$I images and the $^{99m}$Tc-MIBI images.
2. Subtract the weighted $^{123}$I counts from the $^{99m}$Tc-MIBI images and film the subtraction images
   · Select a region of normal thyroid that is comparable in the $^{99m}$Tc-MIBI and in the $^{123}$I images
   · Using a ROI over this area, determine average counts in this area for each region
Determine a normalization factor from the average counts and then multiply each data pixel in the $^{123}$I image from each of the $^{99m}$Tc-MIBI images

3. Archive the images to PACS.
Interpretation:
Activity on the subtraction images should represent pathological parathyroid tissue.

3.) Casas AT et al. Prospective comparison of $^{99m}$Tc-MIBI/$^{123}$I radionuclide scan versus high-resolution ultrasonography for the preoperative localization of abnormal parathyroid glands in patients with previously unoperated primary hyperparathyroidism AM J Surg 1993;166:369-373.
THE RESPIRATORY SYSTEM
Revised 01/03/2007

The most commonly performed study of the respiratory system is the evaluation of regional pulmonary perfusion.

Rationale: The physiologic basis for this study is that intravenously administered macroaggregated albumin, which are larger than 10 microns in diameter, will be mechanically trapped in the pulmonary capillary bed.

A normal perfusion lung scan effectively rules out the diagnosis of pulmonary embolus.

If the lung scan is abnormal then the chest radiograph as well as another nuclear medicine study, the ventilation lung scan, may be used to evaluate the probability of pulmonary embolus versus that of parenchymal lung disease.

The ventilation lung scan uses $^{99m}$Tc-DTPA aerosol as a tracer to access pulmonary ventilation. Xe133 is an acceptable alternative if DTPA is unavailable.

The diagnostic considerations are that pulmonary embolus will cause an abnormal area of pulmonary perfusion with a relatively normal pulmonary ventilation. Pneumonia and chronic lung disease cause matching ventilation and perfusion abnormalities in the same pulmonary regions.

The most common presenting symptom in pulmonary embolism is dyspnea. The chest radiograph is commonly normal. The lung scan is best used to rule out pulmonary embolus. An abnormal lung scan may confirm embolism, or in a difficult diagnostic setting, may direct the pulmonary angiographer to the location of the suspected embolus.
PROCEDURE: Aerosol ventilation lung scintigraphy

Clinical Indication:
To correlate with perfusion scintigraphy when assessing the presence of pulmonary embolism.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: \(^{99m}\text{Tc-DTPA aerosol}
2. Adult or child dose: 45-50 mCi in a minimum of 2 ml are injected into the nebulizer and an estimated 0.5 - 0.8 mCi is retained in the patient.
3. Route: Inhalation
4. Time interval between administration and scanning: Immediate
5. Scanning time required: 30 minutes

Patient Preparation:
1. The ventilation scintigraphy should be performed before the perfusion scintigraphy.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.
4. Aerosol can be administered to patients on a ventilator. (See aerosol unit setup.)

Scintillation Camera Setup:
1. Use LFOV camera with LEAP collimator
2. Use photopeak and window settings predetermined for \(^{99m}\text{Tc (140 keV and 15-20% window)}
3. Use preset counts of 200k/image

Aerosol Unit Setup:
1. Unit to be used: Aero/Vent Lung Aerosol Delivery Unit, Medi-Nuclear Corp., 4501 Littlejohn St., Baldwin Park, CA
2. Attach one end of plastic breathing tube to patient mouthpiece, and the other end to the manifold housing.
3. Place assembled unit into the Aero/Vent Shield. Check to see that the lid closes properly.
4. For patients on a ventilator:
   a. Attach elbow connector to the Aero/Vent exhaust filter.
   b. Attach the ventilator tubing to the elbow connector.
   c. Attach the respirator patient tubing to the Aero/Vent breathing tube with a 22 mm connector.
   d. Proceed with established administration protocol.
5. Open lid of Aero/Vent shield and, using a shielded syringe and needle, inject a minimum of 2 ml of \(^{99m}\text{Tc-DTPA solution into the aerosol generator through the insertion port.}
6. After closing the lid, firmly attach a standard oxygen supply line to the oxygen inlet nozzle at the top of the aerosol generator.
Aerosol Administration:
1. Place the mouthpiece in the patient's mouth.
2. Place the noseclip on the patient's nose.
3. Prior to turning on the oxygen, instruct the patient to take several test breaths from the system. If the patient is not able to tolerate the mouthpiece, replace it with a breathing mask that is firmly attached to the patient.
4. Gradually turn on the oxygen, setting the flow rate at 10 liters per minute. **CAUTION:** At the normal 30-50 PSI pressure for the oxygen supply, an abrupt increase of flow rate from 0 to 10 liters/min. may detach the air line from the aerosol unit.
5. The patient should breathe normally for 5-7 minutes in the supine position. **CAUTION:** To prevent possible radiation leakage into the environment, be prepared throughout the inhalation period to shut off the oxygen supply immediately if the patient releases the mouthpiece. Should release occur, survey the area for possible contamination before continuing the procedure. If contamination is found, it will be necessary to decontaminate following accepted procedures before continuing the procedure.
6. After inhalation, turn off the oxygen and instruct the patient to continue breathing through the mouthpiece for an additional four or five tidal breaths to clear the system of aerosol.
7. Remove the noseclip and mouthpiece from the patient. Have the patient expel any saliva into a disposable towel to minimize gastric activity.
8. The patient imaging procedure may now be started.

Imaging Instructions:
1. Collect all images for 200k counts, in the same sequence as the perfusion views if possible:
   a. Anterior
   b. Posterior
   c. LPO and RPO
   d. Left lateral
   e. Right lateral

Disposal:
1. Disconnect oxygen tubing.
2. Open Aero/Vent Shield lid, remove the used Aerosol Unit from the shield and place in the provided storage bag.
3. Put date on storage bag, place it in a properly labeled lead-lined radioactive materials storage container and permit it to decay for at least 10 half-lives (60 hours) or until background levels are reached. Then survey the bag, record the background readings from the survey, and if the survey indicates that the bag is at background levels dispose of it as biological waste. Note: Be sure to destroy all labels.

Survey:
1. Survey the area using the GM counter for possible contamination at the completion of the study. Decontaminate the area following routine procedures if necessary.
INSTRUCTION FOR USE OF AERO/VENT, MODEL AV-400
IN CONJUNCTION WITH A RESPIRATOR

1. Place assembled unit into the aero/vent shield.
2. Attach elbow connector to the aero/vent exhaust filter.
3. Attach the ventilator tubing to the elbow connector.
4. Attach the respirator patient tubing to the aero/vent breathing tube with a 22mm connector.
5. Proceed with your established administration protocol

NOTE: This protocol is as used at St. John's Hospital and Health Center, Santa Monica, California. Prepared by Eleanor Throckmorton

PROCEDURE: Perfusion lung scintigraphy

Clinical Indications:
1. Diagnosis and management of pulmonary embolism (in conjunction with an aerosol ventilation scan).
2. Peri-operative evaluation of regional pulmonary function in the setting of lung carcinoma for both the involved lung and the uninvolved lung.
3. As an adjunct to the liver spleen scan for the evaluation of subdiaphragmatic abscess.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc macroaggregated HSA is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 5 mCi labeling 100,000 - 1x10$^6$ particle except for evaluation of lung transplant. (The number of particle is 75,000 to 100,000 particles for lung transplant evaluation and patients with known right to left cardiac shunts).
3. Child Dose: Per body weight (see chart). Minimum 3.5 mCi
4. Route: Intravenous with patient supine.
5. Time interval between administration and scanning: Immediately after injection
6. Scanning time required: 30 minutes

Patient Preparation:
1. Chest radiograph obtained within 24 hours
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.

Machine Set-up Instructions (LFOV):
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Collect 1M counts in anterior position and record time. Perform remaining views using this time.

**Scanning Instructions:**
1. Patient must be in a supine position for the injection.
2. Use a 23 gauge butterfly or larger and inject as a bolus using saline flush.
3. Immediately post injection, imaging is done in sitting or supine position as tolerated by patient. Views are collected for 1M counts.
4. For pulmonary embolism, the following views are obtained in the same sequence as the ventilation views, if possible.
   a. Anterior
   b. Posterior
   c. LPO and RPO
   d. Left lateral
   e. Right lateral
5. Additional views may be needed on direction of nuclear medicine physician.
6. For lung transplants: only a posterior view is obtained.
7. If indicated, perfusion lung scintigraphy can be performed after radionuclide venography using the same injection in the feet.

**Computer processing: (see Computer Instructions)**
1. For lung transplants and lung carcinoma: splits lung function are calculated on the posterior view.
2. For lung carcinoma: split lung function upper lobe versus lower lobe should be calculated on the posterior oblique views.
3. Archive the images to PACS.
PROCEDURE: Radionuclide arm venography

Clinical Indication: Evaluation of patency of the upper extremities and superior cava venous system.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 1 - 5 mCi (1 mCi/injection)
3. Child Dose: Per body weight (see chart).
4. Route: Intravenous in antecubital or forearm vein.
5. Time interval between administration and scanning: Immediate
6. Scanning time required: 15 minutes

Patient Preparation: Check that the patient is not pregnant or breast feeding. Explain the procedure and check for metal objects in the FOV.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Set parameter for dynamic acquisition: 2.0 sec/image for 64 sec

Scanning Instructions:
1. Place the patient supine on the table with the upper arm of interest, upper chest and lower neck in the field of view. The upper arm should be in slight external rotation and 30 - 60 degrees abduction to minimize artifact of physiologic compression of the axillary vein.
2. The dose is injected through a 23 gauge butterfly or larger, as a bolus with 5ml saline flush using a 3-way stopcock.
3. Collect dynamic image at 2 seconds/image for 64 seconds.
4. Repeat the same procedure on the other arm.
5. If an obstruction of the superior vena cava is suspected, collect an anterior view of the liver.
6. Archive the images to PACS.
PROCEDURE: Radionuclide leg venography

Clinical Indication:
   Evaluation of patency of deep venous system of lower extremities.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc Macroaggregated HSA is prepared according to the Radiopharmacy Procedure Manual. Sulfur Colloid may be used also.
2. Adult Dose: 4.8 mCi (8 doses of 0.6 mCi each)
3. Child Dose: Per body weight (see chart). Minimum 3.5 mCi
4. Route: Intravenous through the feet. If a suitable pedal vein cannot be located, a $^{99m}$Tc-RBC injection into an antecubital vein may suffice at the discretion of the nuclear physician.
5. Time interval between administration and scanning: Immediate
6. Scanning time required: 30 minutes

Patient Preparation: Check that the patient is not pregnant or breast feeding.
   Explain the procedure and check for metal objects in the FOV.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset counts for 30K/image.

Scanning Instructions:
1. Patient must be in supine position for the injection.
2. Place cobalt-57 markers on knees, mid-thigh, and pubis.
3. Place two tourniquets around each ankle and one above each knee.
4. Use a 23 gauge butterfly or larger and inject as a bolus using saline flush.
5. Scan entire lower extremities in a series of 4 images from ankle to bifurcation.
6. If indicated, perfusion lung images can be obtained, but only if a ventilation scintigraphy has also been performed.
7. Archive the images to PACS.
RADIONUCLIDE DVT IMAGING (AcuTect)

Tc-99m-apcitide is a radiolabeled synthetic peptide which binds to the glycoprotein IIIb/IIA adhesion receptors expressed (only) on activated platelets; it binds less avidly to the vitronectin receptor found on endothelial cells. There is 75% plasma protein binding; T1/2 is 2 hrs with approximately 80% excreted in the urine. Bladder and kidneys are target organs. AcuTect imaging appears to detect only acute and not chronic venous thrombosis; arterial thrombosis may also be detected. It is not know whether ongoing anticoagulation affects the sensitivity of the technique. The accuracy of the technique is thought to be high but has not been adequately studies; the power of a negative exam is uncertain.

Indications:  
detection of acute deep venous thrombosis in the lower extremities of patients who have signs and/or symptoms of DVT

Examination time:  
two hours

Patient preparation:  
(1) A DVT ultrasound performed within the past 48 hrs interpreted as equivocal (or negative) for acute DVT should be available.
(2) Position patient supine on the examination table with the legs aligned symmetrically and identically for early and delayed imaging; avoid knee flexion.
(3) Empty bladder before early and delayed imaging.
(4) Hydration is encouraged.
(5) Pregnancy and lactation are only relative contraindications.
(6) Acute hypotension has been reported; patients with a history of drug reactions or allergies should be observed for 2 hrs p.i..
(7) Remove tight clothing, stockings, or any lower extremity vascular compression devices.
(8) Position the patient supine with the legs positioned symmetrically to allow comparison of early and delayed images; feet should be bound.
(9) Explain the procedure and check for metal objects in the FOV.

Equipment set-up:  
(1) 140 keV with 20% window; LEHR collimator.
(2) Matrix, 128 x 128

Radiopharmaceutical: Tc-99m apcitide, 20 mCi IV into a peripheral UPPER extremity vein.

Imaging protocol:  
(1) Shield the bladder for the pelvic imaging.
(2) Anterior and posterior images of both lower extremities from the ankles to the groins are acquired beginning 10 minute p.i.
   · 750,000 count images of pelvis and thighs from lower edge of the bladder.
   · 500,000 count images from mid-thigh to mid-calf.
   · 500,000 count images from just above the knees to
just above the ankles.

(3) Similar images are acquired in the same sequence at 60 minutes p.i.

(4) Markers on the knees may be helpful.

(5) Lunge images w/ or w/o SPECT are generally insensitive for acute PE.

Processing:

(1) File the 10 and 60-minute static images with enhanced contrast aligned by view for both time points.

(2) Ideally the images should be viewed on the monitor at varying degrees of contrast enhancement.

(3) Archive the images to PACS.

Interpretation:

(1) Positive uptake in the deep venous structures requires:

   (a) Asymmetric linear vascular uptake (with or without superimposed diffuse uptake) in contrast enhanced images which persists or becomes apparent on delayed images and

   (b) Asymmetry in both anterior and posterior projections. If asymmetry appears only after extreme contrast enhancement, then diffuse asymmetry must also be present.

References:


Revised 6-5-05
PROCEDURE: Xenon ventilation lung scintigraphy

Clinical Indications:
Evaluation of lung transplants

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{133}$Xenon gas
2. Adult Dose: 10-20 mCi
3. Route: Inhalation
4. Time interval between administration and scanning: Immediate
5. Scanning time required: 30 minutes
6. Dose must be ordered 24 hours in advance.

Patient Preparation: Check that the patient is not pregnant or breast feeding.
Explain the procedure and check for metal objects in the FOV.

Room Preparation/Safety Precautions:
(Radiology Safety Approved)
1. Must be performed in a negative pressure room
2. Turn on Xenon Exhaust fan (switch in hot lab). Leave on for 24 hours after procedure.
3. Connect Xenon exhaust hose to Xenon vent. Place hose on floor near patient.
4. Keep room door closed during and after procedure.
5. Patient should be positioned toward rear of room while breathing Xenon.
6. Personnel should stand as near the door as possible.

Scanning Procedures:
1. Camera:
   a. LEHR collimator
   b. Photopoint and window settings predetermined for $^{133}$Xe (81 keV, 20%).
   c. Preset counts 100K/image for wash-in and equilibrium views and preset time for 60 sec/image for washout.
2. Computer collection:
   a. 2 pre-static images (100K)
   b. Dynamic 60 sec/image for 7 frames
   c. Use 128 x 128 x 16 pixel matrix
3. Xenon Trap = Pulmonex Xenon System (see "Operations Manual" and "$^{133}$Xenon in Service")
   a. Check the setting of the Xenon trap as explained in Section A of the Operation Manual.
   b. Check that last QC was okay.
4. Patient imaging:
   a. Posterior view only
b. Follow the instruction in Section B (8-16) of Operation Manual from the Xenon trap.

c. Upon initial deep breath the $^{133}$Xenon gas is injected into tubing attached to mouthpiece through which patient breathes, and connected to the Xenon trap.

d. Patient is asked to hold breath for 40 sec. Wash-in image is collected for 100K counts.

e. Patient then continues to re-breathe the $^{133}$Xenon through a closed system for 3-5 minutes until equilibrium is reached and an image is taken.

f. Wash-out images are taken for 5-7 minutes, while patient is breathing in non-radioactive room air and exhaling diluted $^{133}$Xenon gas.

g. Follow the instructions in Section B (17-19) and C of Operation Manual from the Xenon trap.

Emergency Procedure (involving release of mCi amounts of $^{133}$Xenon into the room):

1. Position exhaust hose near point of release.
2. Post "caution-airborne radioactivity" sign on the door.
4. Evacuate room for 90 minutes.

Quality Control for Xenon Trap (1x/month)

1. See "Operation Manual of Pulmonex Xenon System"
2. The bag with 100 Ci Xenon should be placed in a rigid box and stored in the charcoal hood in PET facility.
3. If QC is outside the limits; the charcoal trap will be replaced before doing a next patient.

Computer processing of splits function:

Draw ROI around lungs and report splits function:

a. Total counts in ROI
b. Average counts/pixel in ROI

Archive the images to PACS.
I. Radiation Safety Guidelines
1. No more than two patients/day
2. Turn on exhaust fan (hot lab)
3. Keep door closed during and after procedure
4. Quality control for Trap (performed x 1 month)
   a. Xenon-filled bag to be transported in rigid container to charcoal hood in PET facility
   b. Charcoal cartridge to be exchanged (replaced) if it becomes saturated

II. Pulmonex Trap Guidelines
1. Do not leave Pulmonex in position #3 (washout) when not in use
2. When patient has completed the washout phase, do not leave system running for more than 10 seconds
3. Make sure Drierite (DryAll) is replaced before it changes color
4. Spread studies out over period of time
5. Change Soda-Lime between each patient - (absorbs CO₂)

III. Procedure
1. Position patient in front of camera; turn on O₂ (6-8 l/min)
2. Set handler to start (#1)
3. Set timer to turn on
4. Set air flow to "30" and add O₂ to patient bag (1/4 full) - (can use ambient air - fill by turning to #2, then back to #1 when 1/4 full)
5. Set timer to 9 minutes (arbitrary)
6. Place mouthpiece/mask on patient and have patient breathe to become accustomed to the unit
7. Switch to #2. Add Xenon as patient takes deep breath. Hold breath for 40 sec. - then breathe normally increase airflow to 70
8. When patient reaches equilibrium (1-2 min), switch to washout #3 (for 3-5 min.)
   a. Monitor "from patient bag," if it begins to blow up, patient is breathing too fast
   b. Advise patient to normalize breathing and increase "air flow" speed
   c. If it continues to fill, increase trap airflow by turning knob clockwise
      (Note: return to ½ of its range when study is complete)
9. Upon completion of washout, remove patient and system for a few seconds (not more than 10) until both bags are empty.
LIVER/SPLEEN SCINTIGRAPHY

The physiologic basis of this study is the phagocytosis of radioactive colloidal particles by the reticuloendothelial cells of the liver, spleen and the bone marrow.

Clinical Indications:
1. Detection of focal, space occupying liver disease, such as metastatic tumor, primary tumor, abscess, cysts.
2. Functional evaluation of cirrhosis and other causes of diffuse hepatocellular disease.
3. As an adjunct in the differential diagnosis of the jaundiced patient.
4. Evaluation of subdiaphragmatic abscesses.
5. Evaluation of the liver and spleen size configuration position and size.
6. Evaluation of focal defects in the spleen or liver in the setting of trauma and/or rib fracture.

**PROCEDURE: Liver/Spleen scintigraphy**

The patient is injected in the Nuclear Medicine department. After a delay of 15-20 minutes post-injection, the liver and spleen are imaged.

**Radiopharmaceutical Administration:**

1. Radiopharmaceutical: $^{99m}$Tc Sulfur Colloid is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 5 mCi
3. Child Dose: Per body weight (see chart)  
   Minimum 0.5 mCi
4. Route: Intravenous  
5. Time interval between administration and scanning: 15 minutes post injection  
6. Scanning time required: 45 - 90 minutes

**Patient Preparation:** Check that the patient is not pregnant

**Machine Set-up Instructions:**

1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Collect 1M counts on anterior liver.
4. Record time to accumulate this view.
5. Use time for remainder of liver views.

**Scanning Instructions:**

1. Routine views:  
   a. Anterior  
   b. Anterior with lead markers  
   c. Right lateral  
   d. Right anterior oblique  
   e. Posterior  
   f. Left lateral  
   g. SPECT for evaluation of ANY liver lesion  

   (If clinically indicated, an LAO view of the spleen may be required.)
2. Women with pendulous breasts will need to have them taped up.
3. Check for metallic objects in pockets or on patient.
4. Foundation garments and breast prosthesis must be removed.

**SPECT Instructions (STANDARD FOR ALL LIVER LESION EVALUATION):**

1. LEHR parallel-hole collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 360 degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction.

Archive the images to PACS.
99mTc-RBC SCINTIGRAPHY

Clinical Indications:
1. Evaluation of liver hemangioma.
2. Assessment colloid liver scan porta hepatic defects.
3. Evaluation of patency of major abdominal vasculature.
PROCEDURE: $^{99m}$Tc-RBC scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc Pertechnetate
2. Adult Dose: 25 mCi
3. Child Dose: Per body weight (see chart)
   Minimum 3.0 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately
6. Scanning time required: 45-90 minutes
7. Additional Information:
   The RBC of the patient are labeled in vitro using the ultra tag technique with subsequent re-injection of the tagged autologous cells.

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. The CT or ultrasound report and/or images should be reviewed to determine if the lesion in question is anterior or posterior.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. For static images, preset counts 1M/image.

Scanning Instructions:
1. Place patient supine on the table with the camera positioned anteriorly over abdomen area if the lesion in question is anterior; position the camera posteriorly if the lesion is posterior.
2. A dynamic flow study is performed following a bolus injection of $^{99m}$Tc RBC, and is recorded at 1.5 sec/frame for 40 seconds, followed by one static image of 400K counts.
3. Image every 5 minutes for 1M counts for 30 minutes.
4. Obtain delayed views at 45 and 60 minutes.
5. Acquire a SPECT study after the end of planar scintigraphy at 90 minutes with processing to allow cine display.

SPECT Instructions:
1. LEHR parallel-hole collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 360 degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction

Archive the images to PACS.
PROCEDURE: Hepatobiliary scintigraphy: Revised 1/16/2012

The patient is injected in the department with isotope. Images are acquired immediately after injection for 1 hour. Delayed images are often required including a 24-hour post-injection image. Delayed images depend upon visualization of the gallbladder and bowel activity.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc mebrofenin or $^{99m}$Tc disofenin is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 5 mCi
3. Child Dose: Per body weight (see chart) Minimum 1.0 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately

Patient Preparation:
1. Patient must be N.P.O. for at least 4 hours and no longer than 12 hours.
2. Check that the patient is not pregnant or breast feeding.
3. For outpatient adults, the need for CCK administration should be ascertained before injection of HIDA, preferably by calling the referring MD
4. When looking for biliary atresia, a phenobarbital stimulation can be performed by giving 5 mg/kg/day for 5 days prior to the study.
5. Check time of last narcotic administration (morphine or demerol). Opioids may interfere with hepatic/biliary clearance and ejection fraction calculation. Ideally, opioids should be held for a period of 4 half-lives. For inpatients requiring more prompt scheduling, 4 hours may be a more practical compromise.
   - Half-lives: Morphine 2-3 hrs. Dilaudid 2-3 hrs. Fentanyl IV 0.5-1.5 hrs. Fentanyl patch 7 hrs. Demerol 3-4 hrs. Codeine 3 hrs.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset counts for 1M counts or preset time for 240 sec for adults, 300K/image for infants (0-6 months).

Scanning Instructions (Non CCK Stimulated Studies):
1. Anterior views of abdomen are taken every 5 minutes for 30 minutes at 1M counts/image for non-CCK stimulated studies.

2. Delay images at 45 minutes to 2 hours (or longer) may be necessary.

3. **When gallbladder is visualized, an RAO and Right lateral view are taken.**

4. If acute cholecystitis is suspected and the gallbladder is not seen within 60 min, morphine sulfate may be given.
   - Tracer activity should be present in the small bowel at the time of morphine injection.
   - A booster injection of 1-2 mCi may be necessary if there is insufficient remaining activity in the liver.
   - Morphine sulphate 0.04 mg/kg (maximum 4 mg) IV over 3 min.
   - Contraindications: Increased intracranial pressure in children (absolute), respiratory depression in non-ventilated patients (absolute), morphine allergy (absolute), and acute pancreatitis (relative).
     - Outpatients should be instructed to not drive or operate heavy machinery for 8 hours following morphine injection.
   - Dynamic imaging should be continued for another 30 minutes following morphine administration.
     - Imaging may be stopped earlier if there is definite visualization of the gallbladder after morphine.
   - If morphine is contraindicated, then delayed anterior images at 3-4 hours should be obtained.

5. **For bile leak:**
   a. If the patient is being studied for a bile leak, any drainage bags should be included in the field of view. 4 hour delayed imaging and patient-positioning maneuvers (e.g., decubitus views) should be obtained. Always show to Radiologist prior to patient returning to floor/going home.
   b. T-tube drainage catheters within the common bile duct should be clamped during the procedure. Jackson-Pratt (JP) or Penrose drainage catheters may be left open.

6. Delayed imaging at 18-24 hours may be necessary in some cases (e.g., severe hepatocellular dysfunction, suspected common bile duct obstruction, suspected biliary atresia).

7. Patients whose studies fail to demonstrate either gallbladder or bowel activity should be held until reviewed with the radiologist. Outpatients who fail to demonstrate the gallbladder after morphine or delayed imaging should be held until reviewed with the radiologist.

Archive the images to PACS.
PROCEDURE: Cholecystokinin Cholescintigraphy

The patient is injected in the department with isotope. Images are acquired immediately until the gallbladder is visualized and then CCK is infused for 60 minutes, typically 60 minutes after injection of radiopharmaceutical. If sincalide is unavailable, Ensure Plus may be substituted as an appropriate cholecystagogue upon discussion with the Radiologist.

Normal GBEF is > 30-40%; most are > 65%; use < 30 to 35% as abnormal

DRUGS CAUSING GB DYSFUNCTION AND LOW GBEF
1. Morphine
2. Atropine
3. Octreotide
4. Nifedipine
5. Progesterone
6. Phentolamine

DISEASES ASSOCIATED WITH LOW GBEF
1. Diabetes mellitus
2. Irritable bowel syndrome
3. Sprue
4. Pregnancy
5. Achalasia
6. Sickle cell disease
7. Possibly acute viral illness or metabolic derangement

METHODOLOGY
1) Confirm there is no history of cholelithiasis.
2) Inject radiopharmaceutical.
3) Infuse sincalide with infusion pump, 0.02 ug/kg in 30 ml or 50 ml over 60 min after GB has filled maximally (typically 60 min after radiopharmaceutical injection).
4) Image in 60 1-minute frames, LAO projection.
5) Background correct for liver.
6) Document any complaints of pain or other symptomalogy during CCK infusion.
7) Calculate GB EF at 15, 30, and 60 minutes.
8) Mask the bowel with a led drape/apron if there is extensive bowel activity.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc mebrofenin or $^{99m}$Tc disofenin is prepared according to the Radiopharmacy procedure manual.
2. Adult Dose: 5 mCi
3. Child Dose: Per body weight (see chart) Minimum 1.0 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Image until gallbladder is maximally visualized (typically 60 minutes after injection), then begin imaging for injection fraction during 60 minute CCK infusion.
6. Cholecystokinin (Sincalide or Kinevac):
   a) Obtain CCK.
      1) CCK Contraindications: Hypersensitive to sincalide (absolute).
         Intestinal obstruction (absolute). Pregnancy (absolute). Acute pancreatitis
         (relative).
   b) Get patients weight and calculate dose of CCK, dose - .02 mcg/kg. Do not
      prepare CCK until gallbladder starts to visualize.
   c) Preparation of cholecystokinin: Per package insert/pharmacy.

7. Ensure Plus
   a) At 60 minutes after administration of HIDA, ask the patient to promptly ingest
      8 oz (275 ml) orally over a period of less than 5 minutes
   b) Acquire LAO images of the abdomen for 60 minutes after ingestion of Ensure
      Plus

Patient Preparation:
1. Patient must be N.P.O. for at least 4 hours and no longer than 12 hours.
2. Check that the patient is not pregnant or breast feeding. Follow standard
   procedures to with regards to female patients not being pregnant.
3. The patient should have an ultrasound that excludes the presence of gallstones.
4. Record patient medications

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset counts for 1M counts or time for 240 sec for adults, 300K/image for infants
   (0-6 months).

Scanning Instructions:
1. Anterior views of abdomen are taken every 5 until gallbladder is visualized. Do
   RAO and Right Lateral when GB seen.
2. At 60 minutes, start cholecystokinin infusion after obtaining basline image.
3. Start computer acquisition 1 min prior to injection of cholecystokinin. Dynamic
   acquisition 60 sec/frame for 60 minutes in the LAO projection.
4. Start infusion (0.02 g/kg over 60 min with infusion pump)

Archive the images to PACS.
Computer Processing:
Draw ROI around GB and a background liver ROI as appropriate.

$$\text{GBEF} = \text{Max cts} - \text{Min cts divided by Max cts, all corrected for hepatic background}$$

Calculate gallbladder ejection fraction (GEF) at 20 and 30 minutes after CCK and up to 60 minutes after Ensure Plus:

$$\text{GBEF}_i = \frac{\text{net maximum GB counts} - \text{net minimum GB counts (at time i)}}{\text{net maximum GB counts}}$$

where $\text{GBEF}_i = \text{gallbladder ejection fraction at time } i$

$\text{GB} = \text{gallbladder}$

$i = \text{time after CCK administration, (min)}$

For each observation:

$$\text{net GB counts} = \text{total GB counts} - (\text{background counts/pixel } \times \text{ no. of GB pixel})$$

Normal: GEF > 30%

References (Attached):

SNM Practice Guideline for Hepatobiliary Scintigraphy 4.0*  
Mark Tulchinsky1, Brian W. Ciak2, Dominique Delbeke3, Andrew Hilson4, Kelly Anne Holes-Lewis5, Michael G. Stabin6, and Harvey A. Ziessman. JOURNAL OF NUCLEAR MEDICINE TECHNOLOGY • Vol. 38 • No. 4 • December 2010

Sincalide-Stimulated Cholescintigraphy: A Multicenter Investigation to Determine Optimal Infusion Methodology and Gallbladder Ejection Fraction Normal Values  

Procedure reviewed on: 2/14/2011

Approved by: Tim Baker, MD; Darrin Johnson, MD; Ron Workman, MD.
Sincalide-Stimulated Cholescintigraphy: A Multicenter Investigation to Determine Optimal Infusion Methodology and Gallbladder Ejection Fraction Normal Values

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Sincalide-stimulated cholescintigraphy is performed to quantify gallbladder contraction and emptying. However, different infusion methods are used for this study. Our purpose was to determine the infusion method with the least variability (smallest coefficient of variation [CV]) for calculation of the gallbladder ejection fraction (GBEF) in healthy subjects and to establish normal values.

Methods: Sixty healthy volunteers at 4 medical centers were injected intravenously with 99mTc-mebrofenin. After gallbladder visualization had been confirmed at 60 min, 0.02 mg of sincalide per kilogram was administered using 3 different infusion durations, 15, 30, and 60 min, each performed on separate days. The CV, mean, SD, first to 99th percentile, and fifth to 95th percentile were calculated. GBEF normal values were determined for the different infusion durations. Results: The CV was smallest for the 60-min infusion at 60 min (19%; 95% confidence interval [CI], 16%-22%), compared with the 30-min infusion at 30 min (35%; 95% CI, 29.2%-24.1%) and the 15-min infusion at 15 min (52%; 95% CI, 44%-63%). These were all significantly different (P < 0.0007). For the 60-min infusion at 60 min, the lower limit of normal for the GBEF was 38% defined at the 1% CI. Conclusion: The GBEF at 60 min has the lowest CV in healthy subjects, compared with shorter infusions of 15 or 30 min. This multicenter trial establishes a GBEF lower limit of normal of 38% (first percentile) for a 60-min infusion of 0.02 mg of sincalide per kilogram, quantified at 60 min. Using this infusion method minimizes the variability in measured GBEFs. This sincalide infusion method should become the standard for routine clinical use.

Key Words: gastroenterology; hepatology; cholescintigraphy; gallbladder ejection fraction; sincalide

DOI: 10.2967/jnumed.109.069393

Introduction

Holecystokinin-stimulated cholescintigraphy was first described 3 decades ago as a method to accurately quantify gallbladder emptying (1,2). Sincalide (Kinevac; Bracco Diagnostics, Inc.) is the only commercially available form of holecystokinin in the United States. Patients are commonly referred for sincalide-stimulated cholescintigraphy for calculation of a gallbladder ejection fraction (GBEF) to confirm chronic gallbladder disease as the cause for recurrent upper abdominal pain.

Numerous investigations over the years have reported that a low GBEF is predictive of symptomatic relief from recurrent biliary colic after cholecystectomy in patients without cholelithiasis; however, some investigations have not found the GBEF predictive (3). Two literature reviews found insufficient evidence to confirm the diagnostic utility of sincalide cholescintigraphy to predict outcome after cholecystectomy for chronic acalculous gallbladder disease, precluding any definitive recommendation regarding its diagnostic use (4,5). They concluded that a well-designed sufficiently powered prospective study is needed. One concern the reviews mentioned was the lack of standardization of sincalide infusion methodology. This may be one explanation for the disparate published results.

Almost 30 investigations have now been published that have used different sincalide infusion methodologies, that is, different total doses, infusion times, dose rates, and normal values (3). The dose, duration of sincalide infusion, and normal values used in clinical practice also vary considerably among different imaging centers. Doses of 0.01–0.02 mg/kg are usually used with infusion times ranging from 1 to 60 min. Some of these methods have validated normal values; however, many have not been validated. Before a prospective clinical trial in patients can...
be initiated, a scientifically valid sincalide infusion methodology with well-established GBEF normal values must be determined and standardized.

The purpose of this investigation was to determine an optimal method for sincalide infusion by comparing 3 different sincalide infusion methods in clinical use, 0.02 mg/kg for 15, 30, and 60 min, to determine which has the least variability in healthy adults and to establish normal GBEF values for these methods.

MATERIALS AND METHODS

General

The study protocol was written by the investigators and was approved by the Institutional Review Boards at all 4 institutions. Bracco Diagnostics, Inc., Princeton, NJ, provided an unrestricted grant to the Gastrointestinal Council of the Society of Nuclear Medicine to underwrite the cost of this investigation. Both 99mTc-mebrofenin and sincalide were provided free of charge by Bracco Diagnostics, Inc. The company had no involvement in the development of the protocol or its analysis.

Study Subjects

Sixty healthy volunteers were investigated between July 2008 and June 2009. Four medical institutions each recruited, performed, and completed studies on 15 research volunteer subjects, who had 3 studies each. The institutions included Johns Hopkins University, Baltimore, MD; Pennsylvania State University, Hershey, PA; Memorial Health University Medical Center, Savannah, GA; and Temple University, Philadelphia, PA. Before this investigation, the 4 institutions used different sincalide infusion durations, including 15 min (1 institution), 30 min (2 institutions), and 60 min (1 institution).

To be included, the subjects had to be healthy men or women 18–65 y old, with no gastrointestinal disease as confirmed by initial screening using a modified Mayo Clinic Research Gastrointestinal Disease Screening Questionnaire. They also had to have a high probability for compliance and completion of the study. In addition, they had to have normal results for complete blood count, metabolic profile (including liver, renal, and thyroid function tests), serum amylase, and gallbladder ultrasonography. Women had to have a negative pregnancy test.

Subjects were excluded from participation in the study if they had prior gastrointestinal surgery (excluding appendectomy); any surgery within the past 6 mo; cardiovascular, endocrine, renal, gastrointestinal, or other chronic disease likely to affect motility (including diabetes, renal insufficiency, gastroesophageal reflux disease, gastroparesis, irritable bowel syndrome, or peptic ulcer disease); gastrointestinal symptoms (e.g., heartburn, chest pain, dysphagia, abdominal pain, nausea, vomiting, constipation, or diarrhea); or a history of allergic reaction to sincalide. In addition, any subject was excluded if taking chronic opiate pain medications, atropine, nifedipine (calcium channel blockers), indomethacin, progestosterone oral contraceptives, octreotide, theophylline, benzodiazepine, or phentolamine. Women were excluded if they were pregnant or lactating or if they were not practicing birth control.

Study Protocol

Each of the 60 subjects had 3 infusion studies at least 2 d apart, and all studies were completed within 3 wk. The order in which the 3 different sincalide infusions were performed was determined by randomization at the time of enrollment. Subjects reported to the test facility fasting; 45 subjects at 3 institutions fasted overnight and the morning before the examination, 15 subjects at 1 institution fasted for 4 h before the study. All subjects were injected intravenously with 74–111 MBq of 99mTc-mebrofenin (Choletec; Bracco Diagnostics, Inc.). Images were acquired using a wide-field-of-view gamma-camera and a low-energy collimator. A 20% window was set over the 140-keV 99mTc photopeak. After gallbladder visualization at 60 min had been confirmed, 0.02 mg of sincalide per kilogram was administrated via a constant infusion pump for either 15, 30, or 60 min. A 0.02 mg/kg total dose was used because, first, this dose is approved by the Food and Drug Administration and recommended in the sincalide package insert and, second, the 0.02 mg/kg dose infused over 45 min has been shown to result in a higher GBEF than 0.01 mg/kg but no significant difference compared with 0.04 mg/kg (6).

The sincalide vial was reconstituted with 5 mL of sterile water. Then, 0.02 mg of sincalide per kilogram was withdrawn from the vial using a 1- to 3-mL syringe, transferred into a 30- or 50-mL syringe, and then diluted with sterile normal saline to the 30- to 50-mL syringe volume. The syringe was connected to infusion tubing, which was primed before placing it in the infusion pump. The pump was programmed to infuse the entire volume over 15, 30, or 60 min. Image acquisition began at the start of the sincalide infusion. Images were acquired dynamically as 1-min frames. At 3 institutions, images were acquired for 60 min regardless of the infusion duration in 45 subjects. In 15 subjects at 1 institution, imaging was discontinued at the end of the infusion duration, that is, at 15, 30, or 60 min.

For GBEF quantification, regions of interest were drawn for the gallbladder and background (adjacent normal liver) on computer workstations. Time–activity curves were generated. The percent- age GBEF was calculated using the formula [(maximum counts 2 minimum counts)/maximum counts] · 100, corrected for back- ground and radioactive decay. The GBEF was determined at 15, 30, 45, and 60 min for all 3 infusion methods in 45 subjects; 15 subjects at 1 site had the GBEF calculated at the same time intervals but only until the end of the sincalide infusion. To determine the incidence of side effects associated with each infusion method, the subjects were asked about any adverse symptoms. Each institution processed the studies performed at its center.

Statistical Analysis

The primary statistical endpoint of the study was calculation of the coefficient of variation (CV) as a measure of variability for the GBEF for each infusion method at the different intervals to determine which sincalide infusion method had the lowest variation. The CV is the SD divided by the mean and expressed as a percentage. It reflects the variability of the values. Thus, the method considered best would have the lowest CV.

Healthy subjects were recruited to provide an appropriate mixture of both men and women and a wide, evenly distributed...
GBEF, SD, Lower Limits of Normal for 2 and 3 SDs, CV, and 95% CIs for 3 Different Infusion Methods at 4

<table>
<thead>
<tr>
<th>Infusion</th>
<th>Time of GBEF</th>
<th>No. of Subjects</th>
<th>Mean (%)</th>
<th>SD (%)</th>
<th>-2 SDs</th>
<th>-3 SDs</th>
<th>CV (%)</th>
<th>15</th>
<th>15</th>
<th>60</th>
<th>60</th>
<th>57</th>
<th>29</th>
</tr>
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<tbody>
<tr>
<td>GBEF Duration (min)</td>
<td>Calculation (min) subjects</td>
<td>GBEF (%)</td>
<td>SD (%)</td>
<td>-2 SDs</td>
<td>-3 SDs</td>
<td>CV (%)</td>
<td>15</td>
<td>15</td>
<td>60</td>
<td>60</td>
<td>57</td>
<td>29</td>
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<tr>
<td>21</td>
<td>44</td>
<td>51.66 (43.79, 63.01)</td>
<td>30</td>
<td>45</td>
<td>40.46 (33.49, 51.10)</td>
<td>45</td>
<td>45</td>
<td>35.21 (29.15, 44.48)</td>
<td>30</td>
<td>15</td>
<td>15</td>
<td>60</td>
<td>57</td>
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<tr>
<td>26</td>
<td>62</td>
<td>39.91 (33.05, 50.42)</td>
<td>60</td>
<td>45</td>
<td>63.91 (53.19, 76.53)</td>
<td>30</td>
<td>60</td>
<td>31.30 (25.91, 39.53)</td>
<td>60</td>
<td>45</td>
<td>74</td>
<td>45</td>
<td>71</td>
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<tr>
<td>64</td>
<td>65</td>
<td>24.00 (20.35, 29.28)</td>
<td>45</td>
<td>60</td>
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<td>75</td>
<td>71</td>
<td>18.55 (15.73, 22.64)</td>
<td>45</td>
<td>60</td>
<td>18.55 (15.73, 22.64)</td>
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A substantial increase in precision of the CV was found in going from 20 to 40 subjects and from 40 to 60 subjects, with little additional improvement in going higher than 60 subjects (from 60 to 80).

Normal GBEF values were determined for each method using the mean 2 and 3 SDs, as well as the fifth and 95th percentiles and first and 99th percentiles. Further analysis was done to determine whether there were significant differences based on age, order, or sex. Statistical analysis was performed using version 9.1.3 SAS software (SAS Institute).

RESULTS
Sixty healthy subjects (32 women and 28 men; age range, 20-62 y; mean 6 SD, 38 6 12 y) met the inclusion and exclusion criteria and were included in the study.

All subjects had confirmed gallbladder filling by 60 min for all 3 studies. Only 2 subjects complained of adverse symptoms during the sincalide infusion, that is, mild nausea and abdominal cramping, and these were reported only for the 15-min-infusion method.

Table 1 shows the results for the 3 different infusions in the 60 healthy subjects, including the infusion duration (min), the time of GBEF calculation after the start of the sincalide infusion, the number of subjects studied, the mean percentage GBEF, the SD, the lower limits using the mean and 2 and 3 SDs, the CV, and the 95% upper and lower confidence limits.

The CV was lowest for the 60-min infusion at 60 min (19%), which was significantly different from the CV for the 30-min infusion at 30 min (35%) and for the 15-min infusion at 15 min (52%) (P < 0.0007). The lack of overlap of the CIs shown in Table 1 also confirms statistical significance. The second lowest CV was the 60-min infusion at 45 min (24%), the third and fourth lowest were the 30-min infusions at 60 min (29%) and at 45 min (31%).

The mean 2 and 3 SDs was initially used to calculate normal values for the GBEF. For the 60-min infusion at 60 min, the lower limits of normal for the GBEF were 52% (mean 2 SDs) and 36% (mean 3 SDs). However, because the data did not have a gaussian distribution and were skewed somewhat to the left, the first, fifth, 95th, and 99th percentiles were considered more appropriate for defining normal values (Table 2; Fig. 1). For the 60-min infusion at 60 min, the lower limits of normal for the GBEF were 49% (fifth percentile) and 38% (first percentile). For the 60-min infusion at 45 min, the lower limits of normal for the GBEF were 38% (fifth percentile) and 20% (first percentile). For the 15- and 30-min infusions, the lower limits of normal for all infusion lengths were all less than 25% and 19% (fifth percentile), respectively, and less than 17% and 13% (first percentile), respectively (Table 2).

Secondary analysis of the GBEF at the end of the 60-min infusion, grouped by sex and age (20-40 y vs. 40 y) showed no significant differences. The mean GBEF for men and women 20-40 y old was 89.0% 6 14.7% and 81.9% 6 14.5%, respectively. The GBEF for men and women older than 40 y was 88.1% 6 15.7% and 80.5% 6 17.5%, respectively.

DISCUSSION
Sincalide-stimulated cholescintigraphy has been used for over 3 decades for calculation of a GBEF to evaluate patients for recurrent upper abdominal pain suggestive of chronic gallbladder disease. This disorder has been called by various names, including chronic acalculous gallbladder disease, chronic acalculous cholecystitis, gallbladder dyskinesia, cystic duct syndrome, gallbladder spasm, and functional gallbladder disease. Although there are some
Healthy subjects (12) reported a GBEF lower level of normal of 40% (mean ± 2 SDs) for an infusion method (60 min) that
60 min) that

40 healthy subjects using a similar but not identical protocol (0.02 mg/kg/h infused for 45 min and quantified at
lower limit of normal for GBEF of 38% (first percentile). This value is similar to that obtained in a prior report of
percentiles to calculate normal values, we found that the 60 percentile

Because the data are not gaussian in distribution, normal values a

The latter intervals offer no clinical advantage over the 60

The

FIGURE 1.

Because of the considerable pub-
lished data reporting that a 3-min infusion method is unsatisfactory, it was not included in this trial.
The results of this investigation show that the CV is lowest for the 60-min infusion measured at 60 min (19%), significantly lower than the CV for the 30-min infusion at 30 min (35%) and the 15-min infusion at 15 min (52%). The next lowest CV is the 60-min infusion at 45 min (24%), followed by the 30-min infusion at 60 min (29%). The latter intervals offer no clinical advantage over the 60-min infusion at 60 min.

Because the data are not gaussian in distribution, normal values are more appropriately determined using percentiles rather than the mean ± 2 SDs, although we report both. Using the fifth to 95th and first to 99th percentiles to calculate normal values, we found that the 60-min time-
point of the 60-min infusion resulted in a lower limit of normal for GBEF of 38% (first percentile). This value is similar to that obtained in a prior report of 40 healthy subjects using a similar but not identical protocol (0.02 mg/kg/h infused for 45 min and quantified at 60 min) that found the lower limits of normal for the GBEF to be 40% (mean ± 3 SDs) (16). Another study of 20 healthy subjects (12) reported a GBEF lower level of normal of 40% (mean ± 2 SDs) for an infusion method
similar but not identical to our investigation (0.01 mg/kg infused over 60 min and quantified at 60 min).

Because of the wide CV, the lower limits of normal calculated for the 15- and 30-min infusions at any time point were determined at best to be equal to or less than 25% (fifth percentile) and 17% (first percentile) (Table 2). This is lower than reported in any previous publication (3), probably because of the small numbers of healthy subjects previously studied. The only 2 previous studies of 30-min infusions showed widely different results, with the lower limit of normal being less than 30% (23 healthy subjects) (11) and less than 65% (15 female subjects) (17). The only prior investigation using a 15-min infusion reported normal values of less than 35% but studied only 15 healthy subjects (18). This result demonstrates the importance of studying a statistically valid number of subjects to establish normal values. We believe that these methods should no longer be used.

Standardization of sincalide infusion methodology and use of statistically valid normal GBEF values determined for that methodology are necessary to gain the confidence of clinicians and surgeons who refer patients for this study. Standardization is also needed to provide uniform evidence-based advice to imaging clinics on the optimal infusion methodology and its appropriate normal values. Finally, standardization of sincalide infusion methodology will make it possible to develop a well-designed clinical multicenter prospective trial that can confirm the utility of a GBEF for predicting outcome after cholecystectomy in patients having recurrent upper abdominal pain possibly due to gallbladder disease.

In summary, our data have determined that the optimal methodology for sincalide cholescintigraphy using a 0.02 mg/kg total dose is infusion over 60 min with quantification of the GBEF at 60 min. Using this method, the lower limit of normal is 38%. The large number of healthy subjects studied and the direct comparison of the 3 methodologies in the same subjects make the results of this multicenter investigation compelling.

**CONCLUSION**

This multicenter investigation of 60 healthy subjects compared 3 different sincalide infusion durations for a 0.02 mg/kg total dose and found that that a 60-min infusion duration with calculation of the GBEF at 60 min is the optimal method; it has the lowest CV and the best-defined normal values. The lower range of normal for this method is 38% (first percentile). We believe that this infusion method for sincalide-stimulated GBEF should become the standard.

**REFERENCES**


**SINCALIDE-STIMULATED CHOLESCINTIGRAPHY** • Ziessman et al. 281
SNM Practice Guideline for Hepatobiliary Scintigraphy 4.0*

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PREAMBLE

The Society of Nuclear Medicine (SNM) is an international scientific and professional organization founded in 1954 to promote the science, technology, and practical application of nuclear medicine. Its 16,000 members are physicians, technologists, and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters, and books, the SNM also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine.

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.

Each Practice Guideline, representing a policy statement by the SNM, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Committee on SNM Guidelines, Health Policy and Practice Commission, and SNM Board of Directors. The Practice Guidelines
recognize that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published Practice Guideline by those entities not providing these services is not authorized. These Practice 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 Practice 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, an approach that differs from the Practice Guidelines, standing alone, is not necessarily 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 Practice 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 Practice Guidelines.

The practice of medicine involves not only the science, but also the art, of preventing, diagnosing, alleviating, and treating 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 Practice 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 Practice Guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This Practice Guideline has been developed and revised collaboratively by the SNM Task Force with input from the American College of Radiology and the European Association of Nuclear Medicine. The Task Force consisted of representatives from the other 2 organizations. Optimally performed hepatobiliary scintigraphy is a sensitive method for detecting numerous disorders involving the liver and biliary system. It is generally accepted that scintigraphic findings are not always specific. Therefore, it is crucial to correlate findings on hepatobiliary scintigraphy with clinical information and findings on other relevant modalities in order to arrive at a correct diagnosis. Adjunctive pharmacologic maneuvers may enhance the diagnostic utility of hepatobiliary scintigraphy and provide the quantitative assessment necessary for certain specific applications.

II. GOALS

The purpose of this Practice Guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of hepatobiliary scintigraphy in adults and children. The goal of hepatobiliary scintigraphy is to provide diagnostic and management assistance to physicians who are involved in the care of patients with liver and biliary system ailments.

III. DEFINITIONS

Hepatobiliary scintigraphy is a radionuclide diagnostic imaging study (including planar imaging, SPECT, or hybrid imaging such as SPECT/CT) that evaluates hepatocellular function and the biliary system by tracing the production and flow of bile from the formative phase in the liver, and its passage through the biliary system into the small intestine. Sequential (or dynamic) images of the liver, biliary tree, and gut are obtained. Computer acquisition and analysis, including pharmacologic interventions, are used according to varying indications and an individual patient’s needs.

IV. COMMON CLINICAL INDICATIONS

D. Protocol/image acquisition 1. Image acquisition

A large-field-of-view g-camera equipped with a low-energy all-purpose or high-resolution collimator is recommended. Whenever possible, continuous (dynamic) computer acquisition (usually in the anterior or left anterior oblique view) should be performed (1 frame/minute). The image matrix of 128 by 128 is optimal on a standard large-field-of-view camera. In pediatric patients an appropriate electronic acquisition zoom should be used. Initial images are usually acquired dynamically, starting at injection and continuing for 60 minutes. When visualization of the gallbladder is the endpoint of the study, it can be stopped earlier when activity is seen in the gallbladder. Additional views (e.g., right lateral, left or right anterior oblique) may be obtained as needed to clarify anatomy. To resolve concern about common bile duct obstruction (highly unlikely in the presence of gallbladder visualization), demonstration of tracer activity in the small bowel may need to be pursued. The digital data can be reformatted to 4- to 6-minute images for filming or digital display. Cinematic display of the data may reveal additional information not readily apparent on reformatted display. Image intensity scaling should be study-relative rather than individual frame-relative. The former allows for appreciation of activity...
changes over the duration of the study.

When acute cholecystitis is suspected and the gallbladder is not seen within 60 min, delayed images for up to 3–4 h should be obtained, or morphine augmentation (VI.E.2) may be used in lieu of delayed imaging. Delayed imaging at 18–24 h may be necessary in some cases (e.g., a severely ill patient, severe hepatocellular dysfunction, suspected common bile duct obstruction, or suspected biliary atresia).

If the patient is being studied for a biliary leak, 2- to 4-h delayed imaging (or longer delays in some cases) and patient-positioning maneuvers (e.g., decubitus views) may be helpful. Any drainage bags should be included in the field of view if the biliary origin of a leak or fistula is in question. In patients with a suspected leak, it may be helpful to acquire simultaneous right lateral or other views on a multichannel camera.

2. Processing a. For GBEF, using the immediate presincalide and the postsincalide images, regions of interest (ROI) are drawn around the gallbladder (taking into account patient motion) and adjacent liver (background) using any standard nuclear medicine software package. The liver background ROI is selected taking care to exclude ductal activity. GBEF is calculated from the gallbladder time–activity curve as:

\[
\text{GBEF} \% = \frac{\text{net GB}_{\text{max}} - \text{net GB}_{\text{min}}}{3100 \times \text{net GB}_{\text{max}}}
\]

where GB is gallbladder counts.

b. Hepatocellular function may be assessed by deconvolution analysis from an ROI over the liver and heart (hepatic extraction fraction) or by analysis of a heart ROI for tracer clearance from the blood pool (80,81).

e. Interventions A variety of pharmacologic or physiologic interventions may enhance the diagnostic value of the examination. Appropriate precautions should be taken to promptly detect and treat any adverse reactions caused by these interventions. It is important to be familiar with all contraindications and warnings detailed in package inserts of the pharmaceuticals listed below.

1. Sincalide pretreatment Sincalide, a synthetic C-terminal octapeptide of cholecystokinin, may be given intravenously in doses of 0.02 mg/kg over 30–60 min, 15–30 min before the hepatobiliary tracer injection, to minimize the potential for a false-positive study (e.g., in patients who have fasted longer than 24 h, are on parenteral hyperalimentation, or have a severe intercurrent illness) (82–85).

In patients suspected of sphincter of Oddi dysfunction because of persistent abdominal colic after cholecystectomy, sincalide-pretreatment cholescintigraphy can be used as a diagnostic screening test (73). Sincalide (0.02 mg/kg) is administered intravenously over 3 min, and the imaging starts 15 min later in anterior projection and is continued for 60 min. ROIs are placed over the liver parenchyma and the common bile duct to generate the time–activity curves. The interpretation criteria are based on the scoring system designed by the test developers (73).

2. Morphine sulfate

When acute cholecystitis is suspected and the gallbladder is not seen by 30–60 min, morphine sulfate, 0.04 mg/kg or a standard 2 mg dose, may be administered intravenously over 2–3 min (25,28). If the cystic duct is patent, flow of bile into the gallbladder will be facilitated by morphine-induced temporary spasm of the sphincter of Oddi. The

Of concern was that shorter infusions showed a number of healthy subjects with very low GBEFs that would be commonly reported as pathologic (2,85), raising a false-positive test result.

4. GBEF measurement using a fatty meal challenge instead of sincalide has also been described (89,90). This approach is not as reproducible in healthy subjects (has greater variability) as is the sincalide methodology suggested in the preceding section.

5. In jaundiced infants in whom biliary atresia is suspected, pretreatment with phenobarbital, 5 mg/kg/d, may be given orally in 2 divided doses daily for a minimum of 3–5 d before the hepatobiliary imaging study to enhance biliary excretion of the radiotracer and increase the specificity of the test (41). Mebrofenin may be preferred over disofenin in suspected biliary atresia because the former has better hepatic excretion than the latter, especially in these patients with hepatocellular dysfunction.

6. In jaundiced infants in whom biliary atresia is suspected, pretreatment with ursodeoxycholic acid is an alternative (43). The dose is 20 mg/kg/d in 2 divided doses (12 h apart) for 2–3 d before the scan. This medication is continued until the test is over. In comparison to phenobarbital, ursodeoxycholic acid does not cause sedation in infants and may be an advantage in certain patients. Another advantage to consider is shorter premedication. As with phenobarbital, mebrofenin is favored over disofenin.

F. Interpretation 1. Normal hepatobiliary findings are characterized by the immediate demonstration of hepatic parenchyma and rapid clearance of cardiac blood-pool activity, followed sequentially by activity in the intra- and extrahepatic biliary ductal system, gallbladder, and upper small
bowel. All these structures should be seen within 1 h. Gallbladder filling implies a patent cystic intrahepatic biliary tree and common bile duct must contain radioactive bile, and the tracer activity should be present in the small bowel at the time of morphine injection. A second injection of radiopharmaceutical, 74 MBq (2 mCi), may be necessary before morphine administration if the remaining liver or biliary tree activity appears insufficient to permit gallbladder filling, or the second injection can be given as a standard part of the test (25). Imaging is continued for another 30–60 min after morphine administration. This time should be extended if there is poor hepatocyte function. Contraindications to the use of morphine include increased intracranial pressure in children (absolute), respiratory depression in nonventilated patients (absolute), morphine allergy (absolute), and acute pancreatitis (relative). 3. Sincalide stimulation

Gallbladder contractility may be evaluated by determining GBEF after sincalide stimulation. The study involves an intravenous administration of sincalide, and multiple methodologies exist. Knowledge of validated GBEF in healthy people is essential in determining which patient is exhibiting an abnormal result. Table 1 summarizes the expected GBEF for tested techniques.

The best-validated reference dataset with the greatest number of healthy volunteers points to an infusion of 0.02 mg/kg over 60 min as one that can result in least variability of reference values (85) and may be considered the method of choice. The reference GBEF with this methodology should be $38\%$. The effectiveness of this method in chronic gallbladder disease has not been reported to date.

A dataset with infusion of 0.15 mg/kg over 45 min and GBEF measured at 60 min showed acceptable variability (3). For this method, authors suggest GBEF $40\%$ as normal. This methodology is the only one that has a prospective, randomized study that supports its use in patients with chronic acalculous gallbladder disease.

**TABLE 1**

<table>
<thead>
<tr>
<th>Sincalide dose</th>
<th>Time of infusion (min)</th>
<th>Mean (mg/kg)</th>
<th>GBEF SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>3</td>
<td>35817</td>
<td>6 17</td>
</tr>
<tr>
<td>0.01</td>
<td>3</td>
<td>46620</td>
<td>6 20</td>
</tr>
<tr>
<td>0.02 15</td>
<td>76822</td>
<td>68622</td>
<td></td>
</tr>
<tr>
<td>0.01 30</td>
<td>64820</td>
<td>61825</td>
<td></td>
</tr>
<tr>
<td>0.02 30</td>
<td>71625</td>
<td>68816</td>
<td></td>
</tr>
<tr>
<td>0.01 60</td>
<td>68616</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GBEF: No. of healthy range (%) individuals studied
17–59 6
12–74 20
32–98 15
26–95 14
8–99 60
15–88 20
Reference
(82)
(86)
(88)
(84)
(85)
(86)
0.04 3 43 6 26 15–88 12 (82)
0.02 3 56 6 27 0–100 23 (84)
0.01 10 76 6 16 37–96 13 (87)*
0.02 15 57 6 29 22–98 60 (85)
0.02 30 70 6 22 17–97 23 (84)
0.015 45 75 6 12 .40† 40 (3)
0.02 60 84 6 16 26–100 60 (85)

*Subjects were prescreened with a 3-min sincalide stimulation, and those with GBEF $35\%$ were excluded. †95% confidence limits.

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duct and excludes acute cholecystitis with a high degree of certainty. When patient preparation induces preferential bile flow to the gallbladder (such as in cases of sincalide pretreatment), activity in the small intestine may not be seen during the first hour (or even longer than 2 h) in healthy individuals (91).

2. The hallmark of acute cholecystitis (acalculous as well as calculous) is persistent gallbladder nonvisualization after 3–4 h of passive imaging or 30 min after morphine administration. A pericholecystic hepatic band of increased activity (rim sign) is a sign of severe late-stage acute cholecystitis and has been associated with severe phlegmonous or gangrenous acute cholecystitis, a surgical emergency (92).

3. Chronic cholecystitis and clinical settings associated with physiologic failure of the gallbladder to fill with radiotracer (e.g., prolonged fasting for .24–48 h; severely ill or postoperative hospitalized patients) may result in gallbladder nonfilling within the first hour but may be distinguished from acute cholecystitis using low-dose
intravenous morphine (see above) or delayed imaging. In chronic cholecystitis, the gallbladder will usually be seen within 30 min of morphine administration or on 3- to 4-h delayed images, whereas true cystic duct obstruction (acute cholecystitis) will result in persistent gallbladder nonvisualization. A gallbladder that is not visualized until after the time that the bowel is visualized correlates significantly with chronic cholecystitis.

4. A reduced GBEF in response to sincalide occurs in calculous and acalculous biliary diseases (i.e., chronic acalculous cholecystitis, cystic duct syndrome, sphincter of Oddi spasm) and may also be associated with various nonbiliary diseases and conditions and a variety of medications (e.g., morphine, atropine, calcium channel blockers, octreotide, progesterone, indomethacin, theophylline, benzodiazepines, and histamine-2 receptor antagonists).

5. Delayed biliary-to-bowel transit beyond 60 min raises suspicion of partial obstruction of the common bile duct, although this may be seen as a normal variant in up to 20% of individuals. With high-grade common bile duct obstruction, there is usually prompt liver uptake but no secretion of the radiotracer into biliary ducts. With prolonged obstruction, concomitant hepatic dysfunction may be seen. With partial biliary obstruction, radiotracer fills the biliary system but clears poorly proximal to the obstruction by 60 min or on delayed images at 2–4 h or with sincalide. Clearance into the bowel may or may not be seen. Severe hepatocellular dysfunction may also demonstrate delayed biliary-to-bowel transit.

6. A bile leak is present when tracer is found in a localization other than the liver, gallbladder, bile ducts, bowel, or urine. Leakage may be seen more easily using a cinematic display or decubitus positioning, as described above.

7. Biliary atresia can be excluded scintigraphically by demonstrating transit of radiotracer into the bowel. Failure of tracer to enter the gut is consistent with biliary atresia but can also be caused by hepatocellular disease or immature intrahepatic transport mechanisms. Renal or urinary excretion of the tracer (especially in a diaper) may be confused with bowel activity and is a potential source of erroneous interpretation.

8. During a hepatobiliary scan, activity may reflux from the duodenum into the stomach. Bile reflux that is marked and occurs in a symptomatic patient correlates strongly with bile gastritis, a cause of epigastric discomfort.

9. After cholecystectomy, sphincter of Oddi dysfunction has the appearance of partial common bile duct obstruction. Pretreatment with sincalide or morphine may improve the sensitivity for its detection. Various visual, quantitative, and semiquantitative scintigraphic parameters of bile clearance have been used in conjunction with image analysis. (e.g., a scoring system, hepatic hilum-to-duodenum transit time, and percentage biliary emptying after morphine provocation).

G. Sources of error

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Radiation Dosimetry in Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administered activity</td>
<td>Largest radiation dose</td>
</tr>
<tr>
<td>MBq</td>
<td>mCi</td>
</tr>
</tbody>
</table>

Radioisotopes in the body.
TABLE 3
Radiation Dosimetry in Children

<table>
<thead>
<tr>
<th>Administered activity</th>
<th>MBq/kg</th>
<th>mC/kg</th>
<th>1.85 intravenously</th>
<th>0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largest radiation dose</td>
<td>0.95</td>
<td>3.5</td>
<td>0.29</td>
<td>1.1</td>
</tr>
<tr>
<td>Effective dose</td>
<td>0.10</td>
<td>0.37</td>
<td>0.045</td>
<td>0.17</td>
</tr>
<tr>
<td>Age(y)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gallbladder wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mGy/MBq</td>
<td>1.5</td>
<td>0.12</td>
<td>0.05</td>
<td>10</td>
</tr>
<tr>
<td>rad/mCi</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>10</td>
</tr>
<tr>
<td>Organ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULI</td>
<td>0.11</td>
<td>0.017</td>
<td>0.012</td>
<td>0.044</td>
</tr>
<tr>
<td>Fetal dose mGy/MBq</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.017</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.012</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rem/mCi</td>
<td>0.063</td>
<td>0.044</td>
<td>0.063</td>
<td>0.044</td>
</tr>
<tr>
<td>Stage of gestation</td>
<td>6 mo</td>
<td>3 mo</td>
<td>9 mo</td>
<td></td>
</tr>
<tr>
<td>Fetal dose</td>
<td>0.017</td>
<td>0.015</td>
<td>0.0067</td>
<td>0.025</td>
</tr>
</tbody>
</table>

*Data are from (95). ULI 5 upper large intestine.

TABLE 4
Radiation Dosimetry in the Pregnant or Potentially Pregnant Patient

3. Clinical information (indication for the study; e.g., suspected acute cholecystitis, common bile duct obstruction, or a bile leak)
It is useful to include the patient’s medications in this part of the historical review, especially the last dose of potentially interfering medications. The last oral food intake is also useful to record.

4. Comparison/correlative imaging data
5. Procedure description
a. Radiopharmaceutical and activity administered
b. Other medications given and their dosage (e.g., pretreatment with sincalide, morphine, or post-treatment with sincalide)
c. The duration of imaging and whether special or delayed views were obtained
6. Description of findings
Include the appearance of the liver, intrahepatic ducts, common bile duct, the presence and time of tracer appearance in the gallbladder or small bowel, any unusual activity (e.g., bile leak or enterogastric reflux), and any quantitative data generated (e.g., GBEF).

7. Study limitations (patient reactions to drugs administered)
If there is an allergic or other adverse reaction to the radiopharmaceutical or other administered pharmaceuticals, the reaction must be clearly stated in the findings and impression sections of the report.
Gastrointestinal symptoms elicited by sincalide infusion are related to the rapid infusions and are not observed with the recommended slower infusion techniques of 45 and 60 min. Gastrointestinal symptoms occurring during the shorter sincalide infusion have no specificity for gallbladder pathology (93) and should not be part of the study report.

Stage of gestation
Early
6 mo
Fetal dose
mGy/MBq
0.017
0.012
rad/mCi
0.063
0.044
3 mo
0.015
0.056
9 mo
0.0067
0.025

Dose estimates to fetus are from Russell et al. (96) and allow a physician to make the best possible informed recommendation to an individual patient. However, no information about possible placental crossover of hepatobiliary compounds is available.

f. Activity in the kidneys simulating the gallbladder or small bowel (may be clarified by a lateral image)

VII. DOCUMENTATION/REPORTING
A. Goals of a report See Section VII.A of the SNM Procedure Guideline for General Imaging.
B. Direct communication See Section VII.B of the SNM Procedure Guideline for General Imaging.
C. Written communication See section VII.C of the SNM Procedure Guideline for General Imaging.
D. Contents of the report 1. Study identification 2. Patient demographics

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8. Impression The impression should be concise and as precise as possible, should address the clinical question, should provide a differential diagnosis, and should make recommendations if appropriate. Any urgent or unexpected findings should be directly communicated to the referring physician, and this communication should be documented.

VIII. EQUIPMENT SPECIFICATIONS
A large-field-of-view g-camera equipped with a low-energy all-purpose or high-resolution collimator is recommended. A SPECT or SPECT/CT camera may be used to detect the location of a biliary leak (38) or to estimate liver remnant function in patients preparing for partial hepatectomy (66).

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS
See Section IX of the SNM Procedure Guideline for General Imaging.

X. RADIATION SAFETY IN IMAGING
See Section X of the SNM Procedure Guideline for General Imaging for general guidance. Radiation dosimetry in adults, children, and pregnant or potentially pregnant patients is presented in Tables 2–4. Administration of radiopharmaceuticals to the pregnant or potentially pregnant patient is addressed in the SNM Procedure Guideline for General Imaging. The physician must consider the indication for the test, the potential benefit of information it may provide toward improved care of the patient, and the potential risk it may pose to the fetus.

Administration of radiopharmaceuticals to the breast-feeding patient is addressed in the SNM Procedure Guide- line for General Imaging. ICRP Publication 106, Appendix D, recommends that lactating patients who receive 99mTc- iminodiacetic acid compounds require no interruption of breast feeding (94).

XI. ACKNOWLEDGMENTS
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REFERENCES
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XIII. APPROVAL

This Practice Guideline was approved by the Board of Directors of the SNM on June 4, 2010.

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GASTROINTESTINAL TRACT

Revised 1/3/2007

99mTc-RBC Scintigraphy

Clinical Indications: Evaluation of gastrointestinal hemorrhage

PROCEDURE: GI Bleed Study

The patient is brought to Nuclear Medicine Department. The patients' blood is drawn and the ROC labeled in vitro using the Ultratag kit with subsequent re-injection of the tagged autologous RBCs. Images are acquired for 45 minutes. Delayed views are often necessary.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: 99mTc pertechnetate
2. Adult Dose: 20 mCi
3. Child Dose: Per body weight (see chart) Minimum 3.0 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately
6. Additional Information: The RBC are labeled in vitro using the Ultratag kit with subsequent re-injection of the tagged autologous RBC's.

Patient Preparation:
1. The study shows the site of bleeding if the patient is actively bleeding during imaging.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.
4. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window setting for $^{99m}$Tc (140 keV, 15-20% window).
3. Dynamic acquisition as below.

**Scanning Instructions:**
1. Place patient supine on scan table.
2. Position the camera anteriorly over abdomen area.
3. Preset time for dynamic 60 seconds per image and collect data for 63 minutes beginning immediately following injection.
4. Delayed views are necessary unless the initial images are diagnostic.
5. Process to allow cine display and film summed 5 minute images.
6. Archive the images to PACS.
GASTRIC MUCOSAL SCINTIGRAPHY

Ionic pertechnetate is taken up predominantly by the mucin-secreting cells of the stomach and, to a lesser degree, by parietal and chief cells. This ability of gastric mucosa to concentrate [99mTc] pertechnetate, whether intra- or extragastric in location provides the physiologic basis for the scintigraphic evaluation of clinical entities related to the gastric mucosa. These entities are Barrett's esophagus, retained gastric antrum, and Meckel's diverticulum containing ectopic gastric mucosa.

Clinical Indication:

1. Evaluation of Meckel's diverticulum  
   Meckel's diverticulum is a congenital anomaly resulting from incomplete closure of the omphalomesenteric duct and is present in approximately 2% of the population. It is most commonly located about 2 feet from the ileocecal valve on the antimesenteric border of the small bowel. The majority of Meckel's diverticula are asymptomatic and lined by ileal mucosa. Approximately 10% contain ectopic gastric mucosa capable of producing hydrochloric acid and pepsin, thereby inducing ileal ulceration. Peptic ulceration of adjacent ileal mucosa has been well documented as the cause of acute GIT bleeding in children. Clinical manifestations of this anomaly are usually seen in the first 2 years of life; Meckel's diverticulum is an uncommon cause of adult gastrointestinal hemorrhage. Radiographic diagnosis of Meckel's diverticulum is difficult; however, the scintigraphic procedure is safe and simple, with a specificity of 90%.


2. Evaluation of Barrett's esophagus  

3. Evaluation of Retained gastric antrum  

PROCEDURE: Meckel's Scintigraphy
**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc pertechnetate
2. Adult Dose: 10 mCi
3. Child Dose: Per body weight (see chart). Minimum 1 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediate

**Patient Preparation:**
1. Do not perform any barium enema.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.
4. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

**Machine Set-up Instructions:**
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset counts for 500K/image and obtain images.

**Scanning Instructions:**
1. Place the patient in supine position under camera.
2. Image in the anterior position for 30 minutes. Include from the stomach to the bladder in field of view.
3. Delayed images may be required.
4. Archive the images to PACS.
**GASTRO-ESOPHAGEAL REFLUX (PEDIATRIC)**

**Clinical Indications:**
Evaluation of gastroesophageal reflux and pulmonary aspiration.

**PROCEDURE: Gastro-Esophageal Reflux (Pediatric)**

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid is prepared according to the radiopharmacy procedure manual.
2. Child Dose: 0.5 mCi
3. Route: via a nasogastric tube or gastrostomy tube followed by formula or Ensure.
4. Time interval between administration and scanning: Immediate

**Patient Preparation:**
1. The patient should be N.P.O. (2-3 hours)
2. N/G tube should be inserted on the floor or by the radiology nurse and removed after administration of the radiopharmaceutical.
3. Proper gastric placement of the tube must be verified by KUG X-ray within several hours on the same day prior to initiation of the reflux scintigraphy.
4. Check that the patient is not pregnant or breast feeding.
5. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**
1. LEHR collimator.
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset time for dynamic 60 seconds/image and collect image every minute for 15 minutes in the supine position and 15 minutes prone. Collect on computer also (2 separate studies, prone and supine).

**Scanning Instructions:**
1. Inject dose through N/G tube and flush with formula.
2. Begin imaging immediately. Collect a 60 seconds/image every minute for 30 minutes (15 minutes in supine position, 15 minutes in prone position).
3. Collect in LAO position for 90 min. for gastric emptying.
4. For combination gastric emptying/reflux study, collect in supine position only. This is one study with first portion collecting as dynamic study 60 sec/fr for 30 frames and second portion collecting as static images for remaining 60 minutes.
5. Mark level of shoulders on at least one image.
6. A 3-4 hour delay image over the lungs is usually required with shoulder markers and shielding of the abdominal activity.
7. Archive the images to PACS.
**RADIONUCLIDE SALIVAGRAM (PEDIATRIC)**

**Clinical Indications:**
Detection of aspiration in pediatric patients.

**Examination Time:** Three (3) hours

**Patient preparation:**
1. Fasting is not necessary.
2. Position patient supine on the examination table.
3. Check that the patient is not pregnant or breast feeding.
4. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**
140 keV with 20% window; LEHR collimator

**Radiopharmaceutical:**
Tc-99m sulfur colloid, 300-400 microCi in 0.1-0.3 ml water, is placed on the tongue and allowed to mix with the oral secretions, taking care to avoid contamination of the skin and garments.

**Scanning Instructions:**
1. Dynamic acquisition for one hour in the posterior projection every 60 seconds, 64 x 64 matrix.
2. At the end of one and three hours, acquire 300-500,000 count images of the chest in the posterior and lateral projections.
3. Include the mouth and stomach in the field of view.

**Processing:**
1. Cine the dynamic acquisition
2. Archive the images the 2 minute summed images to PACS.
3. Archive the one and three hour static images to PACS.

**Ref.**
GASTRIC EMPTYING SCINTIGRAPHY

Clinical Indications:
1. Evaluation of gastric dysmotility
2. Evaluation of gastric obstruction

PROCEDURE: Gastric-emptying scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: 99mTc sulfur colloid is prepared according to the radiopharmacy procedure manual.
2. Adult Dose: 0.5 mCi
3. Child Dose: 0.5 mCi
4. Route: P.O. mixed with scrambled eggs (two large egg whites or preferably 120 grams (4 oz) of Eggbeaters), 2 slices of toasted white bread with 30 grams of Strawberry jam/jelly applied, and 120cc of water (4 fluid ounces).
5. Time interval between administration and scanning: immediate.

Patient Preparation:
1. Check that patient is not pregnant or breast feeding.
2. Patient must be N.P.O. for at least 6 hours.
3. Explain the procedure and check for metal objects in field of view.
4. Note medications, especially narcotics, metoclopramide, Reglan, cisapride.
5. In general, diabetic patients should take ½ their normal insulin dose and note their fasting blood glucose prior to the test.

Machine set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for 99m Tc (140 keV, 15-20%).
3. Preset counts for 500k/image. Collect anterior and posterior images immediately post ingestion, then at 1, 2 and 4 hours.
4. All images acquired on computer.

Scanning Instructions:
1. Have patient eat 99mTc-labeled meal with 120 ml of water within 10 minutes.
2. Place patient in standing (or sitting up-right) position if possible.
3. Start the computer and acquire anterior and posterior images immediately and then at 1, 2 and 4 hour time intervals.
4. If the patient vomits or is unable to eat entire meal, please note on history sheet.

Computer Processing:
1. A region of interest is drawn over the stomach for each image. Use the same region of interest for all images.
2. Time-activity curve is plotted on the linear scale using the geometric mean of the anterior and posterior counts. Time activity curves are decay corrected.
3. Half-emptying time is calculated at the time that the initial counts decrease by 50%.
4. The percent of initial activity remaining in the stomach is calculated for each time period.
5. Archive images to PACS.
Technologist Information Sheet:

Was the patient able to ingest the entire meal in 10 minutes or less?  Y  N

Did the patient vomit after the meal?  Y  N

If diabetic, what was their fasting blood glucose (if available):________

GASTRIC EMPTYING DICTATION:

PROCEDURE: The patient was fed a standardized meal consisting of 120 grams of egg white equivalents radiolabeled with __ mCi of Tc99m sulfur colloid, two pieces of toasted white bread, 30 grams of strawberry jelly, and 120cc of water. Images were then acquired immediately and at 1 hour, 2 hours, and 4 hours. Decay corrected time activity curves were then created utilizing the geometric mean from the anterior and posterior images.

FINDINGS:

The following % remaining is noted for the following time periods:
1 Hour:
2 Hour:
4 Hour:
T ½ =

Note any additional pertinent findings (hiatal hernia, reflux, etc)

IMPRESSION:
Classify as one of three categories:
Normal
Abnormally fast emptying suggestive of dumping syndrome
Delayed gastric emptying suggestive of gastroparesis or other cause of delayed gastric emptying.

Guidelines for interpretation:

<table>
<thead>
<tr>
<th>Time Point</th>
<th>% Remaining</th>
<th>% Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If value is less than this, consider “dumping syndrome” FOR 1 HOUR TIMEPOINT ONLY</td>
<td>If value is greater than this, consider gastroparesis or other cause of delayed gastric emptying</td>
</tr>
<tr>
<td>1 Hour (Nml 37-90%)</td>
<td>30%</td>
<td>90%</td>
</tr>
<tr>
<td>2 Hour (Nml 30-60%)</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>4 Hour (Nml 0-10%)</td>
<td>10%</td>
<td></td>
</tr>
</tbody>
</table>


Revised 12/2009 DJ
Patient Information Sheet

Patient name: _____________________________
Today's date: _____________________________
Your doctor: ______________________________
Your weight: ______________________________
Your height: _______________________________

1. What is your main symptom for undergoing the GE test today?
(Please circle the best answer or write in):
Heartburn Chest pain Nausea Vomiting
Abdominal pain Bloating/Distension Constipation Diarrhea
Other symptom: __________________________

2. Do you have diabetes? No Yes
If yes, how long have you had diabetes? ________ years
What medications do you take: insulin pills
Did you measure your glucose this morning before the test? No Yes
If yes, what was the value? __________

3. Do you take any pain medications? These include Percocet, Percodan, Demerol, Tylox, Tylenol #3, oxycodone, duragesic (Fentanyl) patch, Methadone, and others. No Yes
If yes, which one(s)?
How often do you take this?
When did you last take this type of medicine?

4. Do you take any medications to speed up your GI tract – stomach or colon? These include medications such as Reglan, Zelnorm, Domperidone, and erythromycin. No Yes
If yes, which one(s)?
When did you last take this type of medicine?

6. Have you had surgery on your GI tract – the esophagus, stomach, or colon? No Yes
If yes, please describe.
Patient Instruction Sheet

Your doctor has ordered a test that will permit evaluation of how food moves through your stomach. These studies will be performed in the nuclear medicine department.

Preparation for the GE Test:

* You should not eat any food after midnight, the night before the test. If you smoke, do not smoke, beginning on the morning of your test and throughout the time you are having the pictures of GE recorded. You may smoke after you are instructed that the test is completed.
* Some medications are generally stopped for this test. This should be discussed with your doctor or health-care provider. Drugs that affect GE such as Reglan (metoclopramide), Zelnorm (tegaserod), erythromycin, Motilium (domperidone), and antispasmodics such as Bentyl, Donnatal, Levsin, and Robinul are usually stopped for 3 days prior to this test. Do not take any laxatives on the day before or any time during your study.
* Unless otherwise directed by your doctor, the following pain medications should not be taken for 2 days prior to your test: Pain medications such as Demerol, codeine, morphine, Oxycontin, Percodan, and Percocet sedatives or tranquilizers, such as Valium, Librax, Ativan, or Thorazine.
* Unless otherwise directed by your physician, you may continue your normal medications that could be taken with a small amount of water or juice up to 2 h prior to your study. You should not drink coffee or tea.
* If you have diabetes, skipping breakfast may affect your need for diabetic medication. If you are a diabetic and on insulin, we request that you bring your regular morning dose of insulin with you. You can take this with the meal that will be given to you. We may reduce your insulin dose to adjust for the small size of the breakfast. Often half of your insulin is taken with the test meal. If you take oral hypoglycemic medications, generally these are taken with the meal in the nuclear medicine department. If there are any questions concerning your dose of insulin this should be discussed with your physician, radiologist, or the nuclear medicine department's physician performing the test.
* If you have diabetes, we also ask you to bring your glucose monitoring equipment to the test. We will ask you to check your glucose before the test and possibly during or after the test.
* Women, please note: This test should not be performed if you are pregnant. Inform your physician or nurse if you are pregnant or think you may be pregnant. You will be asked if there is the possibility of pregnancy. Often the test is best scheduled for females during the first 10 days of the menstrual cycle.

Description of the GE Test:

* For this test, you will be asked to eat an egg meal that consists of the equivalent of two eggs on toast together with water and jelly. The meal has been labeled with an isotope that will permit pictures to be taken as the meal passes through the stomach and the GI tract.
* Pictures of short duration are acquired with you standing in front of the nuclear medicine department's gamma camera. Between the images you will be permitted to walk about and continue normal activities. It is suggested that you bring some reading material and/or a "Walkman" or an "iPod" if you have personal music preferences. These studies try to simulate normal daily activities. The nuclear medicine department's rooms may be cooler than the rest of the hospital, and you may want to bring a sweater with you.
* The GE test generally takes 4 h once it is started.
Levine-Denver Shuntogram

Levine Denver shunt is placed to drain ascites into the venous system. $^{99m}$Tc-MAA is administered into the peritoneum, if the shunt is patent, it will be drained in the venous system and embolize in the lungs.

Radiopharmaceutical Administration:
1. Radiopharmaceutical $^{99m}$Tc-MAA is prepared according to the Radiopharmacy Procedure Manual.
2. Adult Dose: 5 mCi labeling $10^5$ to $10^6$ particles.
3. Child Dose: Per body weight (see chart) Minimum 3.5 mCi
4. Route: Into the peritoneum by a physician.
5. Time interval between administration and scanning: immediately following injection.
6. Scanning time: 30 minutes

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Explain the procedure and check for metal objects in the FOV.

Machine Set-Up Instructions (LFOV):
1. LEHR collimator.
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%)
3. Collect

Scanning Instructions:
1. Acquire anterior images of the abdomen and thorax, 200K, every 5 minutes for 30 minutes or until lung activity is identified.
2. Archive the images to PACS.
**MISCELLANEOUS NUCLEAR MEDICINE STUDIES**  
Revised 1/3/2007

**67 Gallium Scintigraphy**

**Clinical Indications:**
1. Evaluation of Hodgkin's disease
2. Evaluation of Lymphoma
3. Evaluation of Bronchogenic carcinoma
4. Evaluation of Hepatoma
5. Evaluation of sarcoidosis
6. Evaluation of Spinal Osteomyelitis

**Ref:**

7. Evaluation of occult malignancy


7. Evaluation of inflammatory lesions.

8. Although the package inserts from the commercial kits do not indicate use of 67 Gallium in children, many of the disease processes previously mentioned occur in the pediatric population. It is well established in the medical literature that the risk of morbidity and mortality from these disease processes is much greater than the risk from the radiation exposure. Therefore, gallium scintigraphies are performed in children and the radiopharmaceutical dose is calculated according to body weight (see chart).

The patient may be injected with gallium in his/her room. A 24-hour gallium scan will be done the following day. 48-hour pictures are usually required, and possibly, 72-hours will be necessary.

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: 67Ga citrate
2. Adult Dose: 3-5 mCi (8-10 mCi for lymphoma W/U)
3. Child Dose: Per body weight (see chart) Minimum 1.0 mCi
4. Route: Intravenous - slow infusion over 3 minutes
5. Time interval between administration and scanning:
24-, 48-, and 72-hour images may be requested

6. Additional Information:
   a. Check the $^{67}$Ga citrate vial for clarity prior to injection. If turbidity can be seen, the batch should not be used. Notify the radiopharmacy department.
   b. Frequent need for additional enemas and delayed images due to bowel contents of $^{67}$Ga

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Before scanning, have the patient empty his bladder.
3. Explain the procedure and check for metal objects in the FOV.
4. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).
5. When staging for lymphoma, do a SPECT study of the mediastinum at 72 hrs.

Machine set-up instructions (LFOV):
1. Medium energy collimator
2. Photopeak and window settings for the 3 energies of Gallium using all 3 analyzers (93 keV, 20% + 184 keV, 20% + 296 keV, 20%)
3. Preset time for 5 minutes for image.

Scanning instructions:
1. At the first imaging session (usually at 24H), views over the whole body should be obtained in the anterior and posterior projection.
2. Anterior views only on extremities.
3. At subsequent imaging sessions, selected views can be obtained in consultation with the nuclear medicine physician.
4. When the gallium scan is obtained to correlate with a bone scintigraphy in prosthesis work-up, only selected views are obtained:
   a. Hip prosthesis: anterior and posterior
   b. Knee prosthesis: anterior and lateral of both knees
5. When staging for lymphoma, do a SPECT study of the mediastinum at 72 hrs. (and abdomen if indicated) with processing to allow cine display.
6. Archive the images to PACS.

SPECT instructions (if indicated):
1. Medium energy collimator
2. 3 degrees per step
3. 30 second/frame
4. 360-degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction
6. Use Butterworth filter
7. Reconstruct the images in the transverse, coronal and sagittal planes.
Hepatic Arterial Perfusion Scintigraphy

Clinical Indications:
1. Assess catheter placement.
2. Define precise vascular anatomy receiving the intra-arterial infusion.
3. Assess degree of extra-hepatic perfusion to other abdominal visceral organs.
4. Assess degree of arteriovenous shunting; pulmonary uptake of > 10% is abnormal; >20% of the injected dose predicts systemic toxicity.

Materials Required:
1. Sterile drapes; sterile gloves; Betadine swabs; alcohol swabs, 4x4 gauze.
2. Infusaid (or Arrow) access needle(s).
3. Sterile saline syringes (2), 10 ml.
4. IV tubing with stopcock.
5. Heparinized saline, 100 u/ml, 5 ml, in 10 ml syringe.

Radiopharmaceutical Administration:
1. Prime the IV tubing with saline.
2. The implantable pump port(s) is accessed percutaneously by the oncology staff or nuclear medicine physician.
3. A 3-way stopcock is placed as close as possible to the site of catheter entry.
4. After placement of the patient beneath an LFOV camera fitted with a LEHR collimator, the catheter is flushed with 3-10 ml of saline at a maximum rate of 10 ml/min. to ensure patency of the catheter.
5. Tc$^{99m}$-MAA, 4 mCi in 0.2-0.8 ml, is introduced via the stopcock into the hepatic artery line.
6. Using the persistence scope, the activity is followed through the tubing until it reaches the liver; 6-10 ml of saline is used to slowly advance the MAA to the liver; if the pump port is seen as a "point source" on the scope, additional saline is infused at a very slow rate.
7. Important to ensure that no air is introduced into the catheter during MAA or saline infusion by achieving a "reverse meniscus" at both the orifice of the stopcock and at the syringe tip; place gauze beneath the two to absorb any spillage.
8. Because MAA tends to adhere to the catheter lumen, the tracer must begin to move through the length of the catheter as soon as it is introduced and at a reasonable rate.
9. Before or after imaging, the catheter must be flushed with 5-10 ml saline slowly and then 5 ml of heparinized saline, 100 u/ml.

**Patient Preparation:**
1. Pregnancy and nursing are relative contraindications.
2. Explain the procedure and check for metal objects in the FOV.

**System Set-Up:**
1. 140 keV with 20% window
2. LFOV camera, preferably dual-head, with LEHR collimator.

**Scanning Instructions:**
1. Static 750,000 count views of the abdomen (>300 sec interval) are obtained in the anterior and posterior projections. Right lateral projection image for same time as anterior view; left lateral views may sometimes be helpful. Flow images are not necessary.
2. Static anterior and posterior view of the lungs, excluding the liver, is obtained for the exact time required to obtain the 750,000 count anterior view of the liver.
3. Calculate the total number of counts (geometric mean) in the lungs as compared to the total amount in the (lungs + liver) as an estimate of vascular shunting.
4. SPECT may be useful.
5. Interpretation is aided by correlation with recent Tc$^{99m}$-SC and/or CT scans; a Tc-SC scan may be acquired the same day following the perfusion study after liver activity has cleared.
6. Archive the images to PACS.

**Ref:**

Revised 4/30/2003
Labeled Leukocytes Scintigraphy

Clinical Indications:
1. Evaluation of inflammatory lesions
2. Evaluation of prosthesis infection in correlation with bone scintigraphy
3. Evaluation of inflammatory bowel disease
4. Although the package inserts from the commercial kits do not indicate use of labeled leukocytes in children, inflammatory processes occur in the pediatric population. It is well established in the medical literature that the risk of morbidity and mortality from these disease processes is much greater than the risk from the radiation exposure. Therefore, labeled-WBC scintigraphies are performed on children and the radiopharmaceutical dose is calculated according to body weight (see chart).

With $^{99m}$Tc-HMPAO WBC, there is biliary excretion and bowel activity present after 4 hours.

Procedure: $^{111}$Indium leukocyte (WBC) scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{111}$In Leukocytes prepared using $^{111}$In-oxine by the radiopharmacy.
2. Adult Dose: 0.5 mCi
3. Pediatric Dose: Per body weight (see chart)
4. Route: Intravenous
5. Time interval between administration and scanning: 18-48 hours
6. Additional Information:
   a. 100 cc of heparinized blood must be drawn from patient to use in labeling the white cells. This process takes from 2-3 hours before reinjection.
   b. Patients scanned for bone and $^{111}$indium-leukocytes will be imaged at 48 hours only to reduce the amount of contamination from the $^{99m}$Tc into the $^{111}$In window. As a consequence, outpatients should not be scheduled on Thursday or Friday.

Preparation for $^{111}$In-leukocytes:
1. Aseptic technique should be used at all times during procedure. Obtain 100 ml of heparinized blood in two 60ml syringes (study can be performed with as little as 50 ml of blood).
2. Stand the syringes on the plunger at a 20 to 45° angle and allow the red cells to settle for 45 minutes.
3. Without disturbing the settled red cells, attach a 19g butterfly to each of the 60 ml syringes and express the plasma (containing the leukocytes) into a sterile 50 ml centrifuge tube (express plasma until red cells appear in butterfly tubing).
4. Once transfer is complete (may require 2 - 50 ml centrifuge tubes) balance the tubes in their centrifuge carriers and spin at 1800 RPM (. 4 on the centrifuge dial) for 5 minutes.
5. At this point, the white cells (along with some contaminating red cells) should be pelleted on the bottom of the tube.

6. Remove all of the supernatant plasma using 20ml syringes and save. Resuspend the leukocyte pellet in 2.0 ml of saline (no preservatives added) using a sterilized disposable transfer pipette.

7. After the cells have been suspended, add saline to bring total volume up to 4.0 ml. Calculate volume of In-111 Oxine needed to provide 1.0 mCi activity.

8. Draw In-111 Oxine (Amersham IN #117) and check in dose calibrator. Add In-111 Oxine to cell suspension in a dropwise fashion while swirling the tube. Incubate at room temperature to 20-30 minutes.

9. After incubation, add plasma back to the cell suspension to achieve a total volume of 20 ml. Balance in centrifuge rack and spin again at 1800 RPM for 5 minutes.

10. Remove all of the supernatant plasma and discard. Then, check the leukocyte button for activity in the dose calibrator. If less than 250 mCi repeat steps 7-11.

11. Add 2.0 ml of saline and resuspend the leukocyte pellet with a sterilized disposable transfer pipette. After suspension is complete, visually check for clumped cells that may need further agitation.

12. Add plasma to a total volume of 10.0 ml and draw appropriate volume of cell preparation to inject 500 mCi.

**Patient Preparation:** Check that the patient is not pregnant or breast feeding.

Explain the procedure and check for metal objects in the FOV.

Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

**Machine Set-up Instructions (LFOV):**

1. Medium energy collimator

2. Photopeak and window settings for $^{111}$In (172 keV, 20% + 247 keV, 20%)

3. Preset counts for 200K/image or time for 600 seconds/image.

**Scanning Instructions:**

1. At the first imaging session (usually at 24H), views over the whole body should be obtained in the anterior and posterior projection.

2. Anterior views only on extremities.

3. At subsequent imaging sessions, selected views can be obtained in consultation with the nuclear medicine physician.

4. When the indium-WBC scan is obtained to correlate with a bone scintigraphy in prosthesis work-up, only selected views are obtained:
   a. Hip prosthesis: anterior and posterior
   b. Knee prosthesis: anterior and lateral of both knees

5. If the patient has an arteriovenous fistula/shunt, selected magnified views in 2 planes of the region should be obtained.

6. If the patient is being investigated for inflammatory bowel disease (Crohn's disease or ulcerative colitis or pseudo membranous colitis), initial views of the abdomen in the anterior and posterior projections should be acquired EARLY at 2-3 hours.
**SPECT Instructions (if indicated):**
1. Medium energy collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 360 degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction

Archive the images to PACS.

**PROCEDURE: 99mTc-HMPAO-Leukocyte (WBC) Scintigraphy**


**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: 99mTc-HMPAO Leukocytes prepared using 99mTc-HMPAO by the radiopharmacy.
2. Adult Dose: 25 mCi
3. Pediatric Dose: Per body weight (see chart)
4. Route: Intravenous
5. Time interval between administration and scanning:
   2 sets of images: 1 hour and 4 hours postinjection
   24 hour images may be necessary
6. Additional Information:
   a. 100 cc of heparinized blood must be drawn from patient to use in labeling the white cells. This process takes from 2-3 hours before reinjection.

**Preparation for 99mHMPAO-leukocytes:**

**Technetium Tc-99m-Exametazime Leukocytes (HMPAO)**
1. Obtain 100 ml of heparinized blood in two 60 ml syringes. The study may be performed with as little as 45 ml of blood.
2. Stand the syringes on the plunger end at a 45% angle for 45 minutes to allow red blood cells to sediment.
3. Without disturbing the red blood cells attach a 19 G butterfly to each of the 60 ml syringes and express the leukocyte rich plasma (LRP) into a sterile 50 ml centrifuge tube.
4. Centrifuge the LRP at 1800 RPM (approx. 4 on the centrifuge dial) for 5 minutes.
5. At this point there should be a pellet of white blood cells (WBCs) along with some red blood cells at the bottom of the tube.
6. Draw off all of the platelet rich plasma (PRP) using 20 ml syringes and save.
7. Resuspend the cell button in 2 to 4 ml of saline using a sterile disposable transfer pipette.
8. Place the centrifuge tube on a Rocker and rock for 10-15 minutes. White cells should fall to the bottom of the tube.

9. Remove 2-3 ml of supernate and discard. Add saline to the cells, resuspend, and rock again for 10-15 minutes. Remove the supernate and discard.

10. Reconstitute vial of technetium Tc-99m exametazime with 30 mCi of technetium Tc-99m pertechnetate according to package insert. Withdraw contents of reconstituted kit and add to washed cells.

11. Resuspend cell button in the pertechnetate solution. Swirl to mix.

12. Incubate for 20 minutes.

13. Add 20 ml of the PRP to the Tc-99m exametazime cell mixture. Swirl gently to mix and centrifuge at 1800 RPM. Remove the supernate and discard. This step removes unbound Tc-99m from the preparation.


**Patient Preparation:** Check that the patient is not pregnant or breast feeding. Explain the procedure and check for metal objects in the FOV. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

**Machine Set-up Instructions (LFOV):**
1. LEHR collimator
2. Photopeak and window settings for $^{99m}$Tc (140 keV, 15-20% window.)
3. Preset counts for 500K/image or time for 300 seconds/image.

**Scanning Instructions:**
1. At the first imaging session (1H), views over the whole body should be obtained in the anterior and posterior projection.
2. Anterior views only on extremities.
3. At subsequent imaging sessions, selected views can be obtained in consultation with the nuclear medicine physician.
4. Evaluation of shunt infection: Take 2UH delayed images of both extremities.

**SPECT Instructions (if indicated)**
1. LEHR parallel-hole collimator
2. 3 degrees per step
3. 30 seconds/frame
4. 360 degree rotation
5. 64 x 64 x 16 pixel matrix for reconstruction
6. Reconstruct the images in the transverse, coronal and sagittal plane.

Archive the images to PACS.
SCROTAL IMAGING

Clinical Indications: Evaluation of testicular torsion


PROCEDURE: Scrotal Imaging

Radiopharmaceutical Administration:
1. Radiopharmaceutical: 99mTc pertechnetate
2. Adult Dose: 15 mCi
3. Child Dose: Per body weight (see chart) Minimum 1.5 mCi
4. Route: Intravenous
5. Time interval between administration and scanning: Immediately

Patient Preparation: Explain the procedure and check for metal objects in the FOV.

Machine Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for 99mTc (140 keV, 15-20%).
3. Set-up camera for dynamic flow study followed by serial static images.

Scanning Instructions:
1. Place patient in supine position. The penis is taped up toward the abdomen. The testes are positioned. The rest of the area is shielded after the flow study is completed. Views taken over anterior pelvis area.
2. For the dynamic flow study, the radiopharmaceutical is injected rapidly through a 19 gauge butterfly and is followed by flush of 20ml saline with a 3 way stopcock.
3. Images are collected for 5 sec/frame for 40 seconds.
4. Static images taken at 5, 10, 15 minutes for 200K counts/image. Pinhole images are helpful.
5. Archive the images to PACS.
LYMPHOSCINTIGRAPHY OF EXTREMITIES

Clinical Indications:
1. Evaluation of lymphedema.
2. Evaluation of patency of lymph channels.

Ref.
2) Kaplan W: Oncology-Other Modalities" In: Gottschalk A, Hoffer PB, Potchen EJ, (eds) "Diagnostic Nuclear Medicine, pp. 1101-1110.

PROCEDURE: Lymphoscintigraphy

Patient is brought to Nuclear Medicine Department. Intradermal injection is made in hands or feet. Length of study depends on how fast the isotope travels throughout the lymphatic system.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid is prepared according to the Radiopharmacy procedure manual, and filtered with a 0.2 micron filter.
2. Adult Dose: 1-2 mCi (0.5 mCi/injection).
3. Pediatric Dose: per body weight (see chart), minimum 0.5 mCi.
4. Route: intradermal
5. Time interval between administration and scanning: Immediate
6. Additional information: Both extremities should be studied sequentially to compare abnormal and normal side.

Patient Preparation: Check that the patient is not pregnant or breast feeding. Explain the procedure and check for metal objects in the FOV.

Machine Set-up Instructions (LFOV):
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Preset time for 60 sec/image.

Scan Instructions:
1. Place patient in supine position.
2. Scan entire extremity from injection site to liver.
3. Serial images are taken at 0, 15, 30, 45 min., 1 hr., 2 hrs., etc. until activity is seen in the liver.
4. Both extremities are scanned separately for comparison.
5. Archive the images to PACS.
LYMPHOSCINTIGRAPHY FOR EVALUATION OF MALIGNANCIES

Clinical Indications:
1. Evaluation of lymphatic destruction
2. Evaluation of specific lymphatic drainage basin of cutaneous and breast lesions

PROCEDURE: Lymphoscintigraphy

Patient is brought to Nuclear Medicine Department. Intradermal injection is made. Length of study depends on how fast the isotope travels throughout the lymphatic system.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid is prepared according to the Radiopharmacy procedure manual, and filtered with a 0.2 micron filter.
2. Adult Dose: 300-500 uCi (40 uCi injection x 4 to 8)
3. Pediatric Dose: N/A.
4. Route: intradermal; and intraparenchymal for breast cancer.
5. Time interval between administration and scanning: Immediate

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Obtain the Neoprobe from the operating room if clinically warranted.

Machine Set-up Instructions (LFOV):
1. LEHR parallel hole collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%)

Procedure:
Injection: 300-500 uCi of radiopharmaceutical in 40 microCuries increments are injected intradermally in 4-8 equal parts surrounding the primary lesions. Use lower dose for head and neck lesions. Subcutaneous injections may result in rapid passage of the radiopharmaceutical through separate deeper lymphatic channels along veins, bypassing the nodes draining the dermal plexus. Only small volumes (0.5 ml) should be injected. For extremity lesions, most of the injections should be along the proximal border of the lesion.

For breast cancer patients, 4-6 intra- or subdermal injections of 40 uCi each are made surrounding the mass or biopsy site and 6 ml containing 450 uCi are injected into the breast parenchyma in a peritumoral fashion. The breast should be massaged for one or more minutes following completion of the injections.

Scanning Procedure:
1. Dynamic anterior/posterior images acquired for 30 minutes or until nodes visualized and processed for cine.
2. Static images every 5 minutes for 30 minutes or until node(s) visualized and
2-hour image are presented.
3. Use cobalt-57 markers as required.
4. On the last static and delayed images, shield the injection sites.
5. On the last and 2-hour studies obtain lateral, anterior, and posterior views and PRN obliques.
6. For imaging the axilla, the arm should be held above the head, imaging the nodes in 2 axes. Views should contain a minimum of 100,000 counts.
7. In the imaging of the head and neck, sternocleidomastoid muscle should be marked with a radioactive marker.
8. For breast cancer patients, the ipsilateral thorax should be supported by a wedge and further anterior imaging acquired.
9. Pertinent outlines of the body with markers over the iliac crest, suprasternal notch, xiphoid, umbilicus, etc. should be done.
10. **One image should be acquired with a cobalt sheet source under the patient to outline body contour, when the sentinel node appears.**
11. The hand-held Neoprobe can be used to precisely localize the sentinel node(s).
12. Archive the images to PACS.

**Interpretation:**
1. The sentinel node is defined as the first node in the lymphatic basin that drains to the primary tumor; it is not necessarily the node closest to the primary tumor.
2. The surgeon needs a map of the position of the sentinel node in reference to the other nodes in the basin in order to do sentinel node harvesting under local anesthesia with a small incision.
3. Scintigraphy in 2 planes with cutaneous marking of the sentinel node and any in transit nodes is necessary. Two or even 3 drainage basins/sentinel nodes may be demonstrated. In transit nodes are defined as tracer accumulation in the subcutaneous tissue between the primary site and the regional nodal basin. They are also resected at the time of sentinel node harvesting.
4. Delayed imaging is necessary to ensure that all basins with lymphatic drainage are visualized.
5. Intraoperative mapping with a hand-held probe may follow preoperative mapping. 2-4 hours postinjection is the optimal time for intraoperative mapping. Intraoperatively, an in vivo "hotspot" to background activity ratio of at least 3:1 or an ex vivo sentinel node to nonsentinel node ratio of at least 10:1 is minimal acceptable criteria for sentinel lymph node identification.

Revised 1/3/2007
EARLY DETECTION OF OCCULT MICROMETASTASES BY LYMPH NODE MAPPING IN PATIENTS WITH BREAST CANCER: A MULTI-CENTER TRIAL (REINTGEN, BEAUCHAMP, ET AL.)

Indication:

Patients with palpable breast masses will be injected pre-operatively by a physician to allow identification of the axillary sentinel node intra-operatively using the hand-held Neoprobe.

Radiopharmaceutical: Filtered $^{99m}$Tc sulfur colloid

Route of administration: Subcutaneous peritumoral

Patient preparation: Review with the patient pregnancy and lactation issues, if appropriate, and determine whether informed consent form has been signed. Explain the procedure and check for metal objects in the FOV.

Procedure:

1. Obtain from radiopharmacy 450 microCi filtered $^{99m}$Tc sulfur colloid in 6 ml saline divided into six 1 ml syringes.
2. No images will be acquired.
3. Two to six hours pre-operatively, the radiopharmaceutical will be injected subcutaneously around the breast tumor in a circumferential manner by a physician.

Revised 1/3/2007
DACRYOCYSTOGRAPHY

Clinical Indications:
Evaluation of patency of lacrimal canals.


PROCEDURE: Dacryocystography

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc pertechnetate.
2. Adult Dose: 0.2 mCi (0.1 mCi in each eye).
3. Child Dose: 0.1 mCi
4. Route: Directly placed into eye via pipette or syringe (near the lateral canthus).
5. Time interval between administration and scanning: Immediate
6. Additional Information: Dose volume should be 0.01 - 0.05 ml.

Patient Preparation: Explain the procedure.

Machine Set-up Instructions:
1. Pinhole collimator.
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Collect dynamic images 30 seconds/image for 5 minutes.

Scanning Instructions:
1. Place patient upright in front of pinhole collimator at a distance of 1.5 - 6.0 centimeters.
2. Instill the conjunctival sac laterally of both eyes simultaneously and begin imaging immediately.
3. Collect dynamic images 30 seconds/image for 5 minutes.
4. Obtain 15-min. delayed image
5. Archive the images to PACS.
RADIONUCLIDE SIALOGRAM

The salivary gland shares with the thyroid gland the ability to trap and concentrate pertechnetate and, as such, is amenable to radionuclide scintigraphy. The radionuclide sialogram permits direct visualization of parenchymal glandular tissue. Various functional aspects of the salivary gland including blood flow, trapping mechanism of ductal epithelium, and patency of ductal pathways can be evaluated noninvasively by scintigraphy. The procedure is a sensitive, physiologic approach which frequently discloses salivary gland abnormalities of systemic diseases prior to development of morphologic changes and clinical manifestations. Radionuclide sialography, however, suffers a serious drawback in its inability to detect nonpalpable masses or those smaller than 2 cm in size and to differentiate intrinsic from extrinsic lesions.


Clinical Indications:

1. Evaluation of Dry Mouth
   Dry mouth is often a psychosomatic disorder but is also an important feature of Sjogren's syndrome and other systemic diseases such as rheumatoid arthritis, systemic lupus erythematosus, and sarcoidosis. Demonstration of the normally functioning gland and its rapid response to lemon juice is reassuring as to the psychosomatic nature of the problem.

   In a postmenopausal woman with dysphagia and dysarthria, with or without evidence of other systemic disease, one should consider Sjogren's syndrome. This is a chronic inflammatory disease of autoimmune etiology. Its association with rheumatoid arthritis, as well as with other connective tissue and collagen vascular diseases such as systemic lupus, scleroderma, and polymyositis is well known. In patients with Sjogren's syndrome trapping is usually diminished and there is lack of significant drainage in response to lemon.

2. Evaluation of Sialolithiasis Prior to Surgery
   Complete long-standing ductal obstruction due to sialolithiasis results in parenchymal atrophy and a nonfunctioning gland (cold gland). Partial obstruction leads to the retention of radioactivity and "hot gland". The distinction is important so the proper surgical approach can be established.

3. Evaluation of Focal Glandular Enlargement
   When a focal mass is present within the gland, its functional status must be determined. Metastatic deposits are invariably cold and Warthin's tumors are "hot." Like "hot" thyroid nodules, functioning salivary masses have a much better predictive value, while "cold" masses require further investigation.
Primary tumors of salivary glands are rare and the majority of these are benign (85%). The most common type of benign tumor is the pleomorphic adenoma (mixed tumor) which comprises approximately 75% of salivary tumors. These are commonly seen in females during the 4th and 5th decades of life; these tumors are usually "cold", but it is not uncommon to see mixed tumor as a functional mass. Another benign tumor of the salivary glands is the so-called Warthin's tumor or papillary cystadenolymphomatous which comprises about 7% of salivary gland tumors. It usually occurs in white males over 50 years of age. The tumor is soft and predominantly cystic, is located immediately beneath or outside the parotid gland capsule, and is invariably "hot" by radionuclide sialography. Oncocytoma or oxyphilic adenoma is quite rare. Less than 1% of benign salivary gland tumors are oncocytoma and these tumors can be "hot" or "cold".
**PROCEDURE: Radionuclide Sialogram**

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}\text{Tc}$-pertechnetate
2. Adult Dose: 15 mCi
3. Child Dose: Per body weight (see chart). Minimum 2.0 mCi.
4. Route: Intravenous
5. Time interval between administration and scanning: Immediate

**Patient Preparation:** Check that the patient is not pregnant or breast feeding. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}\text{Tc}$ (140 keV, 15-20%).
3. For the static images, preset time counts for 200K/image.

**Scanning Instructions:**
1. Position the patient under the camera with the neck extended to obtain images in the anterior projection (water's view) including the thyroid gland in the field of view.
2. Inject the radiopharmaceutical as a bolus with saline flush using a 3-way stopcock.
3. Collect dynamic blood flow images 5 seconds/image for 40 seconds.
4. Collect static views (200K/image) in the water's projection and both lateral projections.
5. If indicated, obtain similar delayed projections.
6. Let the patient suck lemon juice for 5 minutes and collect similar projections.
7. Archive the images to PACS.
**131I-MIBG SCINTIGRAPHY**

**Clinical Indications:**
Evaluation of catecholamine secreting tumors (pheochromocytomas, neuroblastomas)

PROCEDURE: $^{131}$I MIBG Scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{131}$I MIBG (methyliodobenzylguanidine)
2. Adult Dose: 0.5 mCi-1.0 mCi
3. Pediatric Dose: per body weight (see chart) Minimum 0.1 mCi (7-15 uCi/kg)
4. Route: Intravenously over 90 seconds

Patient Preparation:
1. Patient is given an iodine preparation (Lugol's or SSKI) orally for three days prior to injection and seven days post injection. The dose is 120 mg/day (10 drops/day of Lugol’s) in patients over 1 year of age.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and need for delayed imaging and check for metal objects in the FOV.
4. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

Potential Drug-MIBG Interactions

Review the patient's medication history as indicated below.

Antidepressants (tricyclics, etc.): discontinue six weeks prior to scanning.
1. amitriptyline (Elavil, Endep, Etrafon, Triavil, Emitrip, Enovil)
2. amoxapine (Ascendin)
3. desipramine (Pertoframe, Norpramin)
4. imipramine (Tofranil, Imavate, Janimine, Pesamine, SK-Pramine, Tipramine)
5. doxepin (Sinequan, Adapin)
6. maprotiline (Ludiomil)
7. nortriptyline (Aventyl, Pameler)
8. protriptyline (Vivactil)
9. Trimipramine (Surmontil)
10. trazodone (Desyrel)

Antipsychotics, Antinauseants, Phenothiazines: discontinue at least two weeks before scan.
1. haloperidol (Haldol)
2. thiothixene (Navane)
3. acetophanazine (Tindal)
4. carphenazine (Proketazine)
5. chlorpromazine (Thorazine, Promapar, Chloramead, Foypromazine)
6. fluphenazine (Prolixin, Permitil): discontinue six weeks before scan.
7. mesoridazine (Serentil)
8. perphenazine (Trilafon)
9. piperacetazine (Quide)
10. prochlorperazine (Compazine)
11. promazine (Sparine, Norazine, Prozine)
12. thioridazine (Mellaril)
13. trifluoperazine (Stelazine)
14. triflupromazine (Vesprin)

Cardiac Drugs: discontinue at least two weeks prior to scanning.
1. labetalol (Normodyne, Trandate)
2. guanethidine (Ismelin)
3. reserpine (Serpasil, Sandril)

Nasal Decongestants: discontinue two weeks prior to scanning.
1. pseudoephedrine (Sudafed and many other cold preparations)
2. phenylpropanolamine (PPA, Entex, Sucrets, and many others)
3. phenylephrine (Neo-Synephrine, Sinex, Coricidin, and many others)

· most OTC and prescription decongestants and allergy medications have one of these three ingredients; check the labels.

Amphetamines, Diet Pills: discontinue for a least two weeks before scanning.
1. amphetamine (Benzedrine, Edrisal, Biphetamine, Amphaplex)
2. benzphetamine (Didrex)
3. chlorphentermine (PreSate)
4. chlortermine (Voranil)
5. dextroamphetamine (Dexedrine, etc.)
6. diethylpropion (Tenuate, Teplanil)
7. flenfluamine (Pondimin)
8. mazindal (Sanorex)
9. methamphetamine (Desoxyn, Methedrine, Methampex, "crystal", "crank")
10. methylphenidate (Ritalin)
11. phendimetrazine (Plegine)
12. phenmetrazine (Preludin)
13. phentermine (Ionamin)
14. Cocaine

Machine Set-up Instructions (LFOV):
1. Medium or high energy collimator.
2. Photopeak and window settings predetermined for $^{131}$I (364 keV, 30%).
3. Preset time for 600 seconds/image.

Scanning Instructions:
1. Place patient in supine position on scanning bed.
2. Image the total body anteriorly and the torso posteriorly.
3. Images are taken for 600 seconds/view.
   It is routine to scan 24, 48, and 72 hours.
4. Make a concerted effort to precisely locate all abnormal foci using cobalt markers and additional views.
5. Archive the images to PACS.

PROCEDURE: $^{123}$I MIBG Scintigraphy

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{123}$I MIBG (methyliodobenzylguanidine)
2. Adult Dose: 10 mCi
3. Pediatric Dose: per body weight (see chart) Minimum 1.5 mCi (150 uCi/kg)
4. Route: Intravenously over 90 seconds

Patient Preparation:
1. Patient is given an iodine preparation (Lugol's or SSKI) orally for three days prior to injection and seven days post injection. The dose is 120 mg/day (10 drops/day of Lugol’s) in patients over 1 year of age.
2. Check that the patient is not pregnant or breast feeding.
3. Explain the procedure and check for metal objects in the FOV.
4. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).
5. The patient should be on clear liquids only for 4 hours prior to radioiodine administration.

Potential Drug-MIBG Interactions

Review the patient's medication history as indicated below.

Antidepressants (tricyclics, etc.): discontinue six weeks prior to scanning.
1. amitriptyline (Elavil, Endep, Etrafon, Triaval, Emitrip, Enovil)
2. amoxapine (Ascendin)
3. desipramine (Pertoframe, Norpramin)
4. imipramine (Tofranil, Imavate, Janimine, Pesamine, SK-Pramine, Tipramine)
5. doxepin (Sinequan, Adapin)
6. maprotiline (Ludiomil)
7. nortriptyline (Aventyl, Pamelor)
8. protriptyline (Vivactil)
9. Trimipramine (Surmontil)
10. trazodone (Desyrel)

Antipsychotics, Antinauseants, Phenothiazines: discontinue at least two weeks before scan.
1. haloperidol (Haldol)
2. thiothixene (Navane)
3. acetophenazine (Tindal)
4. carphenazine (Proketazine)
5. chlorpromazine (Thorazine, Promapar, Chloramead, Foypromazine)
6. fluphenazine (Prolixin, Permitil): discontinue six weeks before scan.
7. mesoridazine (Serentil)
8. perphenazine (Trilafon)
9. piperacetazine (Quide)
10. prochlorperazine (Compazine)
11. promazine (Sparine, Norazine, Proazine)
12. thioridazine (Mellaril)
13. trifluoperazine (Stelazine)
14. triflupromazine (Vesprin)

Cardiac Drugs: discontinue at least two weeks prior to scanning.
1. labetalol (Normodyne, Trandate)
2. guanethidine (Ismelin)
3. reserpine (Serpasil, Sandril)

Nasal Decongestants: discontinue two weeks prior to scanning.
1. pseudoephedrine (Sudafed and many other cold preparations)
2. phenylpropanolamine (PPA, Entex, Sucrets, and many others)
3. phenylephrine (Neo-Synephrine, Sinex, Coricidin, and many others)
   · most OTC and prescription decongestants and allergy medications have
   · one of these three ingredients; check the labels.

Amphetamines, Diet Pills: discontinue for at least two weeks before scanning.
1. amphetamine (Benzedrine, Edrisal, Biphetamine, Amphaplex)
2. benzphetamine (Didrex)
3. chlorphentermine (PreSate)
4. chlorortermine (Voranil)
5. dextroamphetamine (Dexedrine, etc.)
6. diethylpropion (Tenuate, Tepanil)
7. flenfluramine (Pondimin)
8. mazindal (Sanorex)
9. methamphetamine (Desoxyn, Methedrine, Methampex, "crystal", "crank")
10. methylphenidate (Ritalin)
11. phendimetrazine (Plegine)
12. phenmetrazine (Preludin)
13. phentermine (Ionamin)
14. Cocaine

**Machine Set-up Instructions (LFOV):**
1. Low energy, high-resolution energy collimator.
2. Photopeak and window settings predetermined for $^{123}$I (159 keV, ± 10%).
3. Preset time for 600 seconds/image.

**Scanning Instructions:**

1. Place patient in supine position on scanning bed.
2. Acquire anterior and posterior images of the whole body (including the distal extremities for neuroblastoma patients).
3. Images are taken for 600 seconds/view. It is routine to scan 24 and 48 hours.
4. 360 degree SPECT images, 25 sec/step, of the abdomen (plus thorax and pelvis in neuroblastoma patients as needed) with CT transmission imaging for attenuation correction and fusion imaging as deemed appropriate by the physician.
4. Make a concerted effort to precisely locate all abnormal foci using cobalt markers and additional views.
5. Archive the images to PACS.
**I-131 MIBG DOSIMETRY PROTOCOL**

Name ___________________________  MRN ____________________
DOB ______________________________  AGE ______  Height ______  Weight ______

**GOALS:**

1. Using a tracer dose pre-therapy, whole body exposure and tumor uptake and retention are measured so that the therapy may be calculated to deliver over 2000r to tumor masses without delivering > 200 r to the blood; WB retention should be < 120 mCi at 48 h.; if there are diffuse pulmonary metastases, WB retention should be < 80 mCi at 48 hr.

2. Following therapy, dosimetry is used to estimate actual tumor and WB exposure.

**TRACER DOSE:** 0.5-1.0 mCi

**SCANNING STANDARD:** 50-100 µCi in a vial.

**EQUIPMENT SET-UP:**

1. LFOV camera, dual head; high or medium energy collimator.
2. WB scan, ant & post, head to knees; statics for 10 min; std for 4 min., 256 X 256. Use identical separation distance of heads at each session.
3. Acquire all images before voiding.
4. Image the standard 2 cm from collimator in anterior and posterior projections at each whole body acquisition; use identical separation distance of heads. Std should be scanned equidistant from the heads by placing it on a Dixie cup.
5. Must stop scan at overflow when scanning the std and the patient and document the duration of the scan.
6. Important that all procedures be performed identically each day.

<table>
<thead>
<tr>
<th>Diagnostic Dose</th>
<th>mCi</th>
<th>Date</th>
<th>Time</th>
<th>Vol</th>
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<tr>
<td>Therapy Dose</td>
<td>mCi</td>
<td>Date</td>
<td>Time</td>
<td>Vol</td>
</tr>
<tr>
<td>STD</td>
<td>uCi</td>
<td>Date</td>
<td>Time</td>
<td>Vol</td>
</tr>
</tbody>
</table>

**DAY 0 DATE______________

1. Assay standard
2. Dose administration. Dose ___mCi  Time ______
3. WB scan 5 min p.i., ant & post  Time ______
4. Scan of Std 5 min p.i., ant & post  Time ______  Duration ____ min.
5. WB scan 4-6 h p.i., ant & post  Time ______
6. Scan of Std 4-6 h p.i., ant & post  Time ______  Duration ____ min.
DAY 1

1. WB scan 24 h p.i., ant & post  
Time_________  
2. Scan of Std 24 h p.i. ant & post  
Time_________  Duration ____________ min

DAY 2

1. WB counts 48 h p.i. ant & post  
Time_________  
2. Scan of Std 48 h p.i. ant & post  
Time_________  Duration ____________ min

DAY 3

1. WB scan 72 h p.i. ant & post  
Time_________  
2. Scan of Std 72 h p.i. ant & post  
Time_________  Duration ____________ min

DAY 4

1. WB scan 96 h p.i. ant & post  
Time_________  
2. Scan of Std 96 h p.i. ant & post  
Time_________  Duration ____________ min

ANALYSIS

1. Draw a ROI around the largest/most intense lesion(s), a background zone, and the standard in both projections.
2. Draw a ROI around the whole body, liver, bladder, and the kidneys in both projections.
3. Note ROI size in sq. cm.
4. Obtain the BG corrected cps for each ROI and the standard at 24, 48, 72, and 96 hrs. and calculate the geometric mean
5. Calculate the % uptake for each lesion:
   
   \[
   \text{uptake} = \left( \frac{\text{lesion cps} \times F}{\text{std cps}} \right)
   \]

   \[
   F = \text{fraction of administered activity in the standard.}
   \]

6. Calculate blood, whole body, organ, and tumor dosimetry using MIRD formulation.

Revised 1-3-2007
STRONTIUM-89 THERAPY
SOMATOSTATIN RECEPTOR (OCTREOSCAN) SCINTIGRAPHY

Introduction
Pentetreotide is an analog of somatostatin and binds to somatostatin receptors. Visualization of somatostatin-receptor rich tumors such as islet cell tumors, medullary carcinomas of the thyroid, pheochromocytomas, neuroblastomas, pituitary adenomas, carcinoid tumors, and other neuroendocrine tumors is achieved with a sensitivity of 80-90%.

It has a biologic half-life of 6 hours and is renally excreted. Physiologic activity is seen in the normal pituitary gland, thyroid gland, liver, bladder, and frequently the bowel.

Radiopharmaceutical administration:
1. Radiopharmaceutical: $^{111}$In-DTPA-D-Phe-Octreotide
2. Adult dose: 3-6 mCi
3. Pediatric Dose: per body weight
4. Route: Intravenous
5. Time interval between dose administration and scanning:
   - 4 hours, 24 hours, and occasionally 48 hours.

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Explain the procedure and check for metal objects in the FOV.
3. Concurrent administration of Somatostatin receptor agonist (Sandostatin) therapy is not a contraindication to octreotide scintigraphy and does not diminish sensitivity for detection of neoplasm.
4. Laxatives should be used from the time of injection
5. Check that a barium procedure has not been performed within the past several days (obtain a KUB X-ray if there is any doubt).

Machine Set-up Instructions:
1. Medium energy collimator
2. Photo peak and window settings for $^{111}$In (172 keV, 20% and 247 keV, 20%).

Scanning Instruction:
1. At 4 hours perform whole body imaging in the anterior and posterior projections from neck down to and including the pelvis, using step and shoot procedure at 5 minutes per step.
2. At 24 hours, perform whole body imaging in the anterior and posterior projections from the head to the distal femurs using 10 minutes per step.
3. SPECT of the region of interest should be obtained in a 64 by 64 word matrix using at least 40 seconds acquisition time per step.
4. 48-hour imaging of the abdomen may be necessary after consultation with the nuclear medicine physician.

SPECT:
1. Medium energy collimator
2. 3 degrees per step
3. 30 sec/frame
4. 360 degrees rotation
5. 64 x 64 x 16 pixel matrix for reconstruction

Archive the images to PACS.
Radiopharmacy Instructions for In-111-CYT-103 (OncoScint)

1. Store antibody in refrigerator (not freezer)
2. \(^{111}\)Indium-Chloride necessary
3. Kit comes with 1 mg antibody, sodium acetate buffer, filter (Millex-GV, 0.22 filter, Millipore Corporation)
4. 1/2 hour prior to labeling, bring kit to room temp
5. Add 0.5 ml sodium acetate buffer to \(^{111}\)Indium-Chloride, mix carefully
6. Withdraw 6-7 mCi from buffered \(^{111}\)In-Chloride vial; add to antibody vial
7. Mix gently, allow to incubate at room temp for 30 minutes
8. With filter attached to 10 cc syringe, withdraw entire contents of antibody vial
9. Discard filter, attach sterile needle, assay dose (should be 4-5 mCi)

Radiochemical Purity Testing of In-111-CYT-103

1. Reconstitute DTPA kit with 1.0 ml sterile water
2. Express one drop of labeled CYT-103 from dose, mix with equal amount of DTPA
3. Solvent: Sodium Chloride
4. Paper: ITLC-SG
5. Drop DTPA and CYT-103 mixture onto ITLC paper 1 cm from bottom of paper
6. Place gently into container with saline; allow to migrate (2-4 min)
7. Remove strip, cut in half; assay both halves
8. Free \(^{111}\)Indium will migrate to the top (\(^{111}\)In-DTPA); labeled CYT-103 will remain at the bottom
9. RCP = B/(T+B) x 100 (should be greater than 95%)

Patient Factors and Injection Technique for In-111-CYT-103 Imaging

1. Obtain medical history from patient
   a. Allergies
   b. Surgeries
   c. Colostomy
   d. Check that the patient is not pregnant or breast feeding.
2. Have epinephrine available
3. Use a 10 ml saline flush with butterfly and stopcock
4. MD should be present for injection
5. Obtain baseline vital signs
6. Inject SLOWLY (over 5 minutes)
7. Terminate injection if patient is symptomatic
8. Continue at MD discretion
9. After injection, flush tubing thoroughly
10. Leave butterfly in for 15 minutes
11. Patient should remain in department for total of one hour
Planar Imaging Protocol for In-111-CYT-103
1. Imaging sequence: twice between 2 and 5 days
2. Views acquired for 10 minutes: Anterior and posterior chest, abdomen, and pelvis
3. Bowel prep recommended before imaging (i.e. magnesium citrate)
4. Collimator: Medium Energy
5. Energy: 173 & 247 keV
6. Matrix: 256 x 256

SPECT Imaging Protocol for In-111-CYT-103
1. Medium energy collimator
2. Matrix: 128 x 128
3. Orbit: 360 degrees elliptical
4. 64 views, 40 seconds per frame
5. Pre-reconstruction filter - Butterworth 0.3
6. Filtered backprojection, ramp filter
7. No attenuation correction
8. Reconstruct transaxial tomograms, 3 pixels thick
9. Sagittal and coronal tomograms reconstructed
10. Film all views, data can also be displayed on computed screen
11. When filming, adjust threshold to see vascular structures (liver will be intense). May be easiest to film coronal images first

Potential Artifacts
1. Full bladder obstructing positive lesion
2. Urine contamination causing "hot spot"
3. Uptake of In-111-CYT-103 at sites of recent surgery
4. "Hot spot" at colostomy site
5. Bowel activity not cleared out with prep
6. Patient motion
7. Camera non-uniformity
8. Inadequate energy correction
9. Elevated HAMA
10. Uptake of In-111-CYT-103 at recent fracture site

Technical Tips for In-111-103 Imaging
1. Use bowel prep before initial imaging session
2. Have patient void immediately before imaging
3. Change colostomy bags before imaging
4. Mark colostomy site on film, or use lead or In-111 marker
5. Position camera as close to body as possible
6. Image anterior chest view with neck straight, in order to visualize neck nodes
7. Use pillows and arm straps for comfort
8. For optimum pelvic view, position so that only the edge of the liver is seen
9. Use identical positioning for early and delayed images.
10. If patient cannot tolerate long SPECT imaging time, shorten acquisition time to 30 seconds/frame.
11. Use same intensity for filming all views and archive the images to PACS.
SCINTIMAMMOGRAPHY

$^{99m}$sestamibi has been used to image malignant breast disease since 1992. The sensitivity in most reported series is in excess of 90% for palpable lesions but is no higher than 50% for nonpalpable lesions. Specificity ranges from 70-87% with false positive accumulation seen at the areolae (in 3-5% of women) and in sclerosing adenosis, fibroadenoma, new/chronic infections, and in the region of any recent biopsy. Axillary accumulation may occur ipsilateral to an infiltrated dose injection.

Clinical Indications

1. Palpable mass not seen on mammography or ultrasound.
2. Benign-appearing mass on mammography with equivocal changes on follow-up.
3. Mass seen on mammography in only one view.
4. New or changing asymmetric fibroglandular density.
5. Axillary lymphadenopathy.
6. Assessment of the patient with dense breasts or an implanted breast prosthesis.
8. Assessment of the response to chemotherapy.

Patient Preparation

1. Patients must be able to lie prone with arms raised for planar imaging, 20-40 minutes.
2. The patient should remove all clothing and jewelry above the waist and wear a hospital gown open in the front.
3. Recent mammograms and ultrasounds not older than 3 months should be available.
4. Breast physical examination must be performed by the interpreting physician.
5. Check that the patient is not pregnant or breast feeding.
6. History should include date of any breast injury, biopsy or surgery, hormone therapy, chemotherapy, or radiation therapy.
7. Scintigraphy should be delayed two weeks following cyst or fine needle aspiration, and four to six weeks following a core or excisional biopsy.
8. Explain the procedure and check for metal objects in the FOV.

Radiopharmaceutical Administration

1. IV injection of 20-30 mCi $^{99m}$sestamibi followed by a 10 ml saline flush.
2. Inject the arm contralateral to the breast with the suspected lesion; in patients with bilateral lesions or post-mastectomy patients, inject a foot vein.
3. Use an indwelling catheter or butterfly-flush setup to avoid dose infiltration.

System Set-up

1. 140 keV with symmetric 10% window.
2. LFOV camera with LEHR collimator.
3. 128 x 128 or larger matrix.
Scanning Instructions

1. The patient lies prone with a single breast freely dependent from the imaging table. The contralateral breast should be compressed against the table to prevent cross-talk of activity. The patient’s sternum lies on edge of table or use table overlay with cutout for breast.
2. The detector should touch the patient’s side.
3. All images are 10-minute acquisitions.
4. Begin imaging 10 minutes post-injection; delayed images are generally unnecessary.
5. An acquisition zoom of app. 2.0 should be used to include the breast, axilla, and anterior chest wall in the FOV on the prone images, preferably excluding the abdomen.
6. Prone lateral view of the breast with the suspected abnormality.
7. Prone 30° posterior oblique view of the ipsilateral breast to throw lesion near the chest wall more anteriorly.
8. Prone lateral view of the contralateral breast (oblique unnecessary unless bilateral lesions).
9. Anterior upright (or supine) chest image to include both axillae with both arms raised.
10. If the lesion is medial in location, a supine medial oblique view may be obtained by rotating the patient to the side and supporting her with a foam wedge allowing gravity to pull the breast away from the chest wall but not allowing a mobile breast to wrap around the lateral chest wall. The ipsilateral arm is extended above the head. Make sure the opposite breast is held away from the medial chest wall until the camera can be brought down to hold it out of the way. Place the camera parallel to the patient with an additional angle of 1-2 degrees away from the patient to separate the breast from the chest wall.
11. If a radioactive marker is desired over a palpable abnormality, the marker must be placed after the patient is placed in the prone position.
12. SPECT may be acquired at the physician’s request.
   - Prone, dependent-breast position
   - 180° acquisition; 32 frames of 30 seconds each.
   - 45° anterior oblique to 45° posterior oblique

Image Processing

1. Masking of the high-activity chest and abdominal organs such as the myocardium and liver from the final images will improve visualization of breast tissue. Both the masked and the original images should be presented in the final display.
2. Images should be filmed at two intensity settings for presentation and archived to PACS.

References:
Breast Lymphoscintigraphy for Augmentation Mammoplasty Protocol

**Purpose:** To determine whether augmentation mammoplasty alters lymphatic drainage of the breast. Each patient will have lymphoscintigraphy performed pre-operatively and again post-operatively 12 weeks after mammoplasty.

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc sulfur colloid, filtered with a 0.2 micron filter.
2. Dose: 1mCi in 2.5 ml volume.
3. Route: subareolar in one injection.
4. Time interval between administration and imaging: immediate

**Patient Preparation:**
1. A negative pregnancy test is mandatory.
2. Breast-feeding is contraindicated.
3. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**
1. LFOV camera with LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 20%)

**Procedure:**
Injection: 1 mCi of filtered $^{99m}$Tc sulfur colloid in 2.5 ml saline will be injected beneath the nipple/areola complex with a single needle puncture.

**Imaging:**
1. Frequent 5-minute static images are acquired for one hour in the anterior projection with the ipsilateral arm held above the head; additional anterior images should be acquired with the ipsilateral torso supported by a wedge into an obliqued position
2. Additional imaging may be necessary for a maximum of an additional one hour.
3. Use $^{57}$Cobalt markers, transmission imaging, and outlining of the body contour with a $^{99m}$Tc source as necessary

**Processing:**
1. A complete set of filmed images should be presented to the file room
2. A complete set of digitized images should be archived to optical disc and to PACS.

Revised 1/3/2007
IN-111 PROSTASCINT SCINTIGRAPHY

Introduction and Clinical Indications
Capromab pendetide is an IgG murine monoclonal antibody directed against a glycoprotein, PMSA, expressed by prostate epithelium; it is reactive with over 95% of prostate adenocarcinomas. It exhibits slow serum clearance and has a half-life of 67 +/- 11 hrs. Only 10% is excreted renally. Whole body exposure is 2.7 rad/5 mCi with target organs being liver, spleen, and kidneys.

Physiologic activity is seen in the normal prostate gland, liver, spleen, bone marrow, blood pool, genitalia, bladder, kidneys and frequently the bowel. Capromab activity is common at inflammatory sites, including Lupron injection sites, pneumonitis, hernia, tendinitis, arthritis, incision sites (for mos-yrs), Paget’s disease, spermatic cord sites, colostomy sites, aneurysms, and radiation enteritis (for yrs).

Indications are as follows:
1. Detection of metastatic prostate carcinoma.
   A. In newly-diagnosed patients thought to have limited disease.
   B. In post-prostatectomy patients with a rising PSA but negative or equivocal conventional imaging.
   C. In post-radiation patients with a rising PSA but negative or equivocal conventional imaging.
2. Not indicated for re-administration for assessment of response to therapy.

Radiopharmaceutical administration:
1. Radiopharmaceutical: $^{111}$In capromab pendetide (ProstaScint)
2. Adult dose: 5-6 mCi
3. Use a peripheral UPPER extremity vein (preferably antecubital vein)
4. Route: Intravenous over 5 minutes followed by saline flush
5. Time interval between dose administration and scanning:
   Whole body with abdominal and pelvic SPECT at 96 hrs.; additional SPECT at 120 hours as needed.
6. $^{99m}$Tc -Ultragyt, 5 mCi, for labeling autologous RBC’s on imaging day.
7. Imaging time: 3.0 hours.

Patient Preparation:
1. Review patient history sheet:
   Biopsy-proven prostate cancer
   Clinically localized after standard evaluation
   High risk of pelvic lymph node metastases
   Rising PSA post-therapy with negative metastatic work-up
   Negative bone scan
   At least 8 weeks post-op (preferable)
2. Check that patient is able to tolerate SPECT exam(s)
3. Has patient had previous monoclonal antibody scans?
4. A bowel prep (Fleet’s prep kit-2 or similar) should begin 48 hrs before acquisition with a low fiber diet followed by 2 bottles of magnesium citrate the day before imaging, and a Fleet’s enema on the morning of imaging before coming to NM.
5. Hydration is very important to avoid placing an irrigating Foley catheter.
6. Anaphylaxis precautions as per all antibody injections: acute hypotension has been reported; patients with a history of drug reactions or allergies should be observed for 2 hrs p.i
7. Patient must be positioned in an identical fashion for each acquisition.
8. Explain the procedure and check for metal objects in the FOV.

**Machine Set-up Instructions:**

**Whole Body:**
1. Medium energy collimator
2. Photopeak and window settings same as for SPECT
3. 256 x 1024 matrix, minimum 7.5-10 min/step (min. total 35 min.)
4. Dual isotope acquisition

**SPECT:**
1. Hawkeye acquisition of all SPECT images
2. Medium energy collimator
3. $^{99m}$Tc: 140 keV with 5% window
4. $^{111}$In: 173 keV with 15% window
5. $^{111}$In: 247 keV with 20% window
6. 3 degrees per step
7. 50 sec/frame
8. 360 degrees rotation
9. 128 x 128 x 16 pixel matrix for reconstruction
10. Filter per protocol

**Scanning Instruction:**
1. At 96 hours, draw blood for $^{99m}$Tc Ultratag labeling and inject 5 mCi $^{99m}$Tc-RBC’s; have patient void
2. At 96 hours perform dual isotope whole body imaging in the anterior and posterior projections from skull through mid-femur; change colostomy bag before imaging
3. Patient should void again before each SPECT acquisition
4. Position patient for pelvic/abdominal SPECT with penile blood pool near the bottom of the FOV and acquire using dual isotope acquisition
5. If patient must return for 120 hr acquisition, should eat high fiber diet and use laxative that evening. SPECT of abdomen/pelvis, single isotope acquisition ($^{111}$In, 173 keV, 20% and 247 keV, 20%), 50 sec/step.

**Processing:**
1. Process per protocol
2. Use same filter for $^{99m}$Tc as for the $^{111}$In SPECT images
3. Intensity settings are very important.
4. Archive the images to PACS.

**Interpretation:**

1. Use planar images to evaluate extent and distribution of stool and blood pool, to detect disease outside the pelvis (central abdominal and supraclavicular nodes) and to look for altered biodistribution
2. SPECT
   - Tc-RBC to define lower margin of bladder and top of penile blood pool
   - Local recurrence more likely if multicentric focal activity is intense or eccentric, especially if seen in multiple slices
   - Stool in rectum and sacral marrow activity may mimic fossa recurrence
   - Normal prostate activity may mimic tumor
   - Obturator and iliac nodes best seen transverse but confirm with coronal
   - Retroperitoneal and mesenteric nodes best seen coronal but confirm with transaxial
   - Delayed 120 hr SPECT useful if sig. bowel activity is present at 96 hr and to confirm subtle findings
3. False positive interpretations
   - Pubic marrow activity may mimic fossa recurrence
   - Asymmetric ischial activity may mimic obturator LN disease
   - Abdominal wall hernia may mimic central abdominal nodal disease
   - Prominent marrow activity at L4 due to lordosis may mimic disease
   - Pelvic rotation may mimic disease, especially on the transaxial slices
   - Focal inflammatory processes (diverticulitis, arthritis) may mimic disease, and post-radiation prostatitis and proctitis may persist for years
   - Bladder and colonic diverticulae may mimic disease

**References:**
**I-131 MONOCLONAL ANTIBODY THERAPY FOR LYMPHOMA**

Radioimmunotherapy (RIT) seeks to deliver high dose Beta radiation to tumor sites via the interaction of a radiolabeled monoclonal antibody with specific antigens expressed on the surface of malignant lymphocytes. Response rates have varied from 50-90% with duration of responses of one to five years. Retreatment is feasible.

I-131 anti-B1 antibody is available for the treatment of patients with non-Hodgkin’s lymphoma; other radioiodinated radiopharmaceuticals such as LYM-1 are in development. Tennessee state regulations allow outpatient management of patients treated with I-131 antibody therapy based on (1) patient-specific dose calculations using the measured dose rate at one meter from the patient immediately following IV administration of the I-131 labeled antibody and (2) dosimetrically measured total body residence time of the radioiodinated antibody. The major restriction requires that the total effective dose equivalent to any other individual from exposure to the released patient is < 500 mrem.

In order to minimize exposure to family members and caregivers of the RIT patient, the following must be done:

1. Use the measured residence time and the dose rate at 1 meter to assess the releasability of the RIT patient and to calculate the specific time period for separate sleeping arrangements and avoidance of prolonged transportation.
2. Provide simple, clear verbal and written instructions to the patient and/or family members to minimize exposure to other individuals in the context of ALARA.
3. Assess each patient thoroughly in regards to: (a) the patient’s ability to understand and follow the written instructions provided, (b) the patient’s ability to care for himself, (c) the patient’s ability to delay returning to work, (d) the patient’s exposure to other individuals during the return trip home following RIT, and (e) urinary continence.

Using these assessments, patients who do not meet releasability criteria or who cannot comply with detailed instructions would not be considered releasable.

If it is expected that the RIT patient may have contact with children or pregnant women, additional instructions will be provided to (a) restrict intimate contact (< 0.3 m) to less than 30 minutes daily and (b) to discourage contact at <2 meters for any significant time for a specified period of not less than one week but not more than 3 weeks based on calculations as above.

Since the radiopharmaceutical is administered intravenously, there is rapid total body distribution; significant enteric contamination is very unlikely. I-131 anti-B1 antibody is excreted renally, so the primary source of any contamination would be the bathroom. If good hygiene is adhered to by the patient and family members, exposure due to internal contamination should be minimal, with the caveat that small children should use a separate bathroom.

After consultation with the referring physician, nuclear medicine staff, and the Vanderbilt University Radiation Safety Officer, a decision regarding releasability will be determined for each patient prior to therapy. With adherence to the above guidelines we can expect that released patients will expose other adult, non-pregnant individuals to a total effective dose equivalent of no more than 500 mrem and children or pregnant women to less than 100 mrem.
The advantages of outpatient management of these patients include (1) shorter hospital stays accompanied by lower health care costs, (2) psychological and emotional benefits to patients and family members, (3) lower exposure to hospital staff and (4) heightened opportunities for this and other medical centers to participate in funded clinical research protocols.

References
Procedural Specifics of I-131 Therapeutic Administrations

1. One technologist and one MD. The technologist who initiates the procedure on the day of therapy when the dose is ordered should also administer the dose after personally confirming the dose at the time of administration with the attending physician or physician-in-training who ordered the dose.
2. A copy of the prescription should be available at the time the dose is administered, and the dose should coincide (+/- 10%) with the prescribed dose.
3. A signed prescription should be provided to the radiopharmacist before the dose is ordered and should be faxed to the vendor in addition to the paperwork already required by the vendor.
4. All therapeutic doses should be double-checked at the time of administration (two technologists or a tech plus an MD).
5. Any and all student participation in therapeutic administrations must be very closely monitored.
6. The technologist and the physician(s) are ultimately responsible for administering the proper radiopharmaceutical at the PRESCRIBED dose.

Revised 1/3/2007
ZEVALIN ANTIBODY THERAPY

Clinical Indication: Treatment of B-cell non-Hodgkin’s lymphoma

Pharmaceuticals:
Diagnostic dose: $^{111}$In-ibritumomab tiuxetan, 5 mCi
Treatment dose: $^{90}$Y-ibritumomab tiuxetan, 0.4 mCi/kg for patients with platelets > 150,000, and 0.3 mCi/kg for patients with platelets 100,000-149,000

Unlabeled anti-B1 antibody rituximab (Rituxan), 250 mg/m$^2$ by slow IV infusion

Route of Administration: IV

<table>
<thead>
<tr>
<th>Time Relative to the Diagnostic Dose (Day 0)</th>
<th>Administration or Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>Order doses; review labs and contraindications</td>
</tr>
<tr>
<td>Day 1</td>
<td>Rituximab (Rituxan), 250 mg/m$^2$</td>
</tr>
<tr>
<td></td>
<td>Diagnostic Dose $^{111}$In-ibritumomab tiuxetan</td>
</tr>
<tr>
<td>Day 1-5</td>
<td>WB imaging; order treatment dose</td>
</tr>
<tr>
<td>Day 7, 8, or 9</td>
<td>Rituximab (Rituxan), 250 mg/m$^2$</td>
</tr>
<tr>
<td></td>
<td>Treatment Dose $^{90}$Y-ibritumomab tiuxetan</td>
</tr>
</tbody>
</table>

Patient Preparation
1. Signed informed consent is mandatory.
2. CBC, platelet count, and chemistries demonstrating ANC >1500, platelets > 100,000, creatinine < 2 mg/dl, bilirubin < 2 mg/dl.
3. Check that patient is not pregnant and not lactating (pregnancy test is mandatory).
4. A negative HAMA test in patients who have received prior murine proteins.
5. Bone marrow exam with adequate cellularity and < 25% lymphomatous involvement within 8 weeks.
6. No prior radioimmunotherapy or marrow transplantation therapy or history of failed stem cell collection.
7. An accurate weight in kg is necessary to order the treatment dose after completion of the imaging.
8. Explain the procedure and check for metal objects in the FOV.

Diagnostic Dose
1. Prepare unlabeled anti-B1 antibody rituximab (Rituxan), 250 mg/m$^2$
2. Obtain $^{111}$In-ibritumomab tiuxetan, 5 mCi
3. Administer acetaminophen 650 mg po and diphenhydramine 50 mg po (or chlorpheniramine 4 mg po) 30-60 minutes prior to initiation of Rituxan infusion.
4. Obtain baseline VS and then every 15 minutes for duration of study.
5. Infuse unlabeled anti-B1 antibody rituximab (Rituxan), 250 mg/m$^2$, over at least one hour using a 0.22u in-line filter per nursing. Avoid foaming. Fatal infusion reactions have occurred with Rituxan; see package insert regarding infusion instructions.
6. Infuse $^{111}$In-ibritumomab tiuxetan in 30 ml saline over 10 minutes within 4 hours of completion of the Rituxan infusion. Avoid foaming. Do not bolus.
7. Refill syringe/bag with 30 ml normal saline and infuse over 3-5 minutes.

Whole Body Imaging
Camera: dual-head
Collimator: medium energy
Window: dual window for $^{111}$In (171 keV and 245 keV with 20% window)
Matrix: 256 x 1024
Scanning speed: 10 cm/min for first scan; 7 cm/min for 2nd scan; 5 cm/min for 3rd scan.
Acquisition: anterior and posterior whole body excluding extremities 2-24 hour post-administration (preferably 2-4 hr) and again 48-72 hours pi (void before imaging); additional imaging is optional at 90-120 hrs.
Call referring clinician and radiopharmacist immediately with decision re ordering therapy dose
Archive the images to PACS.

Desired Therapy Dose
\[ ^{90}Y \text{-ibritumomab tiuxetan, 0.4 mCi/kg for patients with platelets > 150,000} \]
\[ 0.3 \text{ mCi/kg for patients with platelets 100,000-150,000.} \]
Obese patients: dose determined using 137% of calculated lean body weight rather than the actual weight
**Maximum dose shall not exceed 32 mCi and cannot be given to patients demonstrating altered biodistribution on diagnostic scintigraphy.**

Therapeutic Dose Administration: administer on Day 7 or by Day 14
(1) Assure that there is not altered biodistribution on the diagnostic imaging (absence of blood pool on initial images indicates rapid clearance by RES; diffuse lung or renal uptake > liver uptake on 2nd or 3rd image set is abnormal)(see Addendum B). Blood pool activity is normal and diminishes with time; high uptake in the liver/spleen with low activity in lungs/kidney/bladder is normal. Tumor uptake and uptake in lymphoid aggregates in the bowel wall may be seen.
(2) Check that patient is not pregnant.
(3) Administer acetaminophen 650 mg and diphenhydramine 50 mg po (or chlorpheniramine 4 mg) 30-60 minutes prior to initiation of unlabeled antibody infusion.
(4) Prepare unlabeled anti-B1 antibody rituximab (Rituxan), 250 mg/m\(^2\)
(5) Obtain \(^{90}Y\)-ibritumomab tiuxetan (Zevalin) in 30 ml. saline with 1 cm Lucite/acrylic shield and personally reconfirm dose with pharmacy.
(6) Obtain baseline VS and then every 15 minutes.
(7) Infuse unlabeled anti-B1 antibody rituximab (Rituxan), 250 mg/m\(^2\), over at least one hour using a 0.22u in-line filter per nursing (avoid foaming). Fatal infusion reactions have occurred with Rituxan; see package insert regarding infusion instructions.
(8) Within 4 hours of completing the Rituxan infusion, infuse the therapeutic \(^{90}Y\)-ibritumomab tiuxetan (Zevalin) over 10 minutes using a 0.22u in-line filter and using appropriate shielding of the pump and the patient. Avoid foaming. Do not bolus. Infuse into a freely flowing line to avoid extravasation.
(9) Refill syringe/bag with 20-30 ml saline and infuse over 3-5 minutes.

Radiation Precautions
(1) Patients can be released immediately after treatment with no need for measuring dose rates.
(2) Family members should be advised to avoid contamination from body fluids (saliva, blood, urine, stool) as per Addendum A.

Surveys
(1) After completion of the therapeutic infusion, survey the pump components and other potentially contaminated articles. Any contaminated articles must be properly discarded or held for decay.
(2) Survey all personnel for contamination.
(3) After the patient is released, survey the room for contamination.
(4) Records of all exposure measurements, area monitoring, and any decontamination must be kept for 3 years.

Supportive Care
(1) For mild to moderate symptoms of fever, nausea, vomiting, rigors, hypotension, pruritus, rash, urticaria, mucous membrane congestion, or arthralgias/myalgias, acetaminophen 650 mg po and/or diphenhydramine 50 mg po or IV may be administered.
(2) For severe rigors, meperidine, 25-50 mg IV.
(3) If symptoms occur during antibody infusion, the rate of antibody infusion should be decreased or stopped as follows:

**Addendum A**

**Instructions to the Patient Treated with Zevalin**

1. For 3 days, clean up spilled urine and dispose of any body fluid-contaminated material to prevent its being handled (e.g., flush it down the toilet or place it in a plastic bag in the household trash).
2. For 3 days, always wash hands thoroughly after using toilet.
3. For one week, use condoms for sexual relations.

**Addendum B: Interpretation of Diagnostic \(^{111}\text{In}\) Scintigraphy**

**Normal Biodistribution**

<table>
<thead>
<tr>
<th></th>
<th>Scan 1 (2-24 hrs)</th>
<th>Scan 2 (48-72 hrs)</th>
<th>Scan 3 - Optional (90-120 hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Blood Pool</td>
<td>Present</td>
<td>Decreases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Normal Liver &amp; Spleen</td>
<td>Moderate to High</td>
<td>Moderate to High</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Kidneys, Bladder, &amp; Bowel</td>
<td>Mod Low to Very Low</td>
<td>Mod Low to Very Low</td>
<td>Mod Low to Very Low</td>
</tr>
<tr>
<td>Tumor</td>
<td>Variable</td>
<td>Variable</td>
<td>Variable</td>
</tr>
</tbody>
</table>

**Altered Biodistribution**

<table>
<thead>
<tr>
<th></th>
<th>Scan 1 (2-24 hrs)</th>
<th>Scan 2 (48-72 hrs)</th>
<th>Scan 3 - Optional (90-120 hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Blood Pool</td>
<td>Not visualized</td>
<td>Not visualized</td>
<td>Not visualized</td>
</tr>
<tr>
<td>Diffuse Uptake in Nml Lungs</td>
<td>&gt;cardiac blood pool</td>
<td>&gt; liver</td>
<td>&gt; liver</td>
</tr>
<tr>
<td>Normal Kidneys</td>
<td>-</td>
<td>&gt; liver in post view</td>
<td>&gt; liver in post view</td>
</tr>
<tr>
<td>Normal Bowel</td>
<td>-</td>
<td>&gt; liver in post view</td>
<td>&gt; liver in post view</td>
</tr>
</tbody>
</table>

**Problem**

- Rapid clearance by the RES
- Possible excess radiation to nontarget organ

Revised 5/6/2002
Procedural Specifics of Zevalin Therapeutic Administrations

1. One technologist and one MD. The technologist who initiates the procedure on the day of therapy when the dose is ordered should also administer the dose after personally confirming the dose at the time of administration with the attending physician or physician-in-training who ordered the dose.

2. A copy of the prescription should be available at the time the dose is administered, and the dose should coincide (+/- 10%) with the prescribed dose.

3. A signed prescription should be provided to the VUH radiopharmacist before the dose is ordered and should be faxed to the vendor in addition to the paperwork already required by the vendor.

4. All therapeutic doses should be double-checked at the time of administration (two technologists or a tech plus an MD).

5. Any and all student participation in therapeutic administrations must be very closely monitored.

6. The technologist and the physician(s) are ultimately responsible for administering the proper radiopharmaceutical at the PRESCRIBED dose.

Revised 7/30/2002
THE CARDIO-VASCULAR SYSTEM

Revised 1/3/2007

CARDIAC STRESS PROTOCOLS

These cardiac stress protocols may be used in the performance of stress/rest myocardial perfusion imaging or occasionally for stress radionuclide ventriculography (RVG). The method of stress utilized for an individual patient will be selected by the physician performing the stress in consultation, if necessary, with the attending clinician and referring physician(s). A physician will be present during the procedure.

Patient Preparation for Cardiac Stress Exam

1. Place ECG leads on the patient:
   - **V1** - Fourth intercostal space at right border of sternum
   - **V2** - Fourth intercostal space at left border of sternum
   - **V3** - Fifth rib between V2 and V4.
   - **V4** - Fifth intercostal space on left midclavicular line
   - **V5** - Left anterior axillary line at the horizontal level of V4
   - **V6** - Left midaxillary line at the horizontal level of V4
   - **LA** - Left infraclavicular area
   - **RA** - Right infraclavicular area
   - **RL** - Right lower abdominal quadrant just above inguinal ligament
   - **LL** - Left lower abdominal quadrant just above inguinal ligament

2. Maintain an intravenous line throughout the duration of the imaging study.
3. The patient must be NPO except medications for 4 hours to avoid splanchnic activity.
4. Check that the patient is not pregnant or breast feeding.
5. Explain procedure to patient and obtain signed informed consent.
6. Remove any metal objects from field of view.
7. Clinical history, current medications, resting blood pressure, heart rate and ECG are reviewed by an ACLS-trained physician or nurse specialist/PA.
8. Take baseline resting ECG, blood pressure and heart rate both supine and standing for exercise stress, but supine only for pharmacological stress.
9. Cheese, crackers, and copious fluids are administered after the stress exam.
10. Resume medications not taken with food after stress.
11. Patients weighing more than 400 pounds cannot be imaged.
12. Patients weighing more than 280-300 pounds should have a two-day protocol.
13. Calculate target heart rate (195-age) for exercise and dobutamine stress patients.

Treadmill Stress Test

1. Patient preparation for exercise stress:
   a. hold beta-blocker, nitrates, and calcium antagonists for 24 hours if possible.
2. Goal of exercise stress:
   a. If HR does not exceed 85% MPHR in the absence of typical angina or > 2mm ST segment depression, exercise may be supplemented by atropine administration, 0.4-1.0 mg IV, or the exercise protocol can be stopped, and the patient switched to a pharmacological stress protocol, preferably adenosine (the exercise data should be reported).
   b. Contraindications to atropine administration:
      i. Glaucoma
      ii. History of urinary outlet obstruction

3. Contraindications to exercise includes:
   a. severe unstable angina
   b. recent myocardial infarction (3 days)
   c. hypertension greater than 180/110 (clonidine, 0.1-0.2 mg, nifedipine, 10 mg, or sublingual NTG can be given in agreement with the referring physician in an attempt to drop the BP prior to exercise).
   d. decompensated congestive heart failure
   e. severe aortic stenosis, hemodynamically significant, or hypertrophic obstructive cardiomyopathy
   f. severe dysrhythmia
   g. second or third degree AV block
   h. severe peripheral vascular disease
   i. unwillingness to give informed consent or unable to exercise to 85% MPHR (asthma, COPD, debility, orthopedic problems, claudication, peripheral neuropathy, leg paresis, medications, etc.)
   j. LBBB is a relative contraindication
   k. AAA greater than 5 cm is a relative contraindication
   l. Presence of LV thrombus is a relative contraindication

4. Exercise stress should be terminated if there is any evidence that further exercise may be harmful to the patient such as:
   a. Severe or progressive chest pain or progressive ST depression > 2 mm
   b. Drop in blood pressure > 10 mm
   c. Elevation of ST segments of ECG
   d. Development of significant arrhythmia, e.g., ventricular tachycardia or AVB greater than first degree
   e. Signs of peripheral circulatory insufficiency

5. Exercise the patient with a standard Bruce protocol: (3 minutes in each stage to target heart rate or maximum exercise capacity); atropine, < 1mg IV may be used to augment heart rate if necessary.
   stage 1: 1.7 mph, 10% elevation
   stage 2: 2.5 mph, 12% elevation
   stage 3: 3.4 mph, 14% elevation
   stage 4: 4.2 mph, 16% elevation
   stage 5: 5.0 mph, 18% elevation
   stage 6: 5.5 mph, 20% elevation
stage 7: 6.0 mph, 22% elevation
A modified Bruce or Naughton protocol can be used as deemed appropriate.
6. Obtain blood pressure and heart rate prior to each change of stage.
7. Obtain ECG every minute.
8. Let the patient recover supine and monitor blood pressure, heart rate and ECG every minute until the patient's hemodynamic status returns to baseline.

Adenosine Stress Test

1. Indications for adenosine stress:
   - Inability to exercise
   - Failure to achieve 85% MPHR in the absence of typical angina or > 2mm ST segment depression
   - Concurrent beta-blockade (or calcium antagonist) therapy is a relative indication.
2. Patient preparation for adenosine stress:
   - See patient preparation for stress exam
   - Hold all theophylline and xanthines for at least 72 hours prior to adenosine infusion
   - Hold all caffeine and caffeinated beverages/foods for at least 6 hours and preferably 12 hours prior to adenosine infusion.
   - Hold all dipyridamole and Trental for at least 24 hours prior to adenosine infusion.
3. Contraindications to adenosine:
   a. severe unstable angina
   b. recent myocardial infarction (< 24 hours)
   c. decompensated congestive heart failure
   d. severe dysrhythmia
   e. second or third degree AV block or sick sinus syndrome
   f. bronchospastic disease manifested by active wheezing/rhonchi, steroid dependency for asthma, severely depressed FEV1 (<40% predicted), a history of respiratory failure, or a PHx of difficulty with adenosine/dipyridamole infusion
   g. hypotension (SBP < 90mm)
   h. unwillingness or unable to give informed consent
   i. ongoing TIA or recent CVA (<6 months); known critical (>80%) internal carotid artery stenosis
   j. caffeine intake within the past 12 hours
   k. theophylline intake within the past 48 hours

6. Adenosine is administered
   Dose: 140 mcg/kg/min IV in 50 ml of saline infused with a pump over 6 minutes; rate can be decreased to 100 mcg/kg/min without a loss in sensitivity in the event of significant symptomatology; if symptomatology or heart block progresses or does not resolve, infusion should be terminated.
7. Blood pressure and heart rate are monitored every minute.
8. ECG is monitored every minute.
9. Inject the radiopharmaceutical three minutes into the adenosine infusion.
10. Monitor blood pressure, heart rate and ECG every minute until the patient's hemodynamic status returns to baseline.
11. Antidote to adenosine: Aminophylline
   a. In view of the brief half-life of adenosine, termination of the infusion is often adequate to reverse any ongoing adverse events
   b. Dose: 25 mg/minute slow IV push until symptoms resolve.
   c. Maximum dose: 250 mg.
   d. If possible, wait 1-2 minutes after radiopharmaceutical injection to give Aminophylline.
   e. In case of very severe side effects, administration of sublingual or intranasal nitroglycerin, 0.4 mg, may be helpful.

Combination Adenosine/Exercise Stress Test

1. Indications for adenosine/exercise stress:
   a. Inability to exercise to 85% MPHR, but able to walk
   b. Concurrent beta-blockade (or calcium antagonist) therapy may be a good indication.
2. Patient preparation for adenosine/exercise stress:
   a. See patient preparation for stress exam
   b. See patient preparation and contraindications for exercise stress test
   c. See patient preparation and contraindications for adenosine stress test
3. Contraindications to adenosine/exercise stress: LBBB
4. Most patients for this protocol will be exercised at a reduced level as per the patient’s abilities, such as:
   • Start at 1.7 mph at 0% grade for 1 minute, then
   • 1.7 mph at a 5% grade for two minutes, then
   • 1.7 mph at a 10% grade for two minutes, then
   • 2.5 mph at a 12% grade for the last three minutes
   • If unable to exercise at the next level, maintain the present level
5. Start the adenosine infusion, 140 mcg/kg/min, at the same time the exercise protocol is started, and run it for 6 minutes; inject the radiopharmaceutical at three minutes into the adenosine infusion, but continue to exercise to tolerance
6. Blood pressure and heart rate and ECG are monitored every minute until the patient's hemodynamic status returns to baseline.
7. Report both the exercise tolerance, the hemodynamic data, and any ECG changes or arrhythmias.
Dobutamine Stress Test

1. Indications for dobutamine stress:
   a. Inability to exercise
   b. Failure to achieve 85% MPHR in the absence of typical angina or > 2mm ST segment depression
   c. Vasodilator stress is contraindicated, or the patient is unwilling to undergo adenosine infusion (including recent caffeine intake)
   d. Concurrent administration of beta-blocker medication (or calcium antagonist) is a relative contraindication of dobutamine; expect to such patients to require atropine to achieve 85% MPHR

2. Patient preparation for dobutamine stress:
   - See patient preparation for stress exam

3. Contraindications to dobutamine:
   a. severe unstable angina
   b. recent myocardial infarction (< 72 hours)
   c. decompensated congestive heart failure
   d. severe dysrhythmia, including atrial fibrillation and ventricular tachycardia
   e. severe aortic stenosis or hypertrophic obstructive cardiomyopathy
   f. presence of an implanted ventricular defibrillator
   g. hypotension (SBP < 90mm)
   h. unwillingness or unable to give informed consent
   i. Uncontrolled hypertension (SBP > 200)
   j. AAA is a relative contraindication
   k. Presence of LV thrombus is a relative contraindication
   l. LVEF < 25% is a relative contraindication due to increased risk of ventricular dysrhythmia

4. Dobutamine is administered
   Dose: Titrated at 10, 20, 30 and 40 mcg/kg/min dose rate every 3 minutes.

5. Blood pressure and heart rate are monitored every minute.

6. ECG is monitored every minute.

7. Inject radiopharmaceutical after 1 min of the maximally tolerated dose rate and resume dobutamine for 2 min.; atropine, 0.4-1.0 mg IV may be used to augment heart rate if 85% MPHR is not achieved at 40 mcg/kg/min and HR is < 120 bpm)

8. Contraindications to atropine: (a) glaucoma, (b) Hx of urinary outlet obstruction

9. Monitor blood pressure, heart rate and ECG every minute until the patient's hemodynamic status returns to baseline.

10. Possible adverse reactions to dobutamine:
    a. Supraventricular tachycardia (Rx: reduce dose of dobutamine)
    b. Symptomatic hypotension (Rx: infuse saline)
    c. Nausea, vomiting, dry mouth (vagal) (Rx: reduce dose of dobutamine)
    d. Angina (Rx: sublingual nitroglycerin).
    e. Hypertension (Rx: reduce dose of dobutamine)
    f. Increased ventricular ectopy: rarely ventricular tachycardia.
g. In the event that adverse reactions persist despite the above conservative therapy, IV esmolol, 0.2 mg/kg over 1 minute, or IV bolus metoprolol, 2.5-5 mg, may be administered. Administer esmolol (Brevibloc) cautiously to patients prone to bronchospasm
**Quantitative Radionuclide Ventriculography**

A scintillation camera interfaced to a computer is required. The cardiac blood pool itself can be imaged both during the immediate passage of tracer through the heart following its intravenous injection (first pass study) and after equilibration of the tracer within the blood. The tracer used is $^{99m}$Tc - labeled red blood cells. The computer collects a rapid dynamic study and can rearrange the data in a manner synchronized with the electrocardiogram; this is called an R wave synchronized acquisition. The distribution of the tracer is reframed or rearranged inside the computer to present an average cardiac cycle. The images are examined as a closed loop movie of the beating heart to evaluate regional wall motion.

In addition, the ejection fraction of the right and left ventricle may be calculated by the formula

$$\text{Ejection Fraction} = \frac{\text{End Diastolic Counts} - \text{End Systolic Counts}}{\text{End Diastolic Counts}}$$

The "counts" or quantity of radionuclide within the left ventricle is directly proportional to the left ventricular volume. The normal ejection fraction is greater than 50%.

Detection of intracardiac shunts may be performed by inspecting the rapid dynamic study consisting of sequential images of one second duration collected during the passage of the radioactivity through the right heart, lungs and left heart. Right to left shunts are hallmarked by early appearance of tracer in the left ventricle before appearance in the lungs and left-to-right shunts are hallmarked by the recirculation of activity back into the right heart and lungs; this results in an abnormally slow disappearance of tracer from the lungs. This abnormal pulmonary wash-out can be quantitated and the exact pulmonary-systemic shunt calculated.

Valvular regurgitation can be evaluated by the regurgitant index (RI) or the regurgitant fraction (RF):

$$\text{RI} = \frac{\text{LV stroke counts}}{\text{RV stroke counts}}$$

$$\text{RF} = \frac{\text{LV stroke counts} - \text{RV stroke counts}}{\text{LV stroke counts}}$$

Normal values are: $\text{RI} < 1.2$

The radionuclide ventriculogram, which is a test of ventricular function, may be combined with the stress electrocardiogram for the diagnosis of coronary artery disease. Normal individuals will increase their ejection fraction during stress. Patients with coronary artery disease have diminished ventricular reserve and will fail to increase their ejection fraction or may actually decrease the ejection fraction and will develop regional wall motion abnormality.
The patient can be stressed by supine exercise using a bicycle ergometer. If they are unable to exercise, pharmacological stressing can be performed using dipyridamole (Persantine) or Adenosine. Dipyridamole is a non-nitrate coronary vasodilator whose mechanism of action is not clear. Dipyridamole may act to inhibit myocardial cellular reuptake and capillary endothelial transport of endogenously produced adenosine. Adenosine, known to be a potent coronary vasodilator, then accumulates in the interstitium of the heart, where it produces a vasodilating effect on coronary arteries. Dipyridamole appears to act predominantly on normal coronary arteries with little or no vasodilatory effect on narrowed coronary vessels that cannot dilate normally. Dipyridamole levels rapidly fall after administration but adenosine levels remain increased for 30-45 minutes.

The hyperemic effect of intravenously administered dipyridamole can be instantaneously reversed with intravenous aminophylline (theophylline), a dipyridamole antagonist. Aminophylline most likely inhibits the local and systemic effects of adenosine by blocking the adenosine receptor sites.

In patients with severe stenosis (> 70%):

<table>
<thead>
<tr>
<th></th>
<th>Exercise RVG</th>
<th>Dipyridamole RVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitivity</td>
<td>89%</td>
<td>69%</td>
</tr>
<tr>
<td>specificity</td>
<td>67%</td>
<td>92%</td>
</tr>
</tbody>
</table>

PROCEDURE: First pass radionuclide ventriculogram

Clinical Indications:
1. Determination of RV ejection fraction.
2. Detection and quantitation of intracardiac shunts.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-pertechnetate, $^{99m}$Tc-sestamibi, or $^{99m}$Tc-tetrofosmin
2. Adult Dose: 20 mCi
3. Child Dose: per body weight (see chart), in consultation with cardiologist
4. Route: Intravenous
5. Time interval between injection and imaging: Immediate
6. Additional Information:
The red blood cells are labeled in vivo by the Ultratag technique with subsequent reinjection of the labeled autologous RBC.

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Explain the procedure to the patient.
3. If the Burdick ECG recorder is used: Place ECG leads on the patient's right and left upper chest and right and left lower ribs.
4. If the Quinton ECG recorder is used: Place ECG leads on the patient:
   - V5 - Left anterior axillary line at the horizontal level of V4
   - V6 - Left midaxillary line at the horizontal level of V4
   - RL - Right lower abdominal quadrant just above inguinal ligament
   - LL - Left lower abdominal quadrant just above inguinal ligament
5. Connect the leads to the ECG unit and check for proper gating; then run a rhythm strip.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Connect cables X-Y-Z from the cardiac monitor to the computer.
4. Set the computer for predefined study protocol for first pass.
**Scanning Instructions:**

1. Place the patient supine and position the camera over the heart for an anterior view.
2. Labeled RBC or other $^{99m}$Tc-radiopharmaceutical are injected rapidly through a 19 gauge butterfly followed by a saline flush with a 3-way stopcock.
3. Start computer collection at same time as flushing bolus. There is a 2000 count delay start.
4. When the first pass is completed, preset time for 5 minutes/image and obtain the following gated equilibrium views or perform resting SPECT acquisition as per protocol.
   a. Anterior
   b. LAO 45 degrees
   c. LAO 70 degrees
5. Archive the processed study to PACS.
PROCEDURE: Rest equilibrium gated radionuclide ventriculogram (RVG)

Clinical Indications:
1. Determination of LV and RV ejection fraction.
2. Evaluation of cardiac wall motion abnormalities.
3. Determination of valvular regurgitant indexes.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-pertechnetate
2. Adult Dose: 20-25 mCi
3. Child Dose: Per body weight (see chart), in consultation with cardiologist
4. Route: Intravenous
5. Time interval between injection and imaging: Immediate
6. Additional Information:
   a. The red blood cells are labeled in vivo using the Ultratag technique with subsequent reinjection of the tagged autologous cells.
   b. For oncology patients on chemotherapy a LAO view only is acquired for determination of LVEF.

Patient Preparation:
1. Check that the patient is not pregnant or breast feeding.
2. Explain the procedure to the patient and check for metal objects in the FOV.
3. If the Burdick ECG recorder is used: Place ECG leads on the patient's right and left upper chest and right and left lower ribs.
4. If the Quinton ECG recorder is used: Place ECG leads on the patient:
   - V5 - Left anterior axillary line at the horizontal level of V4
   - V6 - Left midaxillary line at the horizontal level of V4
   - RL - Right lower abdominal quadrant just above inguinal ligament
   - LL - Left lower abdominal quadrant just above inguinal ligament
5. Connect the leads to the ECG unit and check for proper gating; then run a rhythm strip.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Connect cables X-Y-Z intercomgate from the cardiac monitor to the computer.
4. Set the computer for predefined study protocol for rest RVG.

Scanning Instructions:
1. Place the patient supine and position the camera over the heart in the center field of view.
2. Preset counts for 5 minutes/image and obtain the following views:
   a. Patient worked-up for chemotherapy/bone marrow transplants: LAO only.
b. All other patients:
   Anterior
   LAO 45 degrees
   left lateral with patient on right side

**Computer Processing:**
1. Generate cine images for all projection
2. Calculate LVEF on all patients
3. Calculate RVEF when requested
4. Calculate regurgitation index when requested
5. Transfer the processed study to PACS.
PROCEDURE: Rest and dobutamine equilibrium gated radionuclide ventriculogram (Rest/dobutamine RVG)

Clinical Indications:
Evaluation of ischemic heart disease in patients with limited exercise capacity (see Patient Preparation for Cardiac Stress Exam and Dobutamine Stress Test)

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-pertechnetate
2. Adult Dose: 25 mCi
   30 mCi if the patient is over 250 lbs.
3. Route: Intravenous
4. Time interval between injection and imaging: Immediate
5. Additional Information:
   a. The red blood cells are labeled in vitro by the Ultratag technique with subsequent reinjection of the autologous labeled RBC.

Patient Preparation:
1. See Patient Preparation for Cardiac Stress Exam and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1).

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%).
3. Connect cables X-Y-Z intercomgate from the cardiac monitor to the computer.

Resting Images:
1. The radiopharmaceutical is injected intravenously.
2. Resting images must be obtained first.
3. Set the computer for predefined study for rest RVG.
4. Place the patient supine and position the camera with the heart in the center field of view.
5. Preset counts 5 minutes/image and obtain the following views in the following sequence:
   a. Anterior
   b. Left lateral with patient on right side
   c. LAO

Dobutamine Images:
1. Set the computer for predefined study for exercise RVG.
2. Let equilibrate 1 minute post-injection and start imaging (5 minutes/image) in the LAO and then anterior views.
3. Preset counts 5 minutes/image and obtain views similar to rest images
a. Anterior
b. LAO

**Computer Processing:**
1. Generate cine images for resting RVG in all projections.
2. Generate cine images for dobutamine RVG and line-up rest/stress LAO and ANT views.
3. Calculate LVEF on both rest and stress images.
4. Transfer the processed study to PACS.
MYOCARDIAL PERFUSION SCINTIGRAPHY

1. Detection of coronary artery disease
   As an analog of potassium, $^{201}\text{Tl}$ is rapidly taken up by viable myocardial cells via an active transport mechanism. Critical to its utility in imaging is the fact that myocardial $^{201}\text{Tl}$ uptake is linearly related to coronary perfusion. In spite of the myocardial avidity for $^{201}\text{Tl}$ (90% extraction on first pass) only 3-5% of the total 4.5 mCi dose administered localizes in the myocardium. This initial phase of $^{201}\text{Tl}$ extraction by myocardium is followed by a second phase of redistribution-equilibrium. During the redistribution-equilibrium phase, myocardial cells lose ions transported in during the first pass, while simultaneously taking in new ions being presented by the blood pool. The net direction of this equilibrium exchange is a gradual decrease of intracellular $^{201}\text{Tl}$ (biologic half-life of 75 minutes).

   The normal myocardium will appear as an area of thallium activity. The central cavity will appear as an area of decreased activity since the thallium is rapidly cleared from the blood. Abnormalities of myocardial perfusion which occur in the resting patient represent myocardial damage and will appear as defects or "cold spots" on the thallium scan. In general, only the left ventricle is visualized at rest: the right ventricle will contain approximately 1/6th as much activity as the left ventricle because it has lower blood flow and is thinner.

   The myocardial perfusion image may be combined with the exercise electrocardiographic stress test in the diagnosis of ischemic heart disease. For this study, the patient must exercise to maximal stress on a treadmill and the thallium injected intravenously at the time of maximal stress. This stress must be maintained for at least one minute and preferably two minutes following injection of the radionuclide so that the distribution will represent the myocardial perfusion during maximal stress.

   On planar images, the overlap of normal myocardium compromises the detection of "cold" defects. In addition, obtaining planar images delays SPECT imaging. Therefore, planar images are not obtained and SPECT imaging is begun immediately post stress, and again after a 2-1/2 - 3 hours resting period and reinjection of thallium. The reinjection of thallium 30 minutes before the redistribution image increases the blood pool of thallium available for myocardial uptake and improves the detection of ischemic viable myocardium.

   Reversible defects are the hallmark of exercise-induced ischemia and are seen as a photopenic region on the stress image which fill in on delayed images. Analysis of ischemic regions can be performed either visually (qualitatively) or quantitatively of "cold" defects. Nonetheless, visual analysis of planar images using a subjective segmental scoring system can yield a sensitivity and specificity as high as 89% and 90%, respectively. If quantitative analysis is performed on planar images the overall sensitivity is slightly higher (93%). The most widely used quantitative planar evaluation is the Cedars-Sinai method. This approach generates activity curves using circumferential analysis of anterior, 45 degrees, and 70
degrees LAO stress and rest images. Curves are then compared to normal lower limits using 2 standard deviations (SD) below mean normal profiles.

A target (Bull's eye) quantitation can be made by taking perfusion data from the short axis image and presenting it as concentric circles proceeding from apex to base. By applying a gray scale or color scale to the number of counts per voxel, a single image can be created representing all the short axis perfusion data. When the stress target is then subtracted from the redistribution target, regions of ischemia can be readily identified.

Nonreversible perfusion defects present on both stress and delayed images represent infarcted myocardium or delayed perfusion of viable myocardium.

If the patient is unable to exercise, pharmacological stressing can be performed using dipyridamole (Persantine) or Adenosine. Dipyridamole is a non-nitrate coronary vasodilator whose mechanism of action is not clear. Dipyridamole may act to inhibit myocardial cellular reuptake and capillary endothelial transport of endogenously produced adenosine. Adenosine, known to be a potent coronary vasodilator, then accumulates in the interstitium of the heart, where it produces a vasodilating effect on coronary arteries. Dipyridamole appears to act predominantly on normal coronary arteries with little or no vasodilatory effect on narrowed coronary vessels that cannot dilate normally.

The hyperemic effect of intravenously administered dipyridamole can be instantaneously reversed with intravenous aminophylline (theophylline), a dipyridamole antagonist. Aminophylline most likely inhibits the local and systemic effects of adenosine by blocking the adenosine receptor sites.

Sensitivity and specificity (90% and 80%) respectively of dipyridamole $^{201}$Tl imaging are similar to that of $^{201}$Tl treadmill testing.

Reinjection and 24H image protocols have been developed to increase the detection of viable myocardium. About 30-50% of fixed defects on 4H redistribution images show reperfusion on reinjection or 24H images.

2. Detection of coronary artery disease and identification of injured but viable myocardium

Assessment of myocardium viability can be done using various single photon and positron labeled imaging agents.

Myocardial perfusion can be evaluated with $^{201}$Tl chloride, or $^{99m}$Tc-2-hexakis-2-methoxy-2-methylpropyl isonitrile ($^{99m}$Tc-MIBI) single photon emission tomography (SPECT), or $^{13}$N-ammonia and positron emission tomography (PET). PET, however, used to be the only modality allowing direct evaluation of metabolism using $^{18}$FDG.

Recent modification of $^{201}$Tl protocols, which include 24-hour delayed imaging (29) or imaging after reinjection of $^{201}$Tl, have improved the detection of viable myocardium when PET is not available. However, these protocols have been shown to underestimate myocardial viability.

Several groups demonstrated that $^{18}$FDG cardiac images obtained with a SPECT camera equipped with an ultra-high energy collimator provides clinical information equivalent to that obtained with PET.

Recently, a dual isotope single acquisition protocol was developed using a multihead SPECT camera equipped with an ultra-high energy collimator to simultaneously evaluate cardiac perfusion and metabolism with $^{99m}$Tc-MIBI/$^{18}$FDG. With a window of 20% for both photopeaks and a $^{99m}$Tc-MIBI/$^{18}$F concentration ratio of 3.2:1, the "spillover" from $^{18}$F into the $^{99m}$Tc window is 5%. Defects measuring 2x1 and 2x0.5 cm were demonstrated with phantom images. In patients, $^{18}$FDG-SPECT images are similar to $^{18}$FDG-PET images, and the diagnosis of myocardial perfusion/viability is similar if either $^{18}$FDG-SPECT or $^{18}$FDG-PET images are used in combination with $^{99m}$Tc-MIBI. The dual isotope/single acquisition protocol can be used to assess hibernating myocardium if both $^{99m}$Tc-MIBI and $^{18}$FDG are injected at rest. It also has the potential to assess stress-induced ischemia and evaluate myocardial viability simultaneously if $^{18}$FDG is injected at rest and $^{99m}$Tc-MIBI immediately after stress.

The advantages of a single acquisition include patient convenience, shorter length of image acquisition, and perfect registration of the images. Also, the larger axial field of view of most gamma-cameras (40 cm for the APEX Helix) as compared to PET (13-15 cm) is advantageous when imaging patients with cardiomegaly. Additionally, since imaging is performed with $^{18}$FDG, there is no need to have delayed imaging, as is recommended when using $^{201}$Tl, to evaluate for hibernating myocardium.

PROCEDURE: Rest/Redistribution Thallium Cardiac SPECT

Clinical Indications:
1. Determination of extent of myocardial viability in patients with coronary artery disease.
2. Confirmation of location of significant coronary artery lesions.
3. Therapeutic follow-up of ischemic heart disease.


Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{201}$Thallous chloride
2. Adult Dose: 3.5 to 4.5 mCi
3. Route: Intravenous
4. Total time for the study: 4.5 hours to 24 hours

Patient Preparation:
1. See Patient Preparation for Cardiac Stress Exam under Cardiac Stress Protocols (Section 10.1).

Imaging Protocol:
1. 3.5 mCi $^{201}$Tl are injected at rest
2. Acquire supine (first) and prone SPECT images 15 minutes after injection.
3. Acquire supine (first) and prone SPECT images 4-6 hours after injection.
4. Acquire supine SPECT images 16-24 hours after injection as deemed necessary.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window setting predetermined for $^{201}$Tl (80 keV, 20%)
3. 180 degree clockwise rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step
5. 25-30 seconds/frame (depending on weight of patient) for immediate and 4-6 hour images; 45 seconds/frame for 24-hour images
6. 64 x 64 x 16 pixel matrix for reconstruction

Computer Processing:
1. Reconstruct the images, reorient and display images along short axis, vertical long axis and horizontal long axis of the heart.
2. Line-up rest and stress imaging data.
4. Transfer the processed study to PACS.
PROCEDURE: Rest/Stress Thallium Cardiac SPECT (reinjection protocol)

Clinical Indications:
1. Diagnosis of coronary artery disease.
2. Confirmation of location of significant coronary artery lesions.
3. Therapeutic follow-up of ischemic heart disease.


Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{201}$Thallous chloride
2. Adult Dose: 4.5 mCi (split into 3.0 mCi given at peak stress, and 1.5 mCi given 2-1/2 to 3 hours after completion of the stress protocol and 30 minutes before the reinjection images).
3. Route: Intravenous
4. Total time for the study: 4.5 hours
   a. stress time: 15-30 minutes
   b. stress images: 16 minutes
   c. waiting period: 2.5 to 3 hours
   d. $^{201}$Tl reinjection and equilibrium time: 30 minutes
   e. reinjection images: 16 minutes
   f. computer processing: 10 minutes
   g. possible 24 hr SPECT for fixed defects

Patient Preparation:
1. See Patient Preparation for Cardiac Stress Exam under Cardiac Stress Protocols (Section 10.1).

Stress testing:
1. See Exercise, Adenosine, and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1).
2. Inject 3.5 mCi $^{201}$Tl at peak stress per protocol.
2. Acquire supine (first) and prone SPECT images immediately after recovery.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window setting predetermined for $^{201}$Tl (80 keV, 20%)
3. 180 degree clockwise rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step
5. 25-30 seconds/frame (depending on weight of patient)
6. 64 x 64 x 16 pixel matrix for reconstruction

$^{201}$Tl reinjection
1. Wait 2-1/2 to 3 hours
2. Inject 1.5 mCi $^{201}$Tl
3. Wait 30 minutes
6. Obtain a second set of SPECT images as above.
7. Acquire 24 hr SPECT using a 45 sec/frame acquisition for fixed defects if deemed clinically appropriate

**Computer Processing:**
1. Reconstruct the images, reorient and display images along short axis, vertical long axis and horizontal long axis of the heart.
2. Line-up rest and stress imaging data.
4. Transfer the processed study to PACS.
PROCEDURE: Rest/stress $^{99m}$Tc-MIBI/tetrofosmin cardiac SPECT

Clinical Indications:
Same as stress thallium myocardial scintigraphy.


Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-MIBI or $^{99m}$Tc-tetrofosmin
2. Adult Dose: Resting scan: 8-10 mCi (dependent on weight)
   Stress scan: 25-30 mCi (dependent on weight)
3. Route: Intravenous
4. Total time for the study: 2.5 hours
   a. Resting scan time: 90 minutes
   b. Stress time: 30 minutes
   c. Stress images: 30 minutes
   d. Computer processing: 10 minutes

Patient Preparation:
1. See Patient Preparation for Cardiac Stress Exam and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1).
2. For patients with a high likelihood of major interference from attenuation artifact (> 280-300#) due to their body habitus, a two day protocol using 25-30 mCi on each day should be used.

Resting scan:
Inject IV 8 mCi of $^{99m}$Tc-MIBI/tetrofosmin (10 mCi for patients over 250#)
Wait 1 hour for MIBI and 40-50 minutes for tetrofosmin
Acquire supine gated or non-gated SPECT images.

Stress scan:
1. See Patient Preparation for Cardiac Stress Exam and Exercise, Adenosine, and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1)
2. 25 mCi of $^{99m}$Tc-MIBI/tetrofosmin at peak stress.
3. Supine gated and then prone SPECT images are then obtained 15 minutes after recovery for an exercise stress and 60 minutes after a pharmacologic stress for MIBI (40-50 minutes for tetrofosmin).
4. For logistical reasons, a low-dose stress, high-dose rest procedure can be used as deemed appropriate by the physicians.
5. Review resting ECG.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window setting predetermined for $^{99m}$Tc (140 keV, 20%).
3. 180 degree rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step.
5. 22 seconds/frame (non-gated) supine, 30 sec/frame for gated supine, and 18 sec/frame for prone.
6. 64 x 64 x 16 pixel matrix for reconstruction.

**Computer Processing:**
1. Reconstruct the images, reorient and display images along short axis, vertical long axis and horizontal long axis of the heart.
2. Line-up rest and stress scans.
4. Transfer the processed study to PACS.
PROCEDURE: Dual Isotope Rest $^{201}$Tl and Stress $^{99m}$Tc-MIBI or $^{99m}$Tc-tetroflosmin Cardiac SPECT

Clinical Indications:
Same as stress thallium myocardial scintigraphy.


Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{201}$Tl and $^{99m}$Tc-MIBI or $^{99m}$Tc-tetroflosmin
2. Adult Dose: Resting scan: 4 mCi $^{201}$Tl
   Stress scan: 25-30 mCi $^{99m}$Tc-MIBI or $^{99m}$Tc-tetroflosmin
3. Route: Intravenous
4. Total time for the study: 2.5 hours

Patient Preparation:
1. See Patient Preparation for Cardiac Stress Exam and Exercise, Adenosine, and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1).
2. This procedure is not appropriate for patients with a high likelihood of major interference from attenuation artifact (> 280-300%) due to their body habitus; a two day protocol using 25-30 mCi of a $^{99m}$Tc pharmaceutical on each day should be used.

Resting scan:
Inject IV 4 mCi of $^{201}$Tl
Acquire supine nongated (or gated) SPECT images 15 minutes post-injection

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window setting predetermined for $^{201}$Tl (80 keV, 20%).
3. 180 degree clockwise rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step.
5. 30-40 seconds/frame.
6. 64 x 64 x 16 pixel matrix for reconstruction.

Stress scan:
1. See Patient Preparation for Cardiac Stress Exam and Exercise, Adenosine, and Dobutamine Stress Test under Cardiac Stress Protocols (Section 10.1).
2. 25-30 mCi of $^{99m}$Tc-MIBI/tetroflosmin at peak stress.
3. Supine gated and then prone SPECT images are then obtained 15 minutes after recovery for an exercise stress and 60 minutes after a pharmacologic stress for MIBI (40-50 minutes for tetrofosmin).

**Instrument Set-up Instructions:**
1. LEHR collimator
2. Photopeak and window setting predetermined for $^{99m}$Tc (140 keV, 20%).
3. 180 degree rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step.
5. 22 seconds/frame (non-gated) supine, 30 sec/frame for gated supine, and 18 sec/frame for prone.
6. 64 x 64 x 16 pixel matrix for reconstruction.

**Computer Processing:**
1. Reconstruct the images, reorient and display images along short axis, vertical long axis and horizontal long axis of the heart.
2. Line-up rest and stress scans.
4. Transfer the processed study to PACS.
Managing Chest Pain in the ED

Goals: Risk Stratification
1. Detect acute MI and admit.
2. Identify patients at high risk with unstable angina and admit.
3. Identify patients at low risk who can be discharged.

Rest MIBI/Myoview SPECT (Pain Injection)
- Intermediate risk patients (not musculoskeletal pain)
- Normal or nondiagnostic EKG
- Ongoing or recently resolved (30-40 minutes) chest pain
- Patients with PHx of MI not excluded because documentation of prior MI is a significant risk factor for ischemia
- Patients with normal/equivocal scans may require outpatient stress SPECT @ 12-48 hours if enzymes are normal
- If patient is injected more than 30 minutes after resolution of chest pain, sensitivity for the detection of acute coronary ischemia (but not MI) may be reduced

Implementation of Resting “Pain” Myocardial Perfusion Scan
- ED physician/care provider will call the cardiac technologist (20893) 8 am-4:30 pm or radiology resident on call after hours and weekends/holidays with request, and patient will be injected within 10 minutes of that call by a NM technologist or radiology resident
- Patient should be injected prior to administration of therapy, especially nitrates
- ED nurse will accompany and monitor patient in radiology department, especially on weekends and holidays
- The patient will be scanned supine and prone 45-90 minutes post-injection; the technologist will page the interpreting physician as soon as it is processed so that a report may be communicated as quickly as possible.
- Patients with chest pain monitored through the night in the ED who are candidates for stress/rest perfusion SPECT will be given a high priority to be injected (for the rest portion) first at or around 7:30-8 am.
- High priority will also be given to that patient for stress performance

CARDIAC SPECT REQUESTED BY ED OR WEEKEND INPATIENTS

Daily: Tech will call the ED senior resident or attending physician (or charge nurse) at 7 am re scheduling of any cardiac SPECT’s holding in the ED; reminder that a VQ cannot be performed same day.

Procedure: Dual isotope (\(^{201}\text{Tl}/^{99m}\text{Tc}\)) procedure is preferable if available.
- MIBI/MIBI or Myoview/Myoview is the alternative.

Priority: All ED and emergency inpatient studies should be processed immediately upon completion of the acquisition

Weekdays
1. Stress/rest studies available 8 am to 4:30 pm as a priority work-in.
2. A rest only (“pain”) study is available 8 am to 10 pm weekdays using \(^{99m}\text{Tc}\) if the patient can be injected during chest pain or within 30-40 minutes of pain relief.
3. If thallium is unavailable late in the day, a low dose stress/high dose rest $^{99m}$Tc study is appropriate.

**Weekends and Holidays**
1. Stress/rest and “pain” rest studies are available Sat., Sun., and holidays **8 am to 3:00 pm. (outpatient & inpatient).**
2. For stress/rest studies, discussion of the case with the **NM attending or fellow** must occur before the dose is ordered.
3. On holidays and weekends, a physician will stress the patients referred by the ED (w/out cardiology clearance) and by the inpatient services (w/out cardiology clearance). That physician will be a nuclear medicine physician-in-training (fellow/resident), a nuclear medicine attending, or a cardiology fellow who has been trained in nuclear cardiology (this is a negotiated settlement depending on which fellows are readily available). These patients will need to be assessed by the nuclear cardiology physician-in-training in consultation with the referring physician as to appropriateness before ordering a dose, and that physician is responsible for communicating with the on-call technologist and the physician who will be performing the stress procedure.

Nursing coverage from radiology is often not available in an expedient manner on weekends and holidays, so the physician will be responsible for caring for the patient in cooperation with the nursing staff from the ED or inpatient service.

**Protocol:** (1) ED/inpatient clinician will call the radiology resident to request the procedure.
(2) The radiology resident will give that MD the name and numbers of the nuclear med physician on-call.
(3) The nuclear med MD on call and the referring MD will discuss the clinical situation and determine if, when, and how the patient will be stressed and imaged.
(4) The nuclear med MD on call will notify the technologist on call so that she/he can order the dose(s).
(5) The nuclear med MD on call will identify for the technologist which physician to call when the rest scan has been started so that he/she can arrive at the appropriate time to stress the patient in an expedient manner
(6) If the technologist learns from the ED or elsewhere that a myocardial perfusion scan has been requested for a patient, she/he should call the nuclear med MD on call to get approval to order doses.

**PROCEDURE: Rest (“pain”) $^{99m}$Tc-MIBI/tetrofosmin cardiac SPECT**

**Clinical Indications:**
Detection of acute myocardial infarction and unstable angina.

**Ref:** Udelson et al. Myocardial perfusion imaging for evaluation and triage of patients with suspected acute cardiac ischemia: a randomized controlled trial. JAMA 2002;288:2693-2700.

**Radiopharmaceutical Administration:**
1. Radiopharmaceutical: $^{99m}$Tc-MIBI or $^{99m}$Tc-tetrofosmin
2. Adult Dose: 25-30 mCi (dependent on weight)
3. Route: Intravenous
4. Total time for the study: 1.5 hours
   a. Resting scan time: 30 minutes
   b. Computer processing: 10 minutes

Patient Preparation:
3. See Patient Preparation for Cardiac Stress Exam and Exercise Stress Test under Cardiac Stress Protocols (Section 10.1).
4. For patients with a high likelihood of major interference from attenuation artifact (> 280-300 lb) due to their body habitus, a protocol using 30 mCi should be used.

Resting scan:
Inject IV 20-25 mCi of $^{99m}$Tc-MIBI/tetrofosmin (30 mCi for patients over 250 lb)
Wait 1 hour for MIBI and 40-50 minutes for tetrofosmin
Acquire supine and prone gated or non-gated SPECT images.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopake and window setting predetermined for $^{99m}$Tc (140 keV, 20%).
3. 180 degree rotation: RAO to LPO
4. Step and shoot mode: 3 degrees per step.
5. 22 seconds/frame (non-gated) supine, 30 sec/frame for gated supine, and 18 sec/frame for prone.
6. 64 x 64 x 16 pixel matrix for reconstruction.

Computer Processing:
1. Reconstruct the images, reorient and display images along short axis, vertical long axis and horizontal long axis of the heart.
2. Line-up rest and stress scans.
4. Transfer the processed study to PACS.

There is a Standard Operating Procedure and Protocol for the injection of ED patients with $^{99m}$Tc-MIBI/tetrofosmin by which the radiology residents are trained and under which they function.
4. **PROCEDURE: Rest MIBI/\(^{18}\text{FDG}\) Cardiac SPECT**

**Clinical Indications:**

**Evaluation of myocardial ischemia and viability**

Due to erratic myocardial glucose utilization in patients with diabetes mellitus, the indications for FDG imaging in these patients should be strong.


**Equipment:**

Dual head camera with 511 keV ultra high energy collimators

**Radiopharmaceutical Administration:**

1. \(^{99}\text{m-Tc}\)-sestamibi or \(^{99}\text{m-Tc}\)-tetrofosmin
   a. Adult dose: 25 mCi
   b. Route: IV
   c. Time interval between administration and scanning: 60 minutes

2. \(^{18}\text{FDG}\)
   a. Adult dose: 10 mCi
   b. Route: IV
   c. Time interval between administration and scanning: 60 minutes

**Patient Preparation:**

1. See Patient Preparation for Cardiac Stress Exam under Cardiac Stress Protocols (Section 10.1).
2. Obtain fasting blood glucose and inform resident of results.
3. The patient should be fasting for at least 4 hours to avoid splanchnic activity and to allow myocardial uptake of FDG.

**Scanning Instructions:**

1. With the supervision of the physician, load the nondiabetic patient with IV GIK infusion protocol and monitor blood glucose per protocol.
2. For diabetic patients and for most patients with impaired glucose tolerance, follow the protocol for euglycemic hyperinsulinemic clamp to ensure myocardial uptake of \(^{18}\text{FDG}\) per protocol (see addendum).
3. At the time directed by the supervising physician, inject the \(^{18}\text{FDG}\) and the \(^{99}\text{m-Tc-MIBI}\) IV sequentially.
4. Chart blood glucoses, times, and insulin dosages on flow sheet (see addendum).
5. Initiate scanning 60 minutes after FDG/MIBI injection.

**Acquisition of FDG/MIBI Cardiac Images:**

1. Ultra high energy collimator (511 keV)
2. Position the patient supine or prone on the table.
3. Check that the High Energy Flag is on.
4. Set-up the acquisition parameters:
   a. 180 degrees clockwise rotation, single head, RAO to LPO
   b. Step and shoot, 3 degrees per stop, 60 stops, 30 seconds per stop
5. Acquire supine and then prone images in all patients.

**Processing of FDG/MIBI Cardiac Images:**
1. Split the acquisition groups into Redistribution FDG and Stress MIBI raw data groups.
2. The computer will normalize each raw data group one at a time, correcting for decay, uniformity, and center of rotation.
3. Select Stress MIBI normalized group and reconstruct the transaxial images:
   a. During reconstruction, select the proper filter (0.4-0.6 Butterworth)
   b. Select Volume Masking if there is significant GI activity present, making sure to position the rectangular ROI around the heart somewhat loosely to include the right ventricle
4. Reconstruct the Horizontal Long Axis (HLA) using the transaxial images.
5. Create the horizontal short axis (HSA).
6. Create the vertical long axis (VLA).
7. Select the Redistribution FDG normalized group and reconstruct the transaxial images:
   a. Do not move ROIs in view of single acquisition.
   b. Select the proper filter (0.2-0.5 Butterworth).
   c. Select volume masking again if done so for the MIBI images.
   d. Create the HLA, HSA, and VLA as in #4-6.
8. Generate the Polar Map:
   a. Position circular ROI for both sets of data with the heart in the center.
   b. Size ROI to fit tightly around the heart.
   c. Rotate the orientation line to the lower right ventricular junction.
   d. Position the first frame to immediately inside the apex.
   e. Position and size circular ROI for both sets of data again.
   f. Position orientation line parallel to the ventricular walls.
   g. Adjust first and last frames immediately inside ventricular walls.
9. Create Final Report
10. Run Card Pol
    a. Select patient
    b. Select HSA for both Stress MIBI and Redistribution FDG data
    c. Position and size circular ROIs tightly around the heart for the Stress MIBI data
    d. Select best apex frame and best basal frame for Stress MIBI data
    e. Position and size circular ROIs tightly around the heart for the Redistribution FDG data
    f. Select best apex frame and best basal frame for Redistribution FDG data
    g. Enter threshold value of 20%
11. Run 3D Display (TDSTRD)
    a. Select transaxial Stress MIBI images
    b. Select transaxial Redistribution FDG images
12. Transfer the processed study to PACS.
MYOCARDIAL INFARCT IMAGING

The localization of $^{99m}$TcPYP in acutely damaged myocardium is a function of active mitochondrial and cytosol deposition of calcium during the acute phase of myocardial necrosis. Since the maximum rate of this calcium deposition occurs between 24 and 78 hours after onset of infarction, infarct imaging with $^{99m}$TcPYP should be performed between 24 and 78 hours after the onset of symptoms.

Approximately 90% of acute transmural infarcts will accumulate technetium pyrophosphate at 48 to 72 hours following the acute infarction. Subendocardial acute infarctions may accumulate pyrophosphate only approximately 50% of the time.

The thorax is imaged in the anterior, left anterior oblique and left lateral projections at two hours following intravenous administration of $^{99m}$Tc pyrophosphate.

The $^{99m}$Tc pyrophosphate scan is usually negative during the first six to twelve hours following myocardial infarction and becomes positive at an increasing rate after 24 hours. At 24 hours, approximately 60% of acute transmural infarctions will accumulate pyrophosphate. At 72 hours, 90% will show a positive scan. After two weeks, most acute infarcts will no longer accumulate technetium pyrophosphate. Thus, serial scanning can confirm the acute infarct and its resolution.

Entities other than acute myocardial infarction have been shown to produce focal increased radionuclide activity: Cardioversion, metastasis, pericarditis with associated myocarditis, contusion, rib fracture, functional breast tissue in premenopausal females, breast tumor, amyloidosis.

Clinical Indications:
Suspicion of acute myocardial infarct, with the absence of electrocardiographic or enzyme confirmation, such as in left bundle branch block or typical pain with a normal ECG.
PROCEDURE: Myocardial Infarct Scintigraphy

Patient may be injected on the floor. Scan done 2 hours after the injection. Patient is brought down to Nuclear Medicine department for the scan or it may be done portable if indicated.

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc Pyrophosphate from the "Pyrolite" kit
2. Adult Dose: 15 mCi
3. Route: Intravenous
4. Time interval between administration and imaging: 90 minutes or more

Patient Preparation: Check that the patient is not pregnant or breast feeding.

Instrument Set-up Instructions:
1. LEHR collimator
2. Photopeak and window settings predetermined for $^{99m}$Tc (140 keV, 15-20%)
3. Preset counts for 1.2 million counts/image

Imaging Instructions:
1. Position patient under the camera for an anterior view, with a lead disk on tip of sternum. Center heart in center of field of view. Collect an image for 1.2 million counts.
2. Position patient for a 45 degree LAO image with a lead disk on tip of sternum. Collect image for 1.2 M counts.
3. Position for a left 70 degree lateral image. Use a $^{99m}$Tc marker on tip of sternum. Collect image for 1.2 M counts.
4. Additional films or SPECT imaging as deemed appropriate.
5. Transfer the processed study to PACS.
**DIABETICS: IV Glucose + Insulin Clamp for FDG**

**MATERIALS:**

1. **IVII (IV Insulin Infusion):** 100 units regular insulin in 500 ml NS (1u/5 ml or 200 mU/ml); glass bottle preferred.
   - waste the first 50 ml through the IV tubing (no filter).
2. **500 ml D\(_{20}\)W (must add 10 meq KCl/500 ml if serum K < 4.0)**

Check **FBG** and serum potassium (within 36 hrs of PET exam). IVII may be started while awaiting results of serum potassium. FBG should be < 230 mg/dl.

If FBG > 140, inject **10 units** regular insulin IV bolus and start IVII @ 4 mU/kg/min. (**1.2 ml/kg/hr**).

Check BG every 10 minutes until BG < 130 mg/dl.
   - If BG fails to fall after 20 minutes, bolus another 6 u reg insulin and increase IVII to 5.3 mU/kg/min. (**1.6 ml/kg/hr**).

If FBG < 140 mg/dl, inject **6 units** regular insulin IV bolus and start IVII @ 4 mU/kg/min. (**1.2 ml/kg/hr**).

After 8-10 minutes of IVII or when BG < 130 mg/dl, start D\(_{20}\)W (+/- KCl) infusion @ 6 mg/kg/min (**1.8 ml/kg/hr**).

Adjust D\(_{20}\)W infusion rate every 5-10 minutes to maintain BG at 80-140 mg/dl.

After 20-30 minutes of “stable” glycemia, inject FDG.

**Maintain IVII+D\(_{20}\) clamp for 30 minutes** post-FDG injection and then start D\(_{20}\)W infusion.

Maintain D\(_{20}\)W infusion (without insulin) @ 6 mg/kg/min (**1.8 ml/kg/hr**) throughout acquisition for at least 30 minutes after the IVII is discontinued.

Feed patient before he/she leaves the department and advise re risk of late hypoglycemia.

- **Alter the protocol as follows for lean type I JODM patient:**

  If FBG < 140 mg/dl, inject 4 units regular insulin and start IVII @ 1 mU/kg/min. (**0.3 ml/kg/hr**).

  After 8-10 minutes of IVII or when BG < 130 mg/dl, start D\(_{20}\)W + 20 meq/L KCl @ 8 mg/kg/min. (**2.4 ml/kg/hr**).
NONDIAabetics: IV Glucose + Insulin Loading for FDG

Materials: (1) 500 ml D$_{20}$W.
(2) Glc/insulin infusion: 500 ml D$_{20}$W + 20 u regular insulin
   (must add 10 meq KCl/500 ml if serum K < 3.7)
   Use glass bottle and tubing without filter if possible.

Check FBG (if > 110 mg/dl, go to diabetic clamp protocol).

Bolus: 8 units regular insulin IV
       10 gm glucose (50 ml D$_{20}$).

Infuse glc/insulin @ 3 ml/kg/hr for 60 minutes total; waste first 25 ml through tubing.

Check BG every 10 minutes (goal = 100-180 mg/dl); 4-8 u regular insulin IV bolus prn BG > 200.

Inject FDG at 20 minutes (BG < 150 preferably)

Stop glc/insulin infusion at 60 minutes and start D$_{20}$W at 2 ml/kg/hr.

Continue D$_{20}$W infusion until completion of acquisition.

Feed patient upon completion of imaging; warn patient that late hypoglycemia may occur and can be treated with food ingestion.

**Alert:** If BG > 400 mg/dl, call nuclear medicine physician immediately before proceeding further.
If BG drops to < 55 mg/dl or if patient develops symptoms of hypoglycemia (e.g., confusion, tremulousness, diaphoresis, weakness, seizure) concurrent with a BG < 75 mg/dl, discontinue GIK infusion, and administer one amp of 50% dextrose IV, and call the nuclear medicine physician.
Glucose Loading for FDG Tomography

NAME:  
MRN:  
BODY WEIGHT: _________
DATE:  
Infusion: ___ u insulin/500 ml D20
FBG:  
INSULIN: _____ u insulin/_____ ml NS
<table>
<thead>
<tr>
<th>TIME</th>
<th>BLOOD GLC</th>
<th>GIK(GLC) RATE</th>
<th>INSULIN RATE</th>
<th>BOLUS/MEMO</th>
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IN VITRO STUDIES
Revised 1/3/2007

Schilling Test Procedures

Clinical Indications:
1. Megaloblastic anemia with indeterminate Vitamin B12 and folate levels.
2. Significance of low Vitamin B12 and folate levels without megaloblastic anemia.
4. Detection of individuals at risk for pernicious anemia.

Principle:
Vitamin B12 deficiency causes megaloblastic anemia, gastrointestinal and neuropsychiatric symptoms because it is an essential cofactor in DNA synthesis and in myelin synthesis. The main source of Vit B12 is animal products. In the stomach, Vit B12 is digested and liberated from the ingested food. Vit B12 then binds to R-proteins from the saliva. In the jejunum, where the pH is alkaline, the R-proteins are degraded by pancreatic proteases and Vit B12 is transferred to intrinsic factor (IF) which is secreted by the parietal cell of the stomach. Vit B12 is then absorbed in the ileum where the pH is neutral. The absorption mechanism requires the presence of intrinsic factor. The most common cause of Vit B12 deficiency is due to lack of intrinsic factor, causing pernicious anemia, a disease associated with the presence of different types of antibodies against IF and parietal cells of the stomach. The Schilling test evaluates the absorption of Vit B12, after an oral dose of radioactive Vit B12 administered without (stage I) and with intrinsic factor (stage II), by measuring the % of the oral dose absorbed in the ileum and secreted in the urine in the next 24-48 hours.

Patient Preparation (when scheduling):
1. Check that the patient is not pregnant or breastfeeding.
2. Nursing mothers should stop breastfeeding.
3. Blood levels of Vit B12 and folate must have been obtained prior to Schilling test.
4. Avoid contamination with other radionuclide from in vivo studies.
5. Stage I and Stage II Schilling tests need to be performed at 2-week intervals.
6. Record patient's height and weight to interpret adequacy of 24-hour urine collection by urine creatinine levels.
7. Patients should have normal renal function: if creatinine > 2.5 mg/dl, 48 H urine collection is necessary.
8. No parenteral Vit B12 must be given 3 days prior to the study.
9. Avoid drugs that interfere with the absorption of Vit B12:
   - Aminosalicylic acid (PAS)--chronic, high-dose therapy
   - Anticonvulsants (phenobarbital with or without phenytoin and primidone)
   - Biguanides (phenformin, metformin)--chronic therapy
   - Colchicine
   - Cycloheximide
   - Ethanol--chronic intake for greater than 2 weeks
- Calcium-chelating agents (e.g., EDTA)
- Antibiotics (neomycin, others)
- Slow-release potassium tablets
- Cholestyramine
- Dactinomycin
- Methotrexate
- Oral contraceptives
- Pyrimethamine

10. Patients should be NPO from midnight before the test and 2 hours following the administration of the radioactive B12 capsule.

Radiopharmaceutical Administration:

Radiopharmaceutical for Stage I: $^{57}$Co-labeled Vit B12 provided in a capsule containing approximately 0.8 microCi/0.25 mcg Vit B12, obtained from the radiopharmacy.

Radiopharmaceutical for Stage II: $^{57}$Co-labeled Vit B12 bound to human intrinsic factor (IF) provided in a capsule containing approximately 0.5 microCi/0.25 mcg Vit B12, obtained from the radiopharmacy.

Vit. B12 (1 mg) for IM injection obtained from the pharmacy.

Specimen Collection:
Type: urine
Amount: 24-hour urine collection
Inadequate sample: less than 100 ml
Container: urine plastic container for 24-hour urine collection
Stable at room temperature for 24 hours after the end of the collection
Unacceptable specimen: less than 100 ml

Reagents:
None

Supplies:
Plastic container for 24H urine collection
Counting tubes

Equipment:
Gamma well counter
Graduated cylinder
Red-top tube

Calibration:
$^{57}$Co standard is obtained from the radiopharmacy and contain 2% of the activity of the dose given to the patient in 1 ml volume.
Quality Control:
1. No external QC is available
2. Internal QC is performed with standards

Stepwise procedure:
1. Patient preparation, radiopharmaceutical administration and specimen collection
   1.1. Verify ID of the patient, fasting state and points #1-8 from patient preparation.
   1.2. Explain the test to the patient and how to collect 24-hour urine (or 48 H if serum creatinine > 2.5 mg/dl). Give to the patient, a 24-H urine collection container.
   1.3. Have the patient void bladder before giving the dose, and save aliquot for patient's urine background.
   1.4. Administer the test dose consisting of:
       Stage I: $^{57}$Co-labeled Vit B12 provided in a capsule containing approximately 0.8 microCi/0.25 mcg Vit B12.
       Or for Stage II: $^{57}$Co-labeled Vit B12 found to human intrinsic factor (IF) provided in a capsule containing approximately 0.5 microCi/0.25 mcg Vit B12.
   1.5. Note time and start urine collection.
   1.6. At 2 hours after the dose, give 1 mg of Vit B12 IM to promote urinary excretion.
   1.7. The patient may eat.
   1.8. Instruct the patient to bring 24-hour urine collection back to nuclear medicine.

2. Counting Samples
   2.1. Mix urine and measure the volume using a graduated cylinder.
   2.2. Send an aliquot of urine (5 ml in a red-top tube) and requisition to the clinical laboratory for urine creatinine level to verify completeness of 24-hour collection.
       Normal values urine creatinine:
       a: Male: > 18 mg/kg/24 H
       b: Female: > 12 mg/kg/24 H
   2.3. Label counting tubes with sequential numbers.
   2.4. Pipette 3 ml of water in duplicate well counter tubes # 1 and 2 for background.
   2.5. Pipette 3 ml aliquot of background urine in duplicate well counter tube #3 and 4.
   2.6. For stage I: pipette in duplicate well counter tubes #5 and 6, 1 ml of the $^{57}$Co Standard provided with the test kit containing 2% of the activity of the oral $^{57}$Co-Vit B12 dose and add 2 ml of water. Vortex
   2.7. For Stage II: pipette in duplicate well counter tubes # 5 and 6, 1 ml of the $^{57}$Co Standard provided with the test kit containing 2% of the activity of the oral $^{57}$Co-Vit B12-IF and add 2 ml of water. Vortex
   2.8. Accurately pipette 3 ml aliquot of 24-H urine collection in duplicate in well counter tubes, #7 and 8.
   2.9. Put counting tubes in gamma well counter racks in following order:
       1,2 - H2O background
       3,4 - Patient background
       5,6 - $^{57}$Co Standards
       7,8 - Patient samples
2.10 Select Schilling test protocol on gamma counter and start counting:
   Window $^{57}\text{Co}:100-160 \text{ keV}$
   Preset time: 10 minutes
2.11 Write counts on data worksheet
2.12 Enter data into radiopharmacy computer
2.13 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

**Calculations:**
1. Percent excretion $^{57}\text{Co Vit B12}$:
   \[
   \text{Percent excretion} = \frac{\text{Urine sample} \times \text{volume 24-hr urine} - \text{Bg} \times \text{volume 24-hr urine}}{\text{St} \times \text{Bg} \times 100} \times \frac{3 \text{ ml}}{2}
   \]
2. Percent excretion $^{57}\text{Co Vit B12} - \text{IF} =$
   \[
   \text{Percent excretion} = \frac{\text{Urine sample} \times \text{volume 24-hr urine} - \text{Bg} \times \text{volume 24-hr urine}}{\text{St} \times \text{Bg} \times 100} \times \frac{3 \text{ ml}}{2}
   \]
3. Calculate the excretion ratio:
   \[
   \frac{\text{Percent excretion}^{57}\text{Co Vit B12} - \text{IF}}{\text{Percent excretion}^{57}\text{Co Vit B12}}
   \]

**Reporting Results:**
1. Normal values:
   \%
   \[
   \begin{align*}
   \text{\%}^{57}\text{Co excreted (Free Vit B12)} &= 10 - 40\% \\
   \text{\%}^{57}\text{excreted (Vit B12-IF)} &= 10 - 40\% \\
   \text{Excretion ratio} &= 0.7 - 1.3
   \end{align*}
   \]
2. Every instrument printout and data worksheet, is compared to final report.
3. The bench technologist will review all results for clerical and analytical errors, document in the Lab Log Book and bring to the attention of the supervisor.
4. Every test is reviewed by the laboratory supervisor and the final report is reviewed and signed by a nuclear medicine physician.
5. Completion turnaround time: 24 hours
6. Report turnaround time: 24 hours

**Interpretation and Limitations:**
False decreases:
inactive IF in test kit
gastric antibodies to IF
incomplete urine collection
no fasting state
parenteral Vit B12
oliguria
drugs interfering with Vit B12 absorption
megaloblastic gut
pancreatic exocrine insufficiency

False elevations:
$^{99m}$Tc or $^{67}$Ga administration
steroids

DATA WORKSHEET/SCHILLING TEST

Name_________________________________________ Hospital # _____________________________________________ Ward__

Date________________________________________

24-hour Urine Volume __________________________ (A) ml

Urine Aliquot Counted __________________________ (B) ml

<table>
<thead>
<tr>
<th>Sample</th>
<th>Count time</th>
<th>$^{3}Co$</th>
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<tr>
<td></td>
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<td>Count 1</td>
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<td>Background</td>
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<td>$^{3}Co$ Std</td>
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<td>24-hr urine</td>
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$\frac{(E-C) \times A}{B} \frac{D-C}{=} = \% \text{ excreted}$
SCHILLING TEST CHECK LIST AND INFORMATION
FOR THE REFERRING PHYSICIAN

(Please complete and return with urine sample)

CHECK Patient's name:

___ 1. Patient's weight: _________
   Patient's height: _________

___ 2. Serum creatinine level: ________ mg/100 ml
   (if > 2.5 mg/100 ml, 48-hour urine collection is necessary)

___ 3. IM injection of Vit B12 for past 3 days:

___ 4. Current medications (check list of interfering drug):

___ 5. Fasting State:

___ 6. Bladder voided before administration of radioactive capsule:

___ 7. IM injection of 1 mg of Vit B12 2 hours after administration of the radioactive capsule

___ 8. Volume of total 24-hour urine collection:

SCHILLING TEST PROCEDURE

Clinical Indications:
1. Megaloblastic anemia with indeterminate Vit B 12 and folate levels.

2. Significance of low Vit B12 and folate levels without megaloblastic anemia

3. Determination of mechanism of malabsorption in patients with Vit B12 deficiency

4. Detection of individuals at risk for pernicious anemia.

Principle:
Vitamin B12 deficiency causes megaloblastic anemia, gastrointestinal and neuropsychiatric symptoms because it is an essential cofactor in DNA synthesis and in myelin synthesis. The main source of Vit B12 is animal products. In the stomach, Vit B12 is digested and liberated from the ingested food. Vit B12 then binds to R-proteins from the saliva. In the jejunum, where the pH is alkaline, the R-proteins are degraded by pancreatic proteases and Vit B12 is transferred to intrinsic factor (IF) that is secreted by the parietal cell of the stomach. Vit B12 is then absorbed in the ileum where the pH is neutral. The absorption mechanism requires the presence of intrinsic factor. The most common cause of Vit B12 deficiency is due to lack of intrinsic anemia, a disease associated with the presence of different types of antibodies against IF and parietal cells of the stomach. The Schilling test evaluates the absorption
of Vit B12, after an oral dose of radioactive Vit B12 administered without (stage I) and with intrinsic factor (stage II), by measuring the % of the oral dose absorbed in the ileum and secreted in the urine in the next 24-48 hours.

**Patient Preparation: (when scheduling)**

1. Knowledge of patient's height and weight to interpret adequacy of 24-hour urine collection by urine creatinine levels.
2. Patients should have normal renal function: if creatinine > 2.5 mg/dl, 48-hour urine collection is necessary.
3. No parenteral Vit B12 must be given 3 days prior to the study.
4. Avoid drugs that interfere with the absorption of Vit B12:
   - Aminosalicylic acid (PAS)--chronic, high-dose therapy
   - Anticonvulsants (phenobarbital with or without phenytoin and primidone)
   - Biguanides (phenformin, metformin)--chronic therapy
   - Colchicine
   - Cycloheximide
   - Ethanol--chronic intake for greater than 2 weeks
   - Calcium-chelating agents (e.g. EDTA)
   - Antibiotics (neomycin, others)
   - Slow-release potassium tablets
   - Cholestyramine
   - Dactinomycin
   - Methotrexate
   - Oral contraceptives
   - Pyrimethamine
5. Patients should be NPO from midnight before the test and 2 hours following the administration of the radioactive B12 capsule.
6. Check that the patient is not pregnant.
7. Nursing mothers should stop breastfeeding
8. Blood levels of Vit B12 and folate must have been obtained prior to Schilling test
9. Ensure that interfering radiopharmaceuticals have not been recently administered. Tc-99m and I-123 within 5 days; Tl-201, Ga-67, In-111, I-131 MIBG, and I-131 thyroid uptake w/in 6 weeks; I-131 therapy w/in 3 mos.

**Procedure for dose administration:**

1. Verify fasting state and points #1-8 from patient preparation
2. Explain the test to the patient and how to collect 24-hour urine (or 48-hour if serum creat > 2.5 mg/dl). Give to the patient, a container with 5 ml toluene as a preservative.
3. Have the patient void bladder before giving the dose.
4. Administer the test dose consisting of:
   - Stage I $^{57}$Co-labeled Vit B12 provided in a capsule containing approximately 0.8 microCi/0.25mcg Vit B12
   - Stage II $^{57}$Co-labeled Vit B12 bound to human intrinsic factor (IF) provided in a capsule containing approximately 0.5 microCi/0.25 mcg Vit B12
5. Note time and start urine collection
6. At 2 hours after the dose, give 1 mg of Vit B12 IM to promote urinary excretion.

7. The patient may eat

8. Instruct the patient to bring 24-hour urine collection back to nuclear medicine. Keep refrigerated.

Blood Volume Measurements

Clinical Indications:
1. Evaluation polycythemia vera
2. Management of fluid therapy
3. Evaluation of endocrine disorders
4. Evaluation of blood loss
5. Evaluation of anemia

Principle:
Blood volume measurements can be performed based on the tracer and dilution principle with the following assumptions:

a. RBC and plasma are closed systems.
b. or the tracer leaves the open system at a slow rate compared to the rate of mixing to reach equilibrium.
c. Blood samples are taken only after mixing has been completed.

The volume of a compartment may be calculated according to the conservation of mass formula

\[ A_i = V_i C_i = V_p C_p \]

Volume compartment = \( V_p = V_i \times C_i \)

\[ C_p \]

Where \( V_i \) = volume of tracer injected
\( C_i \) = concentration of tracer injected
\( C_p \) = concentration of tracer in the compartment after equilibrium

The tracer for plasma volume is \(^{125}\text{I}-\text{albumin} (10-50 \text{ microCi})\) and the tracer for RBC volume is \(^{51}\text{Cr-RBC} (30-200 \text{ microCi})\).

It is assumed that total blood volume is the sum of plasma and RBC volume.

Plasma volume can theoretically be calculated from the hematocrit and RBC volume and vice versa.

However, the venous hematocrit is usually overestimated because of trapping of plasma: 3-4% by the Wintrobe method, and 1% in the microhematocrit method.

On the other hand, too much anticoagulant in the collection tube (EDTA > 1.5 mg/ml or heparin > 0.1 mg/ml) will cause shrinkage of the RBC and a falsely low hematocrit.

In addition, the body hematocrit is usually lower than the peripheral (venous) hematocrit and the mean of the f cell ratio = body Hct/venous Hct = 0.89 - 0.92 Hct has been widely used to circumvent simultaneous measurements of both RBC and plasma volume. However, the f cell ratio can be variable in disease states and therefore the simultaneous measurement of both RBC and plasma volume is more reliable and recommended.
I-125 Albumin Pharmacokinetics:
After IV administration, uniform distribution in the vascular pool usually occurs within 10-20 minutes but can be variable and take up to 40 minutes. At equilibrium, $^{125}$I albumin diffuses in the extravascular space at a rate of 6-10% hour, and is slowly excreted by the kidneys with a half-life of 20 days. Therefore, at least 2 blood samples are recommended after equilibrium, and extrapolation to zero time is necessary. At Vanderbilt, 3 blood samples are obtained 20, 30 and 40 minutes postinjection.

Cr-51 RBC labeling and Pharmacokinetics:
The autologous RBC of the patient (30-50 ml) are collected in acid-citrate dextrose (ACD) and labeled with $^{51}$Cr ($\text{NaCrO}_4$) in vitro. $^{51}$Cr in the valence +6 state penetrates the RBC membrane, binds to hemoglobin (beta chain) and is reduced in valence +3 state. There is minimal elution of $^{51}$Cr from the RBC (1% day) and the eluted $^{51}$Cr is incapable of repenetrating the RBC.

The labeling procedure lasts 30-60 minutes and is terminated by adding 50-100 mg of ascorbic acid (optional), and by sterile washing of the cells several times. The cells are then reinjected into the patient.

After administration, uniform distribution in the vascular space occurs in 10-20 minutes but can be prolonged in disease states. There is only minimal elution of $^{51}$Cr from RBC and there is rapid renal excretion of the trivalent $^{51}$Cr eluted from the cells. If both plasma and RBC volume are measured simultaneously, the blood samples are obtained at the same time, 20, 30, and 40 minutes postinjection. The RBC are lysed before counting the samples and the concentration of radioactivity in the appropriate compartment is calculated from the average hematocrit measured from the blood samples.

Patient Preparation:
1. Check that the patient is not pregnant or breastfeeding.
2. Nursing mothers should stop breastfeeding.
3. The test should not be performed on patients less than 20 kg.
4. Avoid contamination with other radionuclide from in vivo studies.
5. If $^{125}$I albumin is administered, thyroid should be blocked uptake by giving 30-130 mg/day of iodine the day of the test and for 7 days after the test.
   a. Lugol's = 100 mg KI/ml (10 drops/day)
   b. SSKI = 1 gm KI/ml (1 drop = 0.1 ml)
6. Record patient's height and weight

Radiopharmaceutical Administration:
- Radiopharmaceutical for RBC mass: $^{51}$Cr for RBC labeling obtained from the radiopharmacy.
  - Adult dose: 30 microCuries
  - Child dose: per body weight, minimum 20 kg (see chart)
  - Route: labeled RBC are reinjected intravenously
Radiopharmaceutical for plasma volume: $^{125}$I-albumin obtained from the radiopharmacy.
- Adult dose: 10 microCuries
- Child dose: per body weight, minimum 20 kg (see chart)
- Route: intravenous

Lugol's solution obtained from the pharmacy

**Specimen Collection:**
For RBC labeling:
- Type: blood
- Amount: 10 ml
- Container: 20 ml syringe with ACD
  Unacceptable specimen: clotted or less than 7 ml

For RBC mass and plasma volume measurements:
- Type: blood
- Amount: 8 ml
- Container: purple top tube
  Stable at RT for 24H after the end of the collection
  Unacceptable specimen: clotted or less than 4 ml

**Reagents, Supplies and Equipment:**
**Reagents:**
- ACD solution from Squibb (unit dose packaging)
- Sterile normal saline solution from the pharmacy

**Supplies:**
- Alcohol wipes
- 19 or 21 gauge butterfly needles with tubing
- Three-way stopcock
- 20 ml syringe
- 12 ml syringe
- TB syringe
- Purple top tubes
- Hematocrit capillaries plus reader
- Counting tubes

**Equipment:**
- Centrifuge Beckman T-J-6 and Cru-5000
- Gamma well counter
- Timer
- Balance Mettler H32
- Rotator mixer
Calibration:
1. $^{51}$Cr-RBC Standard: is an aliquot of the $^{51}$Cr-labeled autologous RBC preparation containing 1 ml of blood and diluted 1/100 in water.
2. $^{125}$I-Albumin standard: is an aliquot of the $^{125}$I-albumin dose obtained from the radiopharmacy and diluted 1/1000 in water with 2 drops of Lugol's

Quality Control:
1. No external QC is available.
2. Internal QC is performed with standards.
3. Reproducibility will be tested monthly as outlined in the proficiency SOP.
4. Accuracy will be tested every 6 months as outlined in the proficiency SOP.

Special Technical Precautions during Procedure:
1. Avoid blood clots in syringes.
2. Avoid damaging RBC by using $^{51}$Cr with high specific-activity (50-100 _Ci/_g) resulting in labeling concentration of < 1 mcg of chromium/ml blood.
3. Add the $^{51}$Cr to the citrated blood and not to the ACD solution. Do not autoclave ACD solution because it will impair binding.
4. Avoid injecting $^{125}$I albumin through catheters or polyethylene tubing.
5. Use siliconized glassware for $^{125}$I albumin.
6. Avoid dose infiltration
7. Withdraw blood samples from extremity opposite to site of injection.
8. Withdraw blood samples precisely at 20, 30, 40 minutes postinjection.

Stepwise Procedure for Dual Tracer Blood Volume (Adult):
1. **Patient Preparation**
   1.2. Check ID of the patient.
   1.2. Ask if patient is pregnant.
   1.3. Explain the procedure to the patient.

   **Patient:** Inform the patient that you will be withdrawing about 20-ml of blood and labeling it, which will take approximately one hour. After labeling you will reinject the labeled blood and take three samples that will take another 45 minutes. Total patient time is approximately 2 hours. It is preferable that the patient be brought to the department for this procedure.

   1.4 Ask if patient had exposure to radionuclide in past few days.
   1.5 Record patient's height and weight.

2. **Drawing blood for tagging**
   2.1. Prepare a setup as follows. Add 2 ml of ACD to a 20-ml syringe using sterile technique, add to the 20-ml syringe a 3-way stopcock and 21 or 19 gauge butterfly. At the third opening on stopcock add 12-ml syringe (break suction first). Label the 20-ml syringe with the patient's name.
2.2. To draw sample: apply tourniquet to patient's arm. Have the stopcock open to the 12-ml syringe. Do a venipuncture and withdraw 7 ml of blood into the 12-ml syringe. Put this blood in 10-ml purple top (mix) for background. Turn stopcock open to 20-ml syringe and withdraw 10 ml blood (this will fill to 12 ml because of 2 ml ACD). Remove tourniquet. Withdraw needle. Apply pressure with 4 x 4 gauze on vein to prevent hematoma. Quickly close stopcock to blood and mix gently by inversion.

3. **Tagging RBC**

3.1. Remove butterfly and stopcock (put in radioactive trash). Adapt clear sterile stopcock and injection cap and place syringe and tube with background blood from patient on mixer.

3.2. Draw two syringes (one 12-ml and one 20-ml) of sterile saline.

3.3. Inject the $^{51}$Cr into blood through the injection cap (using sterile technique). Rinse the syringe several times. Wash the $^{51}$Cr and cells into 20-ml syringe by injecting 3-5-ml saline through the injection cap. Add a little air into syringe (put millipore filter on end of stopcock to maintain sterility). Mix the blood for 30 minutes on the rotator mixer (use timer).

4. **Weighing and Preparing $^{125}$I-Albumin and $^{51}$Cr-RBC dose and STD**

The following items must be weighed and recorded on the data worksheet sheet:

4.1. 20-ml syringe with stopcock and injection cap for patient RBC dose-label.

4.2. 3-ml syringe and needle for $^{51}$Cr-STD-label.

4.3. 3-ml syringe and needle for $^{125}$I dose-label.

4.4. 3-ml syringe and needle for $^{125}$I-STD-label.

4.5. Weighing is done on the Mettler H32 balance and should be accurate to 3 decimals, i.e., 18.9731.

4.6. These weights go on the data worksheet at **post-injection**.

5. **Washing cells and preparing $^{51}$Cr-RBC standard and dose**

5.1. When tagging time is ended put the syringe in the large centrifuge canister. Balance with a similar syringe filled with water. Bring the blood all the way up to top of the syringe, then add saline through the injection cap until you feel the plunger hit the bottom of the canister. Turn the stopcock to the off position.

5.2. Place canisters in the Cru-5000 centrifuge and spin for 10 minutes at 3,000 rpm.

5.3. After the first spin, gently remove canister from centrifuge. With a 20-ml syringe with 18-gauge needle remove the plasma, saline, and small layer of white cells from the red cells. Throw in radioactive trash.

5.4. Again add normal saline to the red cells until plunger hits bottom of centrifuge. Turn stopcock to off. Invert the canister and syringe several times to resuspend red cells.

5.5. Spin again at 3,000 rpm for 10 minute.

5.6. Remove saline and any white cells from surface of red cells.

5.7. Note the volume of red cells. Resuspend cells with an equal volume of normal saline. Mix well until red cells are uniformly distributed.

5.8. With weighed $^{51}$Cr-standard syringe withdraw the remaining red cells.

5.9. With weighed $^{51}$Cr-patient syringe withdraw the remaining red cells.

5.10. Weigh these two syringes and note weight in **pre-injection** data worksheet.
6. **Drawing up and preparing $^{125}$I-Albumin standard and dose**

Using prepared 10 microCi/ml $^{125}$I-Albumin draw up 1 ml in each of the weighed $^{125}$I dose syringe and $^{125}$I-patient syringe. Weigh. Record weight on data sheet **pre-injection**. Dilute in water with 2 drops of Lugol's the $^{125}$I-albumin standard in 1000 ml graduated flask. Rinse the syringe 4 or 5 times to be sure all of weighed dose is in the flask. Label the flask. Save the patient $^{125}$I for injection.

7. **$^{51}$Cr-standard**

Dilute in 100-ml graduated flask with water. Add two or three drops of lysing solution to flask before bringing to calibration mark.

8. **Injecting patient and obtaining samples**

Connect a 21- or 19-gauge butterfly to $^{51}$Cr-patient dose. Fill two 20-ml syringes with normal saline. Attach one to the 3-way stopcock. Perform venipuncture, being sure to have good blood flow. Slowly inject the tagged RBC. Wash the syringe several times with saline to be sure patient receives all of the weighed dose. Add the $^{125}$I-albumin dose to the stopcock, inject and wash several times. Note time of injection. Discard syringes in radioactive trash. Apply good pressure to injection site before leaving the patient.

9. **Sampling**

9.1 Draw a 7-ml blood sample, put in a purple-top tube at 20-, 30-, and 40-minutes after injection.

9.2 Be sure you have patient's **height and weight** before returning patient to the floor.

10. **Sample preparation and counting**

10.1 Put bkg, 20-, 30-, 40-minute sample on mixer while you prepare numbered **duplicate** counting tubes for the (a) blank, (b) bkg., (c) $^{125}$I STD, (d) $^{51}$Cr-STD, (e) 20 minute, (f) 30 minute, (g) 40 minute.

10.2 Pour each blood sample or standard sample into small medicine cups. Pipette 3 ml into each appropriately marked tube. Run duplicate hematocrits on each blood sample. Average the readings for the Hct on the data worksheet. Add 2 or 3 drops of lysing agent to each blood sample mix.

10.3 Put counting tubes into gamma well counter racks in the following order:

| 1,2 | Water blank |
| 3,4 | Patient blank |
| 5,6 | $^{125}$I-albumin standard |
| 7,8 | $^{51}$Cr-RBC-standard |
| 9,10 | Patient's sample 20 min |
| 11,12 | " 30 min |
| 13,14 | " 40 min |

10.4 **Select Blood Volume protocol on gamma counter and start counting**

Dual channel counting: Window $^{125}$I:15-80 keV

Window $^{51}$Cr:270-370 keV

Preset time: 4 minutes

10.5 Write counts on data worksheet

10.6 Enter data into radiopharmacy computer
10.7 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

Stepwise Procedure for Red Cell Mass (adult)

1. Patient Preparation
   1.2. Check ID of the patient.
   1.2. Ask if patient is pregnant.
   1.3. Explain the procedure to the patient.
   1.4 Ask if patient had exposure to radionuclide in past few days.
   1.5 Record patient's height and weight.

2. Drawing blood for tagging
   2.1 Prepare a setup as follows: Add 2-ml ACD to a 20-ml syringe using sterile technique, add to the 20-ml syringe a 3-way stopcock and 21- or 19-gauge butterfly. At the third opening on stopcock, add 12-ml syringe (break suction first). Label the 20-ml syringe with the patient's name.
   2.2 To draw sample: apply tourniquet to patient's arm. Have the stopcock open to the 12-ml syringe. Perform venipuncture on patient and withdraw 7-ml of blood into the 12-ml syringe. Put blood in 10-ml purple top (mix) for background. Turn stopcock open to 20-ml syringe and withdraw 10-ml blood (this will fill to 12-ml because of 2-ml ACD). Remove tourniquet. Withdraw needle. Apply pressure with 4 x 4 gauze on vein to prevent hematoma. Quickly close stopcock to blood and mix gently by inversion.

3. Tagging RBC
   3.1 Remove butterfly and stopcock (put in radioactive trash). Put on clear sterile stopcock and injection cap and place syringe and tube on mixer with patient background blood sample.
   3.2 Draw two syringes (one 12-ml and one 20-ml) of sterile saline.
   3.3 Inject the $^{51}$Cr into blood through the injection cap (using sterile technique). Rinse the syringe several times. Wash the $^{51}$Cr and cells into 20-ml syringe by injection 3-5 ml saline through the injection cap. Add a little air into syringe. Mix the blood for 30 minutes on the rotator mixer (use timer).

4. Weighing and preparing $^{51}$Cr-RBC patient dose and STD
   4.1 20-ml syringe with stopcock and injection cap for patient RBC dose-label.
   4.2 3-ml syringe and needle for $^{51}$Cr STD - label.
   4.3 Weighing is done on the Mettler H32 balance and should be accurate to 3 decimals, i.e., 18.9731.
   4.4 These weights go on the data worksheet at post-injection.

5. Washing cells
   5.1 When tagging time is ended put the syringe in the large centrifuge canister. Balance with a like syringe filled with water. Bring the blood all the way up to top of the syringe, then add saline through the injection cap until you feel the plunger hit the bottom of the canister. Turn the stopcock to the off position.
   5.2 Place canisters in the Cru-5000 centrifuge and spin for 10 minutes at 3,000 rpm.
5.3 After the first spin, gently remove canister for centrifuge. With a 20-ml syringe with 18-gauge needle remove the plasma, saline, and small layer of white cells from the red cells. Throw in radioactive trash.

5.4 Again add normal saline to the red cells until plunger hits bottom of centrifuge. Turn stopcock to off. Invert the canister and syringe several times to resuspend red cells.

5.5 Spin again at 3,000 rpm for 10 minutes.

5.6 Remove saline and any white cells from surface of red cells.

5.7 Note volume of red cells. Resuspend cells with an equal volume of normal saline. Mix well until red cells are uniformly distributed.

5.8 With weighted $^{51}$Cr-standard syringe remove 1-ml of tagged red cells from the above syringe.

5.9 With weighed $^{51}$Cr patient syringe withdraw the remaining red cells.

5.10 Weigh these two syringes and note weight in **pre-injection** on data worksheet.

6. $^{51}$Cr-standard
   Dilute in 100-ml graduated flask with water. Add 2 or 3 drops of lysing solution to flask before bringing to calibration mark.

7. **Injecting patient and obtaining samples**
   Connect a 21- or 19-gauge butterfly to $^{51}$Cr-patient dose. Fill two 20-ml syringes with normal saline. Attach one to the 3-way stopcock. Perform venipuncture, being sure to have good blood flow. Slowly inject the tagged RBC. Wash the syringe several times with saline to be sure patient receives all of the weighed dose. Note time of injection. Discard syringes in radioactive trash. Apply good pressure to injection site before leaving the patient.

8. **Sampling**
   8.1 Draw a 7-ml blood sample in a purple-top tube at 20-, 30-, and 40-minutes after injection.
   8.2 Be sure you have patient's **height** and **weight** before returning patient to the floor.

9. **Sample preparation and counting**
   9.1 Put bkg, 20-, 30-, and 40-minute sample on mixer while you prepare numbered duplicate counting tubes for the (a) blank, (b) patient's bkg, (c) $^{51}$Cr-std, (d) 20 minute, (e) 30 minute, (f) 40 minute.
   9.2 Pour each blood sample or standard sample into small medicine caps. Pipette 3 ml into each appropriately marked tube. Run duplicate hematocrits on each blood sample. Average the readings for the Hct on the data worksheet. Add 2 or 3 drops of lysing agent to each blood sample mix.

10. **Counting**
    10.1 Put counting tubes into gamma well counter racks in the following order:
        1,2 Water blank
        3,4 Patient blank
        5,6 $^{51}$Cr-RBC-standard
        7,8 Patient's sample 20 min
        9,10 " 30 min
        11,12 " 40 min
10.2 Select Blood Volume protocol on gamma counter and start counting
   Dual channel counting:
   Window $^{125}$I: 15-80 keV
   Window $^{51}$Cr: 270-370 keV
   Preset time: 4 minutes

10.3 Write counts on data worksheet.

10.4 Enter data into radiopharmacy computer

10.5 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

Plasma Volume (adult):

1. Patient Preparation
   1.2 Check ID of the patient.
   1.2 Ask if patient is pregnant.
   1.3 Explain the procedure to the patient.
   1.4 Ask if patient had exposure to radionuclide in past few days.
   1.5 Record patient's height and weight.

2. Weighing and preparing $^{125}$I dose and STD
   The following items must be weighed and recorded on the data worksheet.
   2.1 3-ml syringe and needle for $^{125}$I-dose-label.
   2.2 3-ml syringe and needle for $^{125}$I-standard-label.
   2.3 Weighing is done on the Mettler H32 balance and should be accurate to 3 decimals, i.e., 18.9731.
   2.4 These weights go on the data sheet at post-injection.

3. Drawing up and preparing $^{125}$I-Albumin Standard and Dose
   Using prepared 10 microCi/ml $^{125}$I HSA draw up 1 ml in each of the weighed $^{125}$I dose syringe and $^{125}$I patient syringe. Weigh. Record weight on data sheet pre-injection. Dilute with water mixed with 2 drops of Lugol's the $^{125}$I standard in 1000 ml graduated flask. Rinse the syringe 4 or 5 times to be sure all of weighed dose is in the flask. Label the flask. Save the patient $^{125}$I for injection.

4. Injecting patient and obtaining samples
   Connect a 21- or 19-gauge butterfly to stopcock and $^{125}$I-Albumin patient dose. Fill one 20-ml syringe with normal saline. Perform venipuncture, being sure to have good blood flow. Slowly inject the $^{125}$I-Albumin. Wash the syringe several times with saline to be sure patient receives all of the weighed dose. Note time of injection. Discard syringes in radioactive trash. Apply good pressure to injection site before leaving the patient.

5. Sampling
   5.1 Draw a 7-ml blood sample in a purple-top tube at 20, 30, and 40 minutes after injection.
   5.2 Be sure you have patient height and weight before returning patient to the floor.

6. Sample preparation and counting
6.1 Prepare **duplicate** numbered counting tubes for the (a) blank, (b) bkg., (c) $^{125}$I STD, (d) 20 minute, (e) 30 minute, (f) 40 minute.

6.2 Pour each blood sample or standard sample into small medicine caps. Pipette 3 ml into each appropriately marked tube. Run duplicate hematocrits on each blood sample. Average the readings for the Hct on the data worksheet. Add 2 or 3 drops of lysing agent to each blood sample mix.

7. **Counting**

7.1 Put counting tubes into gamma well counter racks in the following order:

| 1, 2 | Water blank |
| 3, 4 | Patient blank |
| 5, 6 | $^{125}$I - Albumin standard |
| 7, 8 | Patient's sample 20 min |
| 9, 10 | " 30 min |
| 11, 12 | " 40 min |

7.2 Select Blood Volume protocol on gamma counter and start counting

- **Dual channel counting:**  Window $^{125}$I: 15-80 keV
- Window $^{51}$Cr: 270-370 keV

Preset time: 4 minutes

7.3 Write counts on data worksheet.

7.4 Enter data into radiopharmacy computer

7.5 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

**Calculations:**

\[
V_p = \frac{C_i \times V_i}{V_p}
\]

1. RBC volume:

\[
\frac{\left(\frac{^{51}\text{Cr St} - \text{Bg}}{\text{vol standard}}\right) \times \text{dilution Standard} \times \text{vol patient}}{\text{vol standard}}^{\text{^{51}Cr whole blood} - \text{blank}}^{\text{Hematocrit}}
\]

2. If the dual technique is used, correct the $^{125}$I cpm for downscatter from $^{51}$Cr.

3. Plasma volume:

\[
\frac{\left(\frac{^{125}\text{I St} - \text{Bg}}{\text{vol standard}}\right) \times \text{dilution Standard} \times \text{vol patient}}{\text{plasmacrit}}^{\text{^{125}I zero intercept} \text{ whole blood} - \text{blank}}
\]

4. Total blood volume:

\[
\text{RBC volume} + \text{plasma volume}
\]

5. Calculate RBC plasma and total blood volume/kg
**Reporting Results:**

1. **Predicted normal values:**
   
   **In the male:**
   
   Red cell mass = \([8.2 \times \text{height (cm)}] + [17.3 \times \text{weight (kg)}] - 693\)
   
   Plasma volume = \([23.7 \times \text{height (cm)}] + [9 \times \text{weight (kg)}] - 1709\)
   
   Total blood volume = red cell mass + plasma volume

   **In the female:**
   
   Red cell mass = \([16.4 \times \text{height (cm)}] + [5.7 \times \text{weight (kg)}] - 1649\)
   
   Plasma volume = \([40.4 \times \text{height (cm)}] + [8.4 \times \text{weight (kg)}] - 4811\)
   
   Total blood volume = red cell mass + plasma volume

2. **Critical values:** < 20% or > 130% of the predicted value

3. Every instrument printout and data worksheet is compared to final report.

4. The bench technologist will review all results for clerical and analytical errors, document in the Lab Log Book and bring to the attention of the supervisor.

5. Every test is reviewed by the laboratory supervisor and the final report is reviewed and signed by a nuclear medicine physician.

6. Completion turnaround time: 24H

7. Report turnaround time: 24H

**Interpretation and Limitations:**

Timing of blood sampling is critical

**Ref:**


DATA WORKSHEET/DUAL TRACER BLOOD VOLUME

Name: ________________  Hosp. # ________________  Ward ________________  Date __
M ____  F ____  Height (in): ________  Weight (lbs): ___________  HCT (%): ___

<table>
<thead>
<tr>
<th></th>
<th>$^{125}\text{I-Patient}$</th>
<th>$^{125}\text{I-Standard}$</th>
<th>$^{51}\text{Cr-Patient}$</th>
<th>$^{51}\text{Cr-Standard}$</th>
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</thead>
<tbody>
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<td>Pre injection</td>
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<tr>
<td>Post injection</td>
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<tr>
<td>Net Amount (vol)</td>
<td>A</td>
<td>b</td>
<td>c</td>
<td>d</td>
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</table>

$^{125}\text{I-Samples}$  

<table>
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<th>Sample</th>
<th>Count time</th>
<th>Count 1</th>
<th>Count 2</th>
<th>Avg Count</th>
<th>Count 1</th>
<th>Count 2</th>
<th>Avg Count</th>
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<td>$^{51}\text{Cr-STD}$</td>
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<td>40 min</td>
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</tbody>
</table>

$^{125}\text{I-STD}$ Dilution: ________________ (m)  
$^{51}\text{Cr-STD}$ dilution ________________ (n)

$^{125}\text{I}$-zero time intercept count_________(p)  
$^{51}\text{Cr}$ zero time intercept count________(g)

CALCULATED VALUES:

Total plasma volume

\[
\text{Total plasma volume} = \frac{a \times (g - e) \times m \times (100 - \text{HCT})}{b \times (p - f) \times 100} + \frac{x \times x \times x}{x \times x} = \frac{\text{___________________________ ML (PV)}}{}
\]

Total Red cell Volume

\[
\text{Total Red cell Volume} = \frac{c \times (l - i) \times n \times \text{HCT}}{d \times (q - j) \times 100} + \frac{x \times x \times x}{x \times x} = \text{___________________________ ML (RVC)}
\]

Total blood volume

\[
\text{Total blood volume} = \text{PV} + \text{RCV} = \text{___________________________ ML}
\]
Glomerular filtration rate (GFR)

Clinical Indication:
Quantitation of renal function

Procedure: $^{99m}$Tc-DTPA GFR

Principle:
$^{99m}$Tc-DTPA is almost entirely cleared by glomerular filtration, allowing GFR measurement. GFR is determined by the plasma clearance method requiring multiple blood samples over a period of 4 hours following intravenous injection of 1.0 mCi of $^{99m}$Tc-DTPA.

Patient Preparation:
1. Check that the patient is not pregnant or breastfeeding.
2. Nursing mothers should stop breastfeeding.
3. The test should not be performed on patients less than 14 kg.
4. Avoid contamination with other radionuclide from in vivo studies.
5. The patient should be well hydrated.
6. Record patient's height and weight

Radiopharmaceutical Administration:
1. Radiopharmaceutical: $^{99m}$Tc-DTPA (Pentetate) is obtained from the Radiopharmacy.
2. Adult Dose: 1 mCi
3. Child Dose: per body weight, minimum 14 kg Minimum 0.25 mCi (see chart)
4. Route: intravenous (may be administered on the ward)

Specimen Collection:
Type: blood
Amount: 2 ml per sample
Container: purple top tube
Timing of blood samples: 2 hours, 2 1/2 hours, 3 hours, 3 1/2 hours and 4 hours after injection
Stable at RT for 24H after the end of the collection
Location of blood sampling: Nuclear medicine department
Unacceptable specimen: clotted or less than 2 ml

Reagents, Supplies and Equipment:
Reagents:
None
Supplies:
Syringe for standard and patient's dose.
3-way stopcock
23-gauge butterfly
Purple-top tubes (5 ml)
Volumetric flasks (1000 ml)
Counting tubes
Equipment:
Centrifuge Beckman T-J-6
Gamma well counter

Calibration:
$^{99m}$Tc-DTPA standard (1 mCi) is obtained from the radiopharmacy in the nominal concentration of 1 mCi/ml and diluted 1/1000 with water.

Quality Control:
1. No external QC is available
2. Internal QC is performed with standards
3. Reproducibility will be tested monthly as outlined in the Proficiency testing SOP.
4. Accuracy will be tested every 6 months as outlined in the Proficiency testing SOP.

Stepwise Procedure:
1. Patient Preparation
   1.2. Check ID of the patient.
   1.2. Ask if patient is pregnant.
   1.3. Explain the procedure to the patient.
   1.4 Ask if patient had exposure to radionuclide in past few days.
   1.5 Record patient's height and weight.

2. Radiopharmaceutical Administration
   2.1 Obtain from radiopharmacy 2 doses of $^{99m}$Tc-DTPA each 1 mCi in a syringe for standards and patient dose (nominal concentration 1 mCi/ml)
   2.2 Set up stopcock with 6 ml saline at one end and 23-gauge butterfly at other. Use top opening to attach syringe for blood background and injecting dose.
   2.3 With tourniquet on patient's arm, insert butterfly into vein, and with top syringe, withdraw 2 ml of blood in purple top tube for patient's background and mix well.
   2.4 Remove tourniquet and inject dose. Flush the dose several times with saline. Save dose syringe and needle and measure in dose calibrator on same setting as used when drawing dose and standard. Write measurements on Data Worksheet.
   2.5 Prepare 1,000 dilution of standard. Fill 1,000 ml volumetric flask partially with water. Inject standard, rinse the syringe several times in water (use disposable medicine cups). Save syringe to measure residue on dose calibrator. Write measurement on data worksheet.

3. Specimen Collection:
3.1 Draw 2 ml blood samples into 5 ml purple top tubes at 2 H, 21/2 H, 3 H, and 4 H after injection.

4. Counting Samples:
4.1 Set-up and label numbered counting tubes.
4.2 Centrifuge blood samples 5 minutes at RT at 1500 rpm.
4.3 Pipette into counting tubes, 0.2 ml plasma samples for patient's samples. 0.2 ml water for background, and 0.2 ml for standard.
4.4 Put counting tubes in gamma well counting racks in following order:
   1,2 Water background
   3,4 Patient's blank
   5,6 Standard
   7,8 Patient's samples
4.5 Select $^{99m}$Tc-GFR program on gamma well counter and start counting:
   Window: 110-170 keV
   Preset time: 2 minutes
4.6 Write counts on data worksheet.
4.7 Enter data into radiopharmacy computer.
4.8 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

Calculations:
1. Plot time - activity curve
2. Do manual linear interpolation and measure T$\frac{1}{2}$
3. Calculate GFR:
   \[\frac{\text{[Std (cpm) - bkg (cpm)] x dil std x 0.693 x patient's dose (mCi)}}{\text{Y intercept (cpm) x T$\frac{1}{2}$ (min) x std dose (mCi)}}\]

Reporting Results:
1. Normal values:
   - **In the male:** 125 +/- 15 ml/min
   - **In the female:** 110 +/- 15 ml/min
2. Critical value: none
3. Every instrument printout and data worksheet is compared to final report.
4. The bench technologist will review all results for clerical and analytical errors, document in the Lab Log Book and bring to the attention of the supervisor.
5. Every test is reviewed by the laboratory supervisor and the final report is reviewed and signed by a nuclear medicine physician.
6. Completion turnaround time: 24H
7. Report turnaround time: 24H

Interpretation and Limitations:
1. Timing of blood samples is critical.
2. Patient's hydration status is critical.

DATA WORKSHEET/99M-Tc-DTPA GFR

Pt.Name_________________________________  Hosp#____________________  Ward_____________________

Date_______________________________

Sample count time:____________________  Sample Count Volume___________________________

Time injected:_________________  Sex______  Age_______  Ht__________  WT__________

In. or Cm.          Lbs or Kg

<table>
<thead>
<tr>
<th>Count 1</th>
<th>Count 2</th>
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<tbody>
<tr>
<td>Water</td>
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<tr>
<td>Plasma Bkg</td>
<td></td>
</tr>
<tr>
<td>Std</td>
<td></td>
</tr>
</tbody>
</table>

Dilution factor _____________________ ml

STD. syringe: Pre___________  Post________________  Net wt________________

Dose syringe: Pre___________  Post_______________  Net wt________________

Plasma samples:

<table>
<thead>
<tr>
<th>Time Sample Collected</th>
<th>Time (in min) Post Dose</th>
<th>Count 1</th>
<th>Count 2</th>
</tr>
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</table>
Procedure: $^{125}$I-Glofil GFR

Principle:
$^{125}$I-Iodothalamate ($^{125}$I-glofil) can be used to measure the glomerular filtration rate (GFR). $^{125}$I-Glofil injected subcutaneously is slowly reabsorbed into the bloodstream and mimic a constant intravenous infusion. GFR can be calculated using the constant infusion technique where at equilibrium:

$$GFR = \frac{UV}{P}$$

Where:
- $U =$ urine concentration (cpm)
- $V =$ urine flow rate (ml/min)
- $P =$ plasma concentration (cpm)

Patient's Preparation:
1. No solid food 2 hours before the test, normal fluid intake.
2. Procedure may be contraindicated in the following patients:
   a. Patients in whom water loading is contraindicated
   b. Patients with a known sensitivity to iodine
   c. Women who are pregnant, lactating or menstruating
   d. Patients weighing less than 14 kg.
   e. Patients who have had an MI during the past month
   f. Patients with U.R.I.
3. Exposure to other forms of gamma radiation (i.e., Nuclear Medicine scans) during the preceding week may influence gamma radiation counts. If patient has been exposed to other gamma radiation, blood should be drawn for background or baseline count, labeled as such and sent to laboratory with other specimens at the conclusion of the procedure.
4. All voided urine must be measured accurately and replaced with an equal amount of water in order to insure adequate hydration. Patients should be given tap water to drink. Ice water should not be used.
5. Patients should be allowed to take medications prescribed by their physician prior to beginning the study but no medication should be taken during the study.
6. If the patient has been NPO for another procedure, water load for one hour with 1000 ml of water then begin the study by injecting the GloFil and continue the routine water load of 20 ml/kg of body weight.
7. Multiple GloFil studies should not be done within 72 hours of a preceding GloFil study.
8. In new transplant patients who have a small bladder capacity or patients with indwelling catheters, collection periods may be reduced from 30 minutes to 10 minutes.
9. Patients should refrain from smoking during the study.
10. Patients should be seated during the study whenever possible, rather than reclining in bed or standing.
11. Record patient's height and weight.
**Radiopharmaceutical Administration:**

Radiopharmaceutical:

\(^{125}\text{I}\)-Glofil (iodothalamate) is obtained from the Radiopharmacy

**Adult Dose:** 15 microCi

**Child Dose:** per body weight, minimum 14 kg (see chart)

**Route:** Subcutaneously in the deltoid area

Lugol's solution obtained from the pharmacy

---

**Specimen Collection:**

**Type:** blood and urine

**Amount:** 5-7 ml per blood sample, 10-30 min collection for urine samples

**Container:** green top tube (heparinized) for blood samples, urine specimen container for urine samples

**Timing of blood and urine samples:** 2 hours, 2 1/2 hours, 3 hours after injection

Stable at RT for 24H after the end of the collection, and in refrigerator at 4 degrees C for additional 48 hours

Unacceptable blood specimen: clotted or less than 2 ml

Unacceptable urine specimen: less than 1.5 ml

---

**Reagents, Supplies and Equipment:**

**Reagents:**

None

**Supplies:**

Appropriate water loading containers

Alcohol wipes

10 ml syringe with appropriate needles for drawing blood

3 ml syringes or pipettes

Large urine specimen collection container

Green stoppered heparinized blood tubes

Stop watch

Plastic transport tubes

Counting tubes

**Equipment:**

Centrifuge Beckman T-J-6

Gamma well counter

**Calibration:**

NA
Quality Control:
1. No external QC is available
2. Internal QC is performed with standards

Stepwise Procedure for $^{125}$I-Glofil GFR:

1. **Patient Preparation**
   1.1. Obtain physician order.
   1.2. Check ID of the patient.
   1.2. Check that the patient is not pregnant or breast feeding.
   1.3. Explain the procedure to the patient.
   1.4. Ask if patient had exposure to radionuclide in past few days.
   1.5. Record patient's height and weight.
   1.6. The patient should be well hydrated.
   1.7. Determine if patient has sensitivity to Iodine preparations (Betadine, I.V.P. dye, etc) before administering Lugol's solution. Give 10 drops Lugol's Solution in 30-50 ml water.
   1.8. Wait 30 minutes.

2. **Radiopharmaceutical Administration:**
   2.1. Have patient void. Save specimen for "background urine." Pour into plastic transport tube. Label: patient name, background urine, and date.
   2.2. Measure patient's blood pressure and record.
   2.3. Inject 15 microCi of $^{125}$I-GloFil **subcutaneously** in deltoid area.
   2.4. Record time injection was given.
   2.5. Calculate water load (20 mg/kg of body weight) and have patient drink the desired amount.

3. **Specimen Collection:**
   3.1. Allow patient to equilibrate 40-60 minutes. Using stopwatch, have patient void and note exact time voiding ceased as first timed clearance.
   3.2. Period #1 (30 minute). Measure urine volume. Discard urine and rinse urine collection container with water. **Give patient water to equal exact amount voided.**
      a. Draw 5-7 ml blood using green heparinized tube at midpoint (15 minutes).
         Label: Period #1
         Name
         Unit #
      b. Collect voided specimen at (30) thirty minutes.
      c. Record exact time voiding ends.
      d. Reset stop watch immediately to begin second timed period.
      e. Measure urine accurately and then pour an aliquot of urine into the plastic tube.
         Label:
         Name
         Unit #
         Period
         Type specimen
         Type volume
f. Give patient water replacement equal to voided volume collected at end of period #1.
   Rinse urine collection container after each measured void in order to prevent an
   increased gamma count in subsequent voided specimens.
Patient's bladder must be emptied completely at each voiding to insure proper count and
flow rate.
Time recorded should be the time the patient completes the void. If the patient starts and
stops voiding several times, record voiding time as the end of the last void. Recording the
exact time voiding stops is very important. Each minute of inaccuracy can effect the
accuracy of the results by as much as 3%.
All specimens sent to the laboratory must be labeled with the patient's name, unit number
and period number. Urine specimens should also be labeled with the total urine volume
for that period.

3.3 Period #2-30 minutes.
a. Draw 5-7 ml blood using green heparinized tube at midpoint (15 minutes).
   Label:  Period #2
   Name
   MRN
b. Collect voided specimen at (30) thirty minutes.
c. Record exact time voiding ends.
d. Reset stop watch immediately to begin third timed period.
e. Measure urine accurately.
f. Give patient water replacement equal to voided volume collected at end of period #2.

3.4 Period #3-30 minutes.
a. Draw 5-7 ml blood using green heparinized tube at midpoint (15 minutes).
   Label:  Period #3
   Name
   MRN
b. Collect voided specimen at (30) thirty minutes.
c. Record exact time voiding ends.
d. Measure urine accurately and then pour an aliquot of urine into the plastic transport
tube.
   Label:  Name
   MRN
   Period #
   Type specimen
   Total volume

3.5 Complete report forms. Record patient's age, height, weight, exact period times, and exact
volume measurements.
3.6 Send labeled samples to nuclear medicine in vitro laboratory.
   Label:  Name
   MRN
   Urine or Plasma
   Period #
   Background Urine/Blood

4. Counting Samples
4.1 Centrifuge blood samples 1500 rpm for 5 min RT
4.2 Pipette 0.5 ml of urine and plasma samples in appropriately labeled counting tubes.

4.3 Put counting tubes in gamma well counting racks in following order:
1. Water background
2. Urine background
3. Urine sample period 1
4. Urine sample period 2
5. Urine sample period 3
6. Plasma background
7. Plasma sample period 1
8. Plasma sample period 2
9. Plasma sample period 3

4.4 Select $^{125}$I-Glofil protocol on gamma well counter and start counting:
- Window: 15-80 keV
- Preset time: 2 minutes

4.5 Write counts on data worksheet.

4.6 Enter data into radiopharmacy computer.

4.7 Attach data worksheet, counting printout to a copy of the patient's report and place in Patient's Results Log Book.

Calculations:
1. For each period of collection, calculate the GFR:
   \[ \text{GFR} = \frac{UV}{P} \]
   Where:
   - \( U \) = urine concentration (cpm)
   - \( V \) = urine flow rate (ml/min)
   - \( P \) = plasma concentration (cpm)

2. Calculate the mean and CV

Reporting Results:
1. Normal values:
   - **In the male:** 125 +/- 15 ml/min
   - **In the female:** 110 +/- 15 ml/min

2. Critical value: none
3. Every instrument printout and data worksheet is compared to final report.
4. The bench technologist will review all results for clerical and analytical errors, document in the Lab Log Book and bring to the attention of the supervisor.
5. Every test is reviewed by the laboratory supervisor and the final report is reviewed and signed by a nuclear medicine physician.
6. Completion turnaround time: 24H
7. Report turnaround time: 24H

Interpretation and Limitations:
1. Timing of blood samples is critical.
2. Patient's hydration status is critical.

Ref: Kidney International 4:346-349, 1973
C14-UREA BREATH TEST FOR HELICOBACTER PYLORI (PY test)

**Indications:** Detection of gastric urease as an aid in the diagnosis of H. Pylori infection

**Principle:** At present H. Pylori is thought to be the causative agent for peptic ulcer disease in approximately 90% of affected patients, and the eradication of H. Pylori infection reduces the recurrence rate of peptic ulcer disease dramatically. The urease enzyme is not present in mammalian cells, so the presence of urease in the stomach is evidence that bacteria are present. The presence of urease is not specific for H. Pylori, but other bacteria are not usually found in the stomach. To detect H. Pylori, urea labeled with $^{14}$C is swallowed by the patient. If gastric urease from H. Pylori is present, urea is split to form CO$_2$ and NH$_3$ and the $^{14}$CO$_2$ is absorbed into the blood and exhaled in the breath, peaking at 10-15 minutes following ingestion. $^{14}$C-urea that is not hydrolyzed by H. Pylori is excreted in the urine with a half-life of 12 hours. About 10% of the $^{14}$C remains in the body at 72 hours and is gradually excreted with a biological half-life of 40 days.

**Examination Time:** 20 minutes for the patient

**Patient Preparation (when scheduling):**

1. Fasting for 6 hours
2. Pregnancy and breastfeeding are relative contraindications (discuss with MD).
3. Patient should be off Pepto-Bismol (bismuth) for one month.
4. Patient should be off antibiotics for one month.
5. Patient should be off Carafate (sucralfate) for 2 weeks.
6. Patient should be off proton pump inhibitors for 2 weeks: Prilosec (omperazole), Prevacid/PrevPac (lansoprazole), and Protonix (pantoprazole).
7. Pediatric patients must be able to swallow the intact capsule and blow through a straw.

**Radiopharmaceutical:** 1 microCi $^{14}$C urea capsule by mouth

**Specimen Collection:**

1. Type: breath
2. Amount: fill the Mylar collection balloon completely
3. Inadequate sample: patient unable to fill balloon completely
4. Container: Mylar collection balloon supplied by manufacturer
5. Unacceptable specimen: balloon is incompletely filled or the amount of CO$_2$ in the balloon is inadequate to effect a color change when mixed with the collection fluid

**Reagents:** None
Supplies:

1. Breath test report form
2. One 20 ml scintillation vial
3. Pipette (10 ml)
4. Collection fluid (2.5 ml/vial)
5. Scintillation fluid (10 ml/vial)
6. One Mylar collection balloon
7. One straw
8. Two needles
9. Water (40 ml)

Equipment:

1. Breath transfer pump
2. Liquid scintillation counter
3. Stopwatch or timer
4. Marking pen

Calibration: A positive and a negative standard are supplied by the manufacturer.

Quality Control:

1. A minimum of 1 mmole of CO$_2$ is required to perform analysis of a breath sample. The amount of breath required to provide 1 mmole of CO$_2$ varies depending on the amount of CO$_2$ the patient is producing. Since a full balloon typically contains at least 1 mmole of CO$_2$, the balloon should be completely filled.
2. No external QC is available.
3. Internal QC is performed with standards.

Procedure:

1. The patient should be sitting at rest during the test.
2. The capsule should not be handled directly.
3. To avoid contamination by bacteria in the mouth, the capsule should be swallowed intact.
4. Label balloon, fill in breath test report form, and ensure that all materials are present.
5. Drop the capsule into the cup.
6. Ask the patient to swallow the capsule with 20 ml water and start stopwatch.
7. Ask the patient to drink an additional 20 ml water at 3 minutes.
8. At 10 minutes, ask the patient to completely inflate the balloon via the inserted straw.
9. Tie the neck of the balloon tightly and discharge the patient.
Analysis:

1. Use scintillation and collection fluid supplied by the manufacturer.
2. Label the vial and add 2.5 ml collection fluid.
3. Attach needles and start pump.
4. Place outlet needle into the vial and inlet needle into the balloon.
5. Stop when the fluid turns colorless.
6. Add 10 ml scintillation fluid, mix, and count for 5 minutes.
7. Include a standard and blank control in each run.
8. Complete the report form.

Reporting Results:

1. Complete the report form for sample and blank dpm and calculate the sample background-corrected counts by subtracting the blank dpm from the sample dpm.
2. The Bench technologist will review all results for clerical and analytical errors, document in the Lab Log Book and review the report with the Laboratory supervisor.
3. The final report is reviewed and signed by a nuclear medicine physician.
4. Completion turnaround time: <three hours
5. Report turnaround time: same day results communicated to the referring physician

Interpretation and Limitations of Results (10 minute sample):

- <50 dpm     Negative for Helicobacter pylori
- 50-199 dpm  Indeterminate for Helicobacter pylori
- >199 dpm    Positive for Helicobacter pylori

The indeterminate result should be evaluated by repeating the test or using an alternative diagnostic method. If repeat breath testing is undertaken, careful history to exclude confounding factors should be obtained. If confounding factors are identified, wait an appropriate time before repeating the test.

Factors That May Cause Sub-optimal Breath Test Results

<table>
<thead>
<tr>
<th>Factor</th>
<th>Result</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent antibiotic or bismuth</td>
<td>False negative</td>
<td>Relapse of partially treated HP may take 1-4 weeks.</td>
</tr>
<tr>
<td>Proton pump inhibitors (omperazol/Prilosec)</td>
<td>False negative</td>
<td>Suppress HP in 40% of pts. Stop for at least 2 weeks.</td>
</tr>
<tr>
<td>pantoprazole/Protonix)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(lansoprazole/Prevacid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resective gastric surgery</td>
<td>False negative</td>
<td>Isotope may empty rapidly from stomach.</td>
</tr>
<tr>
<td>Resective gastric surgery</td>
<td>False positive</td>
<td>Achlorhydric patients may have bacterial overgrowth, non-HP urease producing.</td>
</tr>
</tbody>
</table>
Food in stomach: Unknown Isotope may not come into contact with gastroparesis, bezoar gastric mucosa; patient may be achlorhydric

C-14 UREA BREATH TEST REPORT

Name:............................................................ Date:________

MRN:............................................................

HISTORY:  Ulcer Gastrectomy Fasting
Antibiotics stopped ________________ Bismuth stopped ______
Prilosec/Protonix stopped ________________ Carafate stopped ______

RADIOPHARMACEUTICAL: 1 uCi C-14 urea by mouth

COUNTS: Sample __________ dpm  Blank ______________________ dpm

BACKGROUND-CORRECTED COUNTS: __________________________ dpm

Interpretation of Results (10 minute sample):
<50 dpm  Negative for Helicobacter pylori
50-199 dpm  Indeterminate for Helicobacter pylori
>199 dpm  Positive for Helicobacter pylori

The indeterminate result should be evaluated by repeating the test or using an alternative diagnostic method. If repeat breath testing is undertaken, careful history to exclude confounding factors should be obtained. If confounding factors are identified, wait an appropriate time before repeating the test.

Factors Which May Cause Sub-optimal Breath Test Results

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<td>False negative</td>
<td>Isotope may empty rapidly from stomach.</td>
</tr>
<tr>
<td>Resective gastric surgery</td>
<td>False positive</td>
<td>Achlorhydic patients may have bacterial overgrowth, non-HP urease producing.</td>
</tr>
<tr>
<td>Food in stomach; Gastroparesis</td>
<td>Unknown</td>
<td>Isotope may not come into contact with mucosa; patient my be achlorhydic.</td>
</tr>
</tbody>
</table>

Dictation: A breath sample was collected ten minutes after ingestion of 1 uCi of C14-urea and count rate determined using a liquid scintillation chamber.

Impression: Elevated C14-CO₂ expired consistent with GI Helicobacter pylori infection
Radiopharmaceutical Doses
Doses should be within range given below (administered dose must be +/- 10%)

<table>
<thead>
<tr>
<th>Organ</th>
<th>Scan</th>
<th>Agent</th>
<th>activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bone</td>
<td>Bone Scan</td>
<td>$^{99m}$Tc-HDP</td>
<td>20 mCi</td>
</tr>
<tr>
<td></td>
<td>Bone marrow</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>8 mCi</td>
</tr>
<tr>
<td>2. Brain</td>
<td>Brain scan</td>
<td>$^{99m}$Tc-glucoheptonate</td>
<td>25 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-Ceretec (HMPAO)</td>
<td>20 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-Neurolite (ECD)</td>
<td>20 mCi</td>
</tr>
<tr>
<td>3. CSF</td>
<td>Cisternogram</td>
<td>$^{111}$In DTPA</td>
<td>0.5 mCi</td>
</tr>
<tr>
<td></td>
<td>Shuntogram</td>
<td>$^{99m}$Tc-DTPA</td>
<td>1.5 mCi</td>
</tr>
<tr>
<td>4. Kidney</td>
<td>Profile</td>
<td>$^{99m}$Tc-DTPA-GFR</td>
<td>1.0 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-DTPA-bolus</td>
<td>20 mCi</td>
</tr>
<tr>
<td></td>
<td>DMSA scan</td>
<td>$^{99m}$Tc-DMSA</td>
<td>5 mCi</td>
</tr>
<tr>
<td></td>
<td>DTPA flow</td>
<td>$^{99m}$Tc-DTPA</td>
<td>15 mCi</td>
</tr>
<tr>
<td></td>
<td>Tc04</td>
<td>$^{99m}$Tc04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gluco Renogram</td>
<td>$^{99m}$Tc-Gluco</td>
<td>15 mCi</td>
</tr>
<tr>
<td></td>
<td>MAG3</td>
<td>$^{99m}$Tc-MAG3</td>
<td>10 mCi</td>
</tr>
<tr>
<td>Bladder</td>
<td>Cystogram</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>5 mCi</td>
</tr>
<tr>
<td>5. Thyroid</td>
<td>Thyroid scan</td>
<td>$^{99m}$Tc-04</td>
<td>10 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{123}$I Na I</td>
<td>0.2-0.5 mCi</td>
</tr>
<tr>
<td></td>
<td>Parathyroid</td>
<td>$^{99m}$Tc sestamibi</td>
<td>20 mCi</td>
</tr>
<tr>
<td>6. Lung</td>
<td>Perfusion/venogram</td>
<td>$^{99m}$Tc-MAA</td>
<td>4 mCi</td>
</tr>
<tr>
<td></td>
<td>Ventilation</td>
<td>$^{99m}$Tc-DTPA aerosol</td>
<td>30-40 mCi</td>
</tr>
<tr>
<td></td>
<td>DVT</td>
<td>$^{99m}$Tc-aptide</td>
<td>25-30 mCi</td>
</tr>
<tr>
<td></td>
<td>Xenon133</td>
<td></td>
<td>4-30 mCi</td>
</tr>
<tr>
<td>7. Liver</td>
<td>Liver/spleen scan</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>5 mCi</td>
</tr>
<tr>
<td></td>
<td>Hepatobiliary</td>
<td>$^{99m}$Tc-Disida (PRIDA)</td>
<td>4 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc-mebrofenin</td>
<td>4 mCi</td>
</tr>
<tr>
<td></td>
<td>Hepatic perfusion</td>
<td>$^{99m}$Tc-MAA</td>
<td>3 mCi</td>
</tr>
<tr>
<td>8. Esophagus-stomach</td>
<td>Gastric reflux</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>0.5 mCi</td>
</tr>
<tr>
<td></td>
<td>Gastric emptying</td>
<td>$^{99m}$Tc-sulfur colloid</td>
<td>0.5 mCi</td>
</tr>
<tr>
<td>9. GI</td>
<td>GI blood</td>
<td>$^{99m}$Tc-RBCs20 mCi</td>
<td>20-25 mCi</td>
</tr>
<tr>
<td>10. Meckel's diverticulum</td>
<td>Meckel's</td>
<td>$^{99m}$Tc04</td>
<td>5 mCi</td>
</tr>
<tr>
<td>11. Abscess</td>
<td>Gallium scan</td>
<td>$^{67}$Ga citrate</td>
<td>5-11 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{111}$In leukocytes</td>
<td>0.3-0.7 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc- HMPAO-WBC</td>
<td>20-27 mCi</td>
</tr>
<tr>
<td>12. Scrotal scan</td>
<td>scrotal scan</td>
<td>$^{99m}$Tc04</td>
<td>15 mCi</td>
</tr>
<tr>
<td>13. Lymphangiography</td>
<td>sentinel node Dx</td>
<td>$^{99m}$Tc -SC filtered</td>
<td>0.3-0.6 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}$Tc -SC filtered</td>
<td>0.2-0.8 mCi</td>
</tr>
<tr>
<td>14. Heart</td>
<td>myocardial infarct</td>
<td>$^{99m}$Tc-pyrophosphate</td>
<td>20 mCi</td>
</tr>
<tr>
<td></td>
<td>Perfusion</td>
<td>$^{203}$TI chloride</td>
<td>4 mCi</td>
</tr>
<tr>
<td></td>
<td>RVG</td>
<td>$^{99m}$Tc 04</td>
<td>15-25 mCi</td>
</tr>
<tr>
<td></td>
<td>Perfusion</td>
<td>$^{99m}$Tc sestamibi</td>
<td>7-30 mCi</td>
</tr>
<tr>
<td></td>
<td>Perfusion</td>
<td>$^{99m}$Tc tetrofosmin</td>
<td>7-30 mCi</td>
</tr>
<tr>
<td></td>
<td>Viability</td>
<td>$^{18}$FDG</td>
<td>8-11 mCi</td>
</tr>
<tr>
<td>15. Schilling</td>
<td>Schilling</td>
<td>$^{57}\text{Co}$</td>
<td>0.3-0.9 microCi</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------</td>
<td>------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>16. Blood volume</td>
<td>Red cell mass</td>
<td>$^{51}\text{chromium}$</td>
<td>30 microCi</td>
</tr>
<tr>
<td>Plasma volume</td>
<td>$^{125}\text{I HSA}$</td>
<td>10 microCi</td>
<td></td>
</tr>
<tr>
<td>17. Tumor imaging</td>
<td>Octreoscan</td>
<td>$^{111}\text{In-octreotide}$</td>
<td>5-7 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{99m}\text{Tc sestamibi}$</td>
<td>25 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{201}\text{Tl chloride}$</td>
<td>4 mCi</td>
</tr>
<tr>
<td></td>
<td>Thyroid</td>
<td>$^{131}\text{I Na I}$</td>
<td>10 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{131}\text{I MIBG}$</td>
<td>0.3-1.0 mCi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$^{67}\text{Ga citrate}$</td>
<td>7-11 mCi</td>
</tr>
<tr>
<td></td>
<td>Lymphoma</td>
<td>$^{111}\text{In Zevalin}$</td>
<td>4-6 mCi</td>
</tr>
<tr>
<td></td>
<td>Prostate</td>
<td>$^{111}\text{In ProstaScint}$</td>
<td>4-7 mCi</td>
</tr>
<tr>
<td></td>
<td>Myeloma</td>
<td>$^{166}\text{Ho DOTMP}$</td>
<td>25-35 mCi</td>
</tr>
<tr>
<td></td>
<td>Lymphoma</td>
<td>$^{131}\text{I Bexxar}$</td>
<td>4-6 mCi</td>
</tr>
<tr>
<td>18. Therapy</td>
<td>Hyperthyroidism</td>
<td>$^{131}\text{I Na I}$</td>
<td>6-60 mCi</td>
</tr>
<tr>
<td></td>
<td>Thyroid cancer</td>
<td>$^{131}\text{I Na I}$</td>
<td>29-330 mCi</td>
</tr>
<tr>
<td></td>
<td>Bone mets</td>
<td>$^{90}\text{Sr}$</td>
<td>3-5 mCi</td>
</tr>
<tr>
<td></td>
<td>Bone mets</td>
<td>$^{153}\text{Samarium}$</td>
<td>10 mCi</td>
</tr>
<tr>
<td></td>
<td>Myeloma</td>
<td>$^{32}\text{P sodium phosphate}$</td>
<td>3-7 mCi</td>
</tr>
<tr>
<td></td>
<td>Various</td>
<td>$^{32}\text{P chromic phosphate}$</td>
<td>0.1-16 mCi</td>
</tr>
<tr>
<td></td>
<td>Myeloma</td>
<td>$^{166}\text{Ho DOTMP}$</td>
<td>1200-2200 mCi</td>
</tr>
<tr>
<td></td>
<td>Lymphoma</td>
<td>$^{131}\text{I Bexxar}$</td>
<td>50-120 mCi</td>
</tr>
<tr>
<td></td>
<td>Lymphoma</td>
<td>$^{90}\text{Y Zevalin}$</td>
<td>0.3-0.4 mCi/kg (&lt;33 mCi)</td>
</tr>
<tr>
<td></td>
<td>Liver neoplasm</td>
<td>$^{90}\text{Y SirSpheres}$</td>
<td>30-90 mCi</td>
</tr>
</tbody>
</table>
F18-NaFlouride PET/CT Protocol

- Indications: Evaluation of skeletal metastasis (extent/localization)
- Procedure
  - Document relevant history
    - Type of primary, location of primary
    - Prior surgery, especially orthopedic surgery
    - Prior trauma/broken bones
  - Obtain prior relevant Radiology reports with images
  - Patient Preparation
    - Confirm patient is well hydrated
      - 2 8oz glasses of water 1 hour before imaging
      - 2 8 glasses oz (or more) glasses of water after injection
        - Avoid if severe heart failure or renal failure
      - Patient does not need to be NPO, follow a special diet, or modify medications. No need for glucose monitoring
    - Venous access per standard protocol
    - Direct injection of 5-10 mCi of NaF\textsuperscript{18}
      - Higher dose range preferred in overtly obese patients
      - Consult Radiologist for Pediatric dose (in SNM guidelines attached)
      - Patient does not need to be in uptake room for uptake phase. However, it is generally preferred that they be placed in such a room to decrease dose to personnel.
    - Imaging to begin 30-45 minutes after injection
      - Patient must void immediately prior to scan. Urinary catheterization may be required if incontinent.
    - Approximately 3 minutes/stop for BGO scanner; 2 minutes/stop for LSO scanner
      - May need to be adjusted depending on specific PET/CT scanner characteristics and patient characteristics. Increase time/stop for obese patients
      - CT scan should be performed with low dose/low mas technique per ALARA (Effective dose typically well below less than 80 mSv, and more typically 3.2 mSv with 120kev and 30mA).
      - Vertex of skull through proximal thighs
        - **NOTE: If there is a known concern for disease elsewhere, that site needs to be included!**
  - Interpretation guidelines:
    - SUV’s DO NOT APPLY and should not be reported
    - Uptake is similar to Tc99m bonescans but is significantly more sensitive and is sensitive for both lytic and blastic processes (although slightly less sensitive for purely lytic lesions, it is still felt to be more sensitive than conventional bonescans).
    - As with conventional bonescans, degenerative/arthritic uptake is frequently seen. The CT portion is helpful with this. The degree of uptake may NOT be helpful in differentiating benign from malignant conditions.
References:

SNM Practice Guidelines for Sodium F\textsuperscript{18}-Flouride PET/CT Bone Scans 1.0 (Attached)

SNM Webinar:


SNM Guideline for Sodium \textsuperscript{18}F-Fluoride PET/CT Bone Scans

Society of Nuclear Medicine (SNM) is an international scientific and professional organization founded in 1954 to promote the science, technology and practical application of nuclear medicine. Its 16,000 members are physicians, technologists and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters and books, the Society also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine.

The SNM will periodically define new procedure 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 procedure guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each procedure guideline, representing a policy statement by the Society, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Committee on SNM Guidelines, Health Policy and Practice Commission, and SNM Board of Directors. The procedure guidelines recognize that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published procedure guideline by those entities not providing these services is not authorized.

THE SNM PRACTICE GUIDELINE FOR SODIUM \textsuperscript{18}F-FLUORIDE PET/CT BONE SCANS 1.1

PREAMBLE

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 Society of Nuclear Medicine (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, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach 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.

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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

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 assure 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

18F-Fluoride is a highly sensitive bone-seeking PET tracer used for detection of skeletal abnormalities (1). The uptake mechanism of 18F-Fluoride resembles that of Tc-99m MDP with better pharmacokinetic characteristics including faster blood clearance and two-fold higher uptake in bone. Uptake of 18F-Fluoride reflects blood flow and bone remodeling. The use of novel hybrid PET/CT systems, has significantly improved the specificity of 18F-Fluoride imaging as the CT component of the study allows morphologic characterization of the functional lesion and more accurate differentiation between benign lesions and metastases.

II. GOALS

The purpose of this information is to assist health care professionals in performance, interpretation, and reporting the results of PET/CT bone scans performed with 18F-Fluoride. Variable institutional factors and individual patient considerations make it impossible to create procedures applicable to all situations, or for all patients.

III. DEFINITIONS

18F is a diagnostic molecular imaging agent used for identification of new bone formation. 18F administered as i.v. Na18F was approved by the United States Food and Drug Administration in 1972, but has been listed as a discontinued drug since 1984. In 2000, the FDA listed it in the Orange Book for discontinued drug products. The original approval in 1972 may be used as a basis to reapply for marketing approval via a New Drug Application (NDA) or Abbreviated New Drug Application (ANDA). Several clinical trials are currently using Na18F with Investigational New Drug exemptions. The National Cancer Institute filed an NDA in December 2008, with a different potency and dose than the original NDA. At the present time, Na18F is currently manufactured and distributed for clinical use by authorized user prescription under state laws of pharmacy. In December 2011, Na18F for clinical use will have to be prepared under NDA or ANDA and meet the cGMP requirements of 21 CFR 212.

PET/CT is a molecular imaging technology that combines cross-sectional functional and anatomic imaging for diagnosis.

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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

PET/CT may be limited to a single anatomic region such as head and neck, thorax, or abdomen and pelvis; may include the body between the skull base and middle of the thighs; or image the entire body from the top of the head to the toes.

IV. EXAMPLES OF CLINICAL AND RESEARCH INDICATIONS

A. No appropriateness criteria have been developed to date for this procedure. B. PET/CT18Fbonescansmaybeusedtoidentifytheskeletalmetastases,including localization and determination of the extent of disease. (2-18)

C. Insufficient information exists to recommend the following indications in all patients, but may be appropriate in certain individuals:

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.

Back pain (19,20) and otherwise unexplained bone pain (21) Child abuse (22,23) Abnormal radiographic or laboratory findings Osteomyelitis
Obtained without CT for attenuation correction. It is possible to survey the whole body with emission-only images, NaF PET in patients with metastatic osteoblastic metastases. Several reports have shown an improvement in sensitivity of the NaF PET over planar 99mTc bone scintigraphy in patients with metastatic osteoblastic metastases. The addition of CT also appears to improve the specificity of NaF PET.(4,5) Due to the high bone to soft tissue activity ratio of 18F bone scans, high quality images may be obtained without CT for attenuation correction. It is possible to survey the whole body with emission-only images.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL
See Section V. of the SNM Procedure Guideline for General Imaging. See SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

VI. PROCEDURE/SPECIFICATION OF THE EXAMINATION

VI.A. Nuclear Medicine Request
The request for the examination should include sufficient medical information to demonstrate medical necessity, and should include the diagnosis, pertinent history, and questions to be answered.

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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans
The medical record should be reviewed. A history of trauma, orthopedic surgery, cancer, osteomyelitis, arthritis, radiation therapy and other localized conditions affecting the bony skeleton may affect the distribution of 18F. Relevant laboratory tests, such as prostate-specific antigen (PSA) in patients with prostate cancer, and alkaline phosphatase, should be considered.

The results of prior imaging studies should be reviewed, including plain film x-ray, CT, MR, bone scan, and FDG PET/CT. Relevant prior studies should be directly compared to current imaging findings when possible.

VI.B. Patient Preparation and Precautions

1. Pregnancy and breastfeeding: See Section III of SNM Procedure Guideline for General Imaging. Exams involving ionizing radiation should be avoided in pregnant women, unless the potential benefits outweigh the radiation risk to the mother and fetus.

2. Patients should be well hydrated to promote rapid excretion of the radiopharmaceutical to decrease radiation dose and to improve image quality. Unless contraindicated, patients should drink two or more 8-ounce (224 mL) glasses of water within 1 hour prior to the examination, and another two or more 8-ounce glasses of water after administration of 18F. Patients should be instructed to empty their bladder immediately before imaging. Appropriate precautions for proper disposal of radioactive urine should be taken in patients who are incontinent.

3. Patients do not need to fast, and may take all their usual medications. The impact of treatments such as diphosphonates, anti-hormonal therapy, chemotherapeutic and radiotherapy on the uptake of 18F and the role of 18F PET/CT in monitoring response to therapy is yet to be determined (35, 36).

VI.C. Radiopharmaceutical

18F-Fluoride is injected intravenously by direct venipuncture or intravenous catheter. The adult activity is 185-370 MBq (5-10 mCi). A higher activity (370 MBq, 10 mCi) may be used in obese patients. Pediatric activity should be weight-based (2.22 MBq/kg, 0.06 mCi/kg), using a minimum and maximum activity of 18.5 to 185 MBq (0.5 to 5 mCi).

VI.D. Protocol/Image Acquisition

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

1. Patient positioning

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

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VI.E. Patient Preparation and Precautions

1. Pregnancy and breastfeeding: See Section III of SNM Procedure Guideline for General Imaging. Exams involving ionizing radiation should be avoided in pregnant women, unless the potential benefits outweigh the radiation risk to the mother and fetus.

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VI.F. Protocol/Image Acquisition

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

1. Patient positioning

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

4
SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

The medical record should be reviewed. A history of trauma, orthopedic surgery, cancer, osteomyelitis, arthritis, radiation therapy and other localized conditions affecting the bony skeleton may affect the distribution of 18F. Relevant laboratory tests, such as prostate-specific antigen (PSA) in patients with prostate cancer, and alkaline phosphatase, should be considered.

The results of prior imaging studies should be reviewed, including plain film x-ray, CT, MR, bone scan, and FDG PET/CT. Relevant prior studies should be directly compared to current imaging findings when possible.

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The request for the examination should include sufficient medical information to demonstrate medical necessity, and should include the diagnosis, pertinent history, and questions to be answered.

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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

The medical record should be reviewed. A history of trauma, orthopedic surgery, cancer, osteomyelitis, arthritis, radiation therapy and other localized conditions affecting the bony skeleton may affect the distribution of 18F. Relevant laboratory tests, such as prostate-specific antigen (PSA) in patients with prostate cancer, and alkaline phosphatase, should be considered.

The results of prior imaging studies should be reviewed, including plain film x-ray, CT, MR, bone scan, and FDG PET/CT. Relevant prior studies should be directly compared to current imaging findings when possible.

VIII.B. Patient Preparation and Precautions

1. Pregnancy and breastfeeding: See Section III of SNM Procedure Guideline for General Imaging. Exams involving ionizing radiation should be avoided in pregnant women, unless the potential benefits outweigh the radiation risk to the mother and fetus.

2. Patients should be well hydrated to promote rapid excretion of the radiopharmaceutical to decrease radiation dose and to improve image quality. Unless contraindicated, patients should drink two or more 8-ounce (224 mL) glasses of water within 1 hour prior to the examination, and another two or more 8-ounce glasses of water after administration of 18F. Patients should be instructed to empty their bladder immediately before imaging. Appropriate precautions for proper disposal of radioactive urine should be taken in patients who are incontinent.

3. Patients do not need to fast, and may take all their usual medications. The impact of treatments such as diphosphonates, anti-hormonal therapy, chemotherapeutic and radiotherapy on the uptake of 18F and the role of 18F PET/CT in monitoring response to therapy is yet to be determined (35, 36).

VIII.F. Protocol/Image Acquisition

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

1. Patient positioning

See also the SNM Procedure Guideline for Tumor Imaging with 18F-FDG PET/CT.

4
SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

The medical record should be reviewed. A history of trauma, orthopedic surgery, cancer, osteomyelitis, arthritis, radiation therapy and other localized conditions affecting the bony skeleton may affect the distribution of 18F. Relevant laboratory tests, such as prostate-specific antigen (PSA) in patients with prostate cancer, and alkaline phosphatase, should be considered.

The results of prior imaging studies should be reviewed, including plain film x-ray, CT, MR, bone scan, and FDG PET/CT. Relevant prior studies should be directly compared to current imaging findings when possible.
and then acquire additional images, as needed, using PET/CT of a limited area. The diagnostic accuracy of this approach has not been studied.

3. Protocol for PET emission imaging
   a. 
   b. 
   c. Emission images of the axial skeleton may begin as soon as 30-45 minutes after administration of the radiopharmaceutical in patients with normal renal function, due to the rapid localization of $^{18}$F in the skeleton and rapid clearance from the circulation. There have not been any studies looking at image quality or accuracy with a longer delay. It is necessary to wait longer to obtain high quality images of the extremities, with a start time of 90-120 minutes for whole body imaging, or imaging limited to the arms or legs. Images may be acquired in 2D or 3D mode. 3D mode is recommended for whole body imaging because higher count rates compensate for short acquisition times required for imaging a large area. Acquisition time per bed position will vary depending on the amount of injected radioactivity, decay time, body mass index, and camera factors. Typical acquisition times are 2-5 minutes per bed position.

   In a patient with normal body mass index, good images of the axial skeleton may be obtained with an acquisition time of 3 minutes/bed position starting 45 minutes after injection of 185 MBq (5 mCi) of $^{18}$F. Good whole body images may be obtained with an acquisition time of 3 minutes/bed position starting 2 hours after injection of 370 MBq (10 mCi) of $^{18}$F.

5. SNM Guideline for Sodium $^{18}$F-Fluoride PET/CT Bone Scans

4. Intervention
   Intense urinary bladder tracer activity degrades image quality and can confound interpretation of findings in the pelvis. Hydration and a loop diuretic, without or with bladder catheterization, may be used to reduce accumulated urinary tracer activity in the bladder.

5. Processing
   See SNM Procedure Guideline for Tumor Imaging with $^{18}$F-FDG PET/CT 1.0 and reference (37).
   Images are typically acquired in a 128 x 128 matrix, although a 256 x 256 matrix may be advantageous if processing times are reasonable. Commercially available software packages for iterative reconstruction are widely available. The optimal number of iterations and subsets, filters, and other reconstruction parameters will depend on patient and camera factors. In general, the same reconstruction protocols used for imaging $^{18}$F-fluorodeoxyglucose PET may be used for $^{18}$F. Maximum intensity projection (MIP) images should be generated to help facilitate lesion detection. Combination imaging with simultaneous $^{18}$F-FDG and $^{18}$F injection has been reported (38-40) although there is not enough evidence to support its use in routine clinical practice, and there is some suggestion that it may lead to confusion in interpretation due to uncertainty in separating the contribution of each radiopharmaceutical, e.g. in post-therapy “flare” phenomenon, in patients on colony-stimulating factor medications, and in patients with marrow metastases in which $^{18}$F-FDG uptake may be obscured by adjacent cortical $^{18}$F activity. (41)

VI.E. Interpretation Criteria
   See also the SNM procedure Guideline for Bone Scintigraphy.

$^{18}$F is normally distributed throughout the entire skeleton. The major route of excretion is the urinary tract. Kidneys, ureters, and bladder should be visible in the absence of renal insufficiency. The degree of localization in the urinary tract depends on renal function, state of hydration, and interval between administration of $^{18}$F and imaging. Renal insufficiency will decrease localization in the urinary tract. Urinary outflow obstruction will increase localization proximal to the site of obstruction. Chronic severe obstruction, however, may reduce localization. Soft tissue activity reflects the amount of circulating $^{18}$F in the blood pool at the time of imaging, and should be minimal. Local or regional hyperemia may cause increased visualization of the soft tissues.

$^{18}$F localization in the skeleton is dependent on regional blood flow, as well as new bone formation. $^{18}$F is substituted for hydroxyl groups in hydroxyapatite, and covalently bonds to the surface of new bone. Uptake is higher in new bone (osteoid) due to higher availability of binding sites. Local or regional hyperemia may also cause increased localization in the skeleton. Physiologic $^{18}$F uptake in the skeleton is generally uniform in adults. Normal growth causes increased localization in the metaphyses of children and adolescents. Symmetrical uptake between the left and right sides is generally observed in individuals of all ages, except in periarticular sites where $^{18}$F uptake can be variable. Nearly all causes of increased new bone formation cause increased localization of $^{18}$F. The degree of increased...
localization is dependent on many factors including blood flow, and amount of new bone formation. Processes that result in minimal osteoblastic activity, or primarily osteolytic activity, may not be detected. In general, the degree of 18F uptake does not differentiate benign from malignant processes. The pattern of 18F uptake, however, may be suggestive or even characteristic of a specific diagnosis. Correlation with skeletal radiographs and other anatomic imaging is essential for diagnosis. The CT component of PET/CT, even when performed primarily for attenuation correction and anatomic registration, also provides diagnostic information. Any degree of 18F uptake that is visibly higher or lower than uptake in adjacent bone, or uptake in the corresponding contralateral region, indicates an alteration in bone metabolism. Due to the higher resolution of PET/CT compared to single photon imaging, physiologic variability is more prominent. Subclinical joint disease commonly causes increased periarticular 18F uptake that may be asymmetric, and occurs anywhere in the body, especially in the small bones of the spine and the hands and feet. Dental disease commonly causes increased periodontal 18F uptake. Subclinical injury (especially the ribcage and costochondral junctions) may cause increased 18F uptake. The use of quantitative indices, such as standardized uptake value (SUV), has not been validated, and their value in clinical studies is undefined. Quantitative assessment of bone metabolism using kinetic modeling has been described, but requires dynamic imaging of the skeleton at one bed position up to one hour post-injection. Accurate interpretation requires correlation with clinical history, symptoms, prior imaging studies, and other diagnostic tests.

VII. DOCUMENTATION/REPORTING

VII. A. Goals of a report

See Section VII. A of the SNM Procedure Guideline for General Imaging.

VII.B. Direct Communication

See Section VII. B of the SNM Procedure Guideline for General Imaging.

VII.C. Written Communication

See ACR Practice Guidelines for Communication of Diagnostic Imaging Findings. See Section VII. C of the SNM Procedure Guideline for General Imaging.

VII.D Contents of the report

See Section VII. D of the SNM Procedure Guideline for General Imaging

1. Study identification

The report should include the full name of the patient, medical record number, and date of birth. The name of the examination should also be included, with the date and time it is performed. The electronic medical record provides this data, as well as a unique study number.

2. Clinical information

At a minimum, the clinical history should include the reason for referral, and the specific question to be answered. If known, the diagnosis and a brief treatment history should be provided. The results of relevant diagnostic tests and prior imaging findings should be summarized.

3. Procedure description

The type and date of comparison studies should be stated. If no comparison studies are available, a statement should be made to that effect. Study specific information should include the name of the radiopharmaceutical (sodium 18F-fluoride), dose in megabecquerels (MBq) or millicuries (mCi), route of administration

VIII. SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

(intravenous), as well as the date and time of administration. The site of administration is optional. The name, dose, and route of administration of non-radioactive drugs and agents should also be stated. The type of camera should be specified, but specific equipment information is optional. A description of the procedure should include the time the patient was scanned, or the time interval between
administration of $^{18}$F and the start time of the scan. The part of the body that is scanned should be described from the starting to the ending point. The position of the patient (supine or prone), and the position of the arms (elevated or by the sides) should be stated if non-standard.

Description of the CT part of the examination may be limited to a statement that CT was performed for attenuation correction and anatomic registration of the emission images. If CT was optimized for diagnosis, then a more complete description of the protocol should be provided.

Routine processing parameters are usually not stated in the report, but any special circumstances requiring additional processing, such as motion correction, should be described.

4. Description of the findings

Significant findings should be described in a logical manner. Findings may be grouped by significance, or described by body region. An integrated PET/CT report is preferred, although CT optimized for diagnosis may be reported separately.

The location and extent of significant findings should be described. The information should include the name of the bone. At a minimum, extent should be described as focal or diffuse. Designation of the involved anatomic subdivision of a bone should be included, if appropriate. The appearance of the corresponding finding on CT should be described (e.g., normal, sclerotic, lucent, lytic, blastic, or mixed). The size of focal lesions measured on CT should be reported in at least one axial dimension if this information is clinically important. The description of significant abnormalities may also include a description of the relative level of $^{18}$F uptake, but there is no standard nomenclature. Standardized uptake value (SUV) may be used as a purely descriptive means of reporting, but the measurement should not be used to render a specific diagnosis.

Uptake in the urinary tract and soft tissues should be described. Significant non-skeletal CT findings should also be described as fully as possible.

Limitations should be addressed. Where appropriate, identify factors that can limit the sensitivity and specificity of the examination.

The report should address or answer any pertinent clinical questions raised in the request for imaging examination.

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SNM Guideline for Sodium $^{18}$F-Fluoride PET/CT Bone Scans

Comparisons with previous examinations and reports, when possible, should be a part of the imaging consultation and report. Integrated PET/CT studies are more valuable when correlated with previous diagnostic CT, previous PET, previous PET/CT, previous MRI, and all appropriate imaging studies and clinical data that are relevant.

5. Impression

a. A precise diagnosis should be given whenever possible.

b. A differential diagnosis should be given when appropriate.

c. When appropriate, recommend follow-up and additional diagnostic studies to clarify or confirm the impression.

VIII. EQUIPMENT SPECIFICATIONS

See SNM Procedure Guideline for Tumor Imaging with $^{18}$F-FDG PET/CT.

See ACR section on “Equipment specifications” and “Quality Control” from the ACR Practice Guideline for the Performance of Computed Tomography of the Extracranial Head and Neck in Adults and Children, ACR Practice Guideline for the Performance of Pediatric and Adult Thoracic Computed Tomography (CT), ACR Practice Guideline for the Performance of Computed Tomography (CT) of the Abdomen and Computed Tomography (CT) of the Pelvis.

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

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR and SNM Policies on Quality Control, and Patient Education where appropriate.

In all patients, the lowest exposure factors should be chosen that would produce images of diagnostic quality.

Equipment performance monitoring should be in accordance with ACR Technical Standards for Medical Nuclear Physics Performance Monitoring of PET/CT Imaging Equipment.

See SNM Procedure Guideline for General Imaging. See SNM Procedure Guidelines for Use of Radiopharmaceuticals. See SNM Procedure Guidelines for Tumor Imaging with $^{18}$F-FDG PET/CT.

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SNM Guideline for Sodium $^{18}$F-Fluoride PET/CT Bone Scans

X. RADIATION SAFETY IN IMAGING

See also Section X of the SNM Procedure Guideline for General Imaging.
The effective dose for $^{18}$F is 0.024 mSv/MBq (0.089 mrem/mCi). For a typical activity of 370 MBq (10 mCi), the effective dose is 10 mSv (1 rem).

For comparison, the effective dose for $^{99m}$Tc-methylene diphosphonate (MDP) is 0.0057 mSv/MBq (0.021 rem/mCi). For a typical activity of 925 MBq (25 mCi), the effective dose is 5.3 mSv (0.53 rem).

Thus, the radiation dose to patients is approximately 70% higher using $^{18}$F-fluoride ($370 \times 0.024 = 8.9$ mSv) compared to $^{99m}$Tc-MDP.

**Table 1: Radiation Dose Comparison between $^{18}$F-fluoride and $^{99m}$Tc-MDP**

<table>
<thead>
<tr>
<th></th>
<th>$^{18}$F-fluoride</th>
<th>$^{99m}$Tc-MDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.22 mGy/MBq Bladder* (0.81 rad/mCi)</td>
<td>0.063 mGy/MBq Bone Surfaces (0.23 rad/mCi)</td>
<td></td>
</tr>
<tr>
<td>0.024 mSv/MBq (0.089 rem/mCi)</td>
<td>0.0057 mSv/MBq (0.021 rem/mCi)</td>
<td></td>
</tr>
<tr>
<td>2.22 MBq/kg (0.06 mCi/kg)</td>
<td>7.11 MBq/kg (0.2-0.3 mCi/kg)</td>
<td></td>
</tr>
<tr>
<td>0.61 mGy/MBq Bladder* (2.3 rad/mCi)</td>
<td>0.22 mGy/MBq Bone Surfaces (0.81 rad/mCi)</td>
<td></td>
</tr>
<tr>
<td>0.086 mSv/MBq (0.32 rem/mCi)</td>
<td>0.025 mSv/MBq (0.092 rem/mCi)</td>
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</tbody>
</table>

$^{18}$F-fluoride: Dose estimates to the fetus were provided by Russell et al. (44). No information about possible placental crossover of this compound was available.

**Patient**

**Intravenous Administered Activity MBq (mCi)**

**Organ Receiving the Largest Radiation Dose mGy per MBq (rad per mCi)**

**Effective Dose**

**mSv per MBq (rem per mCi)**

**$^{18}$F-Fluoride**

- Adult
  - 185-370 MBq (5-10 mCi)
  - 0.22 mGy/MBq Bladder* (0.81 rad/mCi)
  - 0.024 mSv/MBq (0.089 rem/mCi)
- Child (5 y old)
  - 2.22 MBq/kg (0.06 mCi/kg)
  - 0.61 mGy/MBq Bladder* (2.3 rad/mCi)
  - 0.086 mSv/MBq (0.32 rem/mCi)

**$^{99m}$Tc-MDP**

- Adult
  - 740-1,110 MBq 20-30 mCi
  - 0.063 mGy/MBq Bone Surfaces (0.23 rad/mCi)
  - 0.0057 mSv/MBq (0.021 rem/mCi)
- Child (5 y old)
  - 7-11 MBq/kg (0.2-0.3 mCi/kg)
  - 0.22 mGy/MBq Bone Surfaces (0.81 rad/mCi)
  - 0.025 mSv/MBq (0.092 rem/mCi)

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SNM Guideline for Sodium $^{18}$F-Fluoride PET/CT Bone Scans

**Stage of Gestation**

**Fetal Dose**

**mGy/MBq (rad/mCi)**

**Fetal Dose**

**mGy (rad)**

- Early
  - 0.022 (0.081)
  - 4.1-8.1 (0.41-0.81)
- 3 months
  - 0.017 (0.063)
  - 3.1-6.3 (0.31-0.63)
- 6 months
  - 0.0075 (0.028)
  - 1.4-2.8 (0.14-0.28)
- 9 months
  - 0.0068 (0.025)
1.3-2.5 (0.13-0.25)  
99mTc-MDP: Dose estimates to the fetus were provided by Russell et al. (44). Information about possible placental crossover of this compound was available and was considered in estimates of fetal doses.  

The Breastfeeding Patient  
ICRP Publication 106, Appendix D does not provide a recommendation about interruption of breastfeeding for 18F-fluoride; the authors recommend that no interruption is needed for breastfeeding patients administered 99mTc-phosphonates.  

Issues Related to the CT Radiation Dose from PET/CT  
With PET/CT, the radiation dose to the patient is the combination of the radiation dose from the PET radiopharmaceutical and the radiation dose from the CT portion of the study. Radiation dose in diagnostic CT has attracted considerable attention in recent years, in particular for pediatric examinations. It can be very misleading to quote a ‘representative’ dose for a CT scan because of the wide diversity of applications, protocols and CT systems. This also applies to the CT component of a PET/CT study. For example, a body scan may include various portions of the body using protocols.

<table>
<thead>
<tr>
<th>Stage of Gestation</th>
<th>Fetal Dose mGy/MBq (rad/mCi)</th>
<th>Fetal Dose mGy (rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>0.0061 (0.023)</td>
<td>0.0061 (0.023)</td>
</tr>
<tr>
<td>1.1-2.3 (0.11-0.23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 months</td>
<td>0.0054 (0.020)</td>
<td>0.0054 (0.020)</td>
</tr>
<tr>
<td>1.0-2.0 (0.10-0.20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>0.0027 (0.010)</td>
<td>0.0027 (0.010)</td>
</tr>
<tr>
<td>0.5-1.0 (0.050-0.10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 months</td>
<td>0.0024 (0.0089)</td>
<td>0.0024 (0.0089)</td>
</tr>
<tr>
<td>0.44-0.89 (0.044-0.089)</td>
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<tr>
<td>12</td>
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</tbody>
</table>

SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans  
aimed to reduce the radiation dose to the patient or aimed to optimize the CT for diagnostic purposes. The effective dose could range from approximately 5 to 80 mSv (0.5 to 8.0 rem) for these options. It is therefore advisable to estimate CT dose specific to the CT system and protocol.  
Pediatric and adolescent patients should have their CT examinations performed at an mAs appropriate for patient size, since radiation dose to the patient increases significantly as the diameter of the patient decreases. The effective dose for a typical adult whole body CT scan performed for attenuation correction and registration of emission images is 3.2 mSv (0.32 rem), using the following parameters: voltage 120 keV, current 30 mA, rotation 0.5 sec, pitch 1.

XI. ACKNOWLEDGEMENTS  
Authors  
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SNM Guideline for Sodium 18F-Fluoride PET/CT Bone Scans

XII. BIBLIOGRAPHY/REFERENCES


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ROH NUCLEAR MEDICINE QA FORM

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