Nuclear Medicine: Protocols and Pearls

Prepared by:
Stephen W. Humes, MD
Thewritingrad.com
This guide serves as a general orientation to the most commonly performed procedures in Nuclear Medicine. Please realize that there are many different protocols used for various procedures performed in Nuclear Medicine, and that this document represents an amalgam of different approaches with the goal being to produce a concise overview of the field.

Protocols are arranged according to various areas of Nuclear Medicine, and include the following:

- Musculoskeletal
- Infection and Inflammation
- Gastrointestinal
- Endocrine: Thyroid and Parathyroid
- Tumor Imaging
- Radionuclide Therapy
- Pulmonary
- Central Nervous System
- Cardiac Imaging
- Genitourinary

Each section also includes various “pearls” to help guide radiologists interpreting Nuclear Medicine studies.

Please note that this guide is not intended to provide formal recommendations for patient management and treatment, and that references are provided for further detail concerning particular patient circumstances.
Musculoskeletal

Standard Bone Scan

Protocol:
- Inject 30 mCi of Tc-99m MDP
- Acquire study after 3 hour delay
- Whole body acquisition uses 2 headed gamma camera

Pearls:
- Works by “chemiabsorption” where tracer localizes to areas of new bone formation or increased blood flow
- Cold lesions are harder to identify than hot lesions
- Always consider artifacts (orthopedic hardware, pacers) and soft tissue uptake
- “Flare phenomenon” reflects favorable response of bone metastases to treatment
- SPECT imaging will detect spondylolysis in about one third of patients with normal planar images
- “Superscan” shows increased bone/soft tissue ratio (absent renal activity) with differential including metabolic disease (renal osteodystrophy, osteomalacia) and metastatic disease (breast or prostate carcinoma), which usually presents with some focal abnormality
### 3-Phase Bone Scan

#### Protocol:
- Bolus injection of 30 mCi of Tc-99m MDP with dynamic flow 3-5 second images for 1 minute of area of interest
- Acquire immediate blood pool images for either counts = 1000K or time = 3 minutes
- Do whole body scan with planar images and area of interest after 3 hour delay

#### Pearls:
- Osteoid osteoma is hot on all three phases
- Osteomyelitis is hot on all three phases
- Cellulitis is hot on flow and blood pool, but not on delayed phase
- In a child, hyperemia may be absent, and there may even be a cold defect on delayed images in osteomyelitis; do followup bone scan or gallium scan
- Gallium scan may be used to verify bone scan findings: Discordant gallium uptake (more intense than Tc99m MDP uptake) suggests osteomyelitis, minimal gallium uptake suggests no osteomyelitis, and concordant uptake is nonspecific

![Phase I: Flow](image1)

![Phase II: Blood Pool](image2)

![Phase III: Delay](image3)
Infection and Inflammation

**Gallium Scan for Infection**

**Protocol:**
- Inject 8 mCi of gallium citrate
- For acute infection, can do 3-4 hour early acquisition (decreased bowel activity)
- Use 5 minute spots or whole body images for 20 minutes
- All delayed imaging is to clear bowel activity or to better define localization
- SPECT imaging may be used to improve localization

**Pearls:**
- Gallium is an iron analog which binds to transferrin
- Diffuse heterogeneous lung uptake has increased specificity for PCP
- “Panda sign” for patients with Sarcoid
- May combine bone scan and gallium scan to increase specificity
**In-111 White Blood Cell Scan**

**Protocol:**
- Withdraw 60cc blood and isolate WBCs by centrifuge, resulting in WBC pellet
- Label WBCs with 500 µCi In-111 and incubate for 30 minutes
- It is CRUCIAL that the patient receive his/her own cells back
- Inject and image at 4 and 24 hours using medium energy collimator
- SPECT as needed

**Pearls:**
- High energy scan with spleen greater than liver activity
- WBCs do NOT accumulate at a healing fracture unless there is a complicating osteomyelitis
- Antibiotics, steroids, hyperglycemia, uremia have NOT been shown to reduce sensitivity of In-111 WBC imaging
- In-111 WBCs preferred for abdominal imaging, while gallium is preferable for pulmonary pathology and FUO
- In-11 is NOT sensitive for detection of spine infection (80% false negative!)
- In the evaluation of the diabetic foot, neuropathic bones and degenerative changes do not show increased uptake of WBCs
- By 1 month postop, an uncomplicated vascular graft should not be visualized using In-111 WBCs
Gastrointestinal

GI Bleeding Scan

Protocol:

- Label patient’s RBCs with 20 mCi Tc-99m- using in vitro kit for best label (Ultratag)
- Reinject labeled RBCs and scan continuously until bleed is detected or until 60 to 120 minutes (delay)
- Image at 2 minutes per frame over abdomen and pelvis

Pearls:

- Review in cine mode
- Causes of GI bleed include diverticulosis, angiodysplasia, polypectomy
- Scintigraphy is about 10 times more sensitive than angiography for detecting GI bleeding (can detect bleeding rates as low as 0.05 to 0.1cc/min, while angiography requires a bleeding rate of 1.5 to 3.0cc/min)
- Criteria for positive bleeding scan include: focus of increased activity that changes in location and increases in intensity over time; blood may move antegrade and retrograde
- Retrograde peristalsis can result in incorrect localizations
- If initial scans are negative, can reimage up to 24 hours
**Meckel's Scan**

**Protocol:**
- Inject 20 mCi Tc99m pertechnetate
- Image immediately and continuously the anterior abdomen for 30 – 45 minutes
- At 30 minutes, do 3 minute right lateral and posterior spots to look behind bladder
- May pretreat with Cimetidine 1mg one day prior and 1 mg prior to start of study

**Pearls:**
- Activity in diverticulum parallels activity in stomach and increases progressively over the course of exam
- Pertechnetate accumulates in mucous producing cells of gastric mucosa
- Pharmacologic manipulation: Cimetidine inhibits secretion of pertechnetate, Pentagastin stimulates uptake, and Glucagon decreases peristalsis
- False positives include hemangioma, AVM, vascular tumor, duplication cyst containing gastric mucosa, inflammation such as intussusception or appendicitis, and renal collecting system or ureters containing tracer
**Gastric Emptying Study**

**Protocol:**
- Solid phase performed using 3 mCi Tc99m Sulfur Colloid in standard solid meal (1 egg, 2 pieces white bread, 50cc water) or in Liquid phase (Tc99m Sulfur Colloid in milk or formula)
- Image continuously for 90 minutes at 1 minute per frame in simultaneous anterior and posterior images using a geometric mean
- Normal values vary according to meal and protocol (<120 minutes for solids)

**Pearls:**
- Solid phase half time (T_1/2) of 45-90 minutes often considered normal
- Solid meal clears in a linear fashion following an initial lag phase, while liquids clear exponentially
- Delayed gastric emptying occurs in diabetic neuropathy, gastric outlet obstruction (peptic ulcer, neoplasm), post surgical (vagotomy or Billroth II), scleroderma
- Accelerated gastric emptying occurs in post surgical patients (vagotomy, pyloroplasty), ZE syndrome, hyperthyroidism, and malabsorption syndromes
**Biliary Scan**

**Protocol:**
- Patient prep: Must be NPO for 4 hours / less than 24 hours, off all narcotics
- Inject 5 mCi Tc99m Choletec
- Scan anteriorly for 1 hour at 2 minutes per frame
- Obtain delayed spots and R lateral images as needed

**Pharmacologic Intervention:**
- Morphine 0.04mg/kg if bowel activity seen; contraindication is pancreatitis
- Glucagon to slow bowel motility
- For biliary atresia, pretreat with phenobarbital 2.5mg/kg x 5 days and image for 1 hour at 1 minute per frame; delays as needed up to 24 hours
- Cholecystokinin 0.02 µg/kg given by slow IV infusion (4-5 minutes) to evaluate gallbladder ejection fraction (normal > 35%)

**Pearls:**
- Visualization of the biliary system with non-visualization of the gallbladder after 4 hours is considered diagnostic of acute cholecystitis
- Negative predictive value of a normal exam (visualized gallbladder in 1 hour) in excluding acute cholecystitis is greater than 99%
- Normal outpatients—if no gallbladder, do 4 hour delay
- Inpatients—if no gallbladder, do 24 hour delay
- “Rim sign” indicates need for emergent surgery or percutaneous cholecystostomy
- Prolonged biliary to bowel transit can be seen following CCK infusion due to preferential shunting of bile into recently emptied gallbladder
- DDx of non-visualized gallbladder includes recent meal, prolonged fasting or hyperalimentation, prior cholecystectomy, acute pancreatitis
- An abnormal gallbladder ejection fraction is considered <35% and is not affected by age and may be associated with chronic acalculous cholecystitis
Liver Spleen Scan

Protocol:
- Give 10 mCi of Tc99m Sulfur Colloid
- Wait 20 minutes
- Perform planar and SPECT acquisitions (120 stops, 10 secs / stop)

Pearls:
- SC particles are phagocytized by reticuloendothelial cells
- “Colloid shift” occurs with loss of functioning liver cells and a “shift” of uptake by other reticuloendothelial cells in spleen and bone marrow
- DDx for focal hot spot includes Budd-Chiari, SVC obstruction, hemangioma, focal nodular hyperplasia
- DDx for solitary cold lesion includes metastatic disease, hepatoma, hematoma, or abscess
Nuclear Medicine Protocols

Endocrine: Thyroid and Parathyroid

Thyroid Scan

Protocol:
- Give 400 uCi of I-123 orally
- Wait 6 hours
- Using pinhole collimator do anterior and anterior oblique spots of thyroid (oblique views distort the gland, making one lobe appear larger)
- Do first images for counts (500K), others for time (10 minutes)
- Use markers at the sternal notch to evaluate for substernal goiter
- Uptake measured at 6 and 24 hours:
  - Normal 6 hour RAIU = 5-12%
  - Normal 24 hour RAIU = 12-35%

Pearls:
- Patients must be off Synthroid, no recent IV contrast studies
- Normal range for TSH is 0.5 – 5.0 mU/L
- Both iodine and technetium are secreted in breast milk, and nursing should be delayed (discontinued in patients undergoing I-131 therapy)
- Pregnancy is an absolute contraindication to thyroid scanning (iodine crosses placenta)
- “Discordant nodule” in Tc99m scan vs I-123 is thyroid carcinoma until proven otherwise (recommend ultrasound with biopsy if nodule is solid)
- DDx for cold nodule includes colloid cyst, adenoma, focal hemorrhage, and malignancy (20%)
- Risk factors for thyroid carcinoma include history of XRT to head and neck as a child, adenopathy, male gender, positive family history
- Hot nodule (Plummer’s disease) may suppress remainder of gland
- Subacute thyroiditis typically results in poor visualization of entire gland
- Hashimoto’s thyroiditis results in painless thyroid enlargement, and most patients are euthyroid
Parathyroid Scan

Protocol:
- Inject 25 mCi tc-99m Sestamibi and perform dual-phase exam or use Sestamibi and pertechnetate for subtraction exam
- For dual phase Sestamibi scan, do 15 minute delay spot of anterior neck and chest
- Do 20 minute SPECT (60 spots, 20 sec per stop)
- At 3 hours, do delayed spot of neck and chest and SPECT if necessary

Pearls:
- Mitochondria-rich cells in parathyroid adenomas show increased tracer accumulation on both initial and delayed images
- Exam is for localization only, not for diagnostic purposes; uptake can also be seen in thyroid adenoma and thyroid carcinoma
Tumor Imaging

Metastatic Thyroid Survey

Protocol:
- Thyroid manipulation:
  Patient off Synthroid for 6 weeks
  TSH > 65 IU/dl
- Give 2.5 mCi I-123 orally
- Wait 24 hours
- Do 30 minute whole body scan using high energy collimator and dual head camera
- Do pinhold spot of neck for 10 minutes

Pearls:
- Thyrogen protocol can be used instead of withdrawing Synthroid, but is expensive and is less effective
- False positive of esophageal activity; clear by giving patient water to drink and do repeat acquisition
- See “Radionuclide Therapy” section below for treatment
**Gallium Scan for Tumor**

**Protocol:**
- Inject 8 mCi of gallium citrate
- Wait 48 hours
- Do 20 minute whole body scan with dual headed camera / medium energy collimator
- SPECT of chest / abdomen / pelvis for improved localization

**Pearls:**
- Gallium largely supplanted by FDG PET for lymphoma
- Chemotherapy and tumor irradiation may suppress gallium uptake after treatment, despite active disease
- Post-therapy hilar uptake is almost always insignificant if symmetric; if activity increases on followup exams, it’s more suspicious
- Kaposi’s is NOT gallium-avid; do Thallium scan
Adrenal Scan (MIBG)

Protocol:
- Patient must be off drugs competing with MIBG for uptake
- Must block thyroid gland using Lugol’s solution, SSKI
- Inject 10 mCi of I-131 or I-123 MIBG
- At 4 and 24 hours, do 30 minute whole body scan using dual head camera
- SPECT as needed

Pearls:
- MIBG is a norepinephrine analog and localizes to storage granules in adrenergic tissue; uptake is proportional to number of granules in tumor
- MIBG is primarily used to image pheochromocytoma and neuroblastoma; other APUD cell line tumors (carcinoid, medullary thyroid carcinoma) show less frequent uptake
- Lab abnormalities in pheochromocytoma include elevated urinary catecholamine, VMA, and metanephrine
Octreotide Scan

Protocol:
- Patient must be off somatostatin
- Inject 6 mCi of In-111 Octreotide
- Do scan of whole body at 4 and 24 hours:
  - 20 minute whole body scan
  - Dual headed camera
  - Medium energy collimator
- SPECT at 4 and 24 hours as needed

Pearls:
- Octreotide is a somatostatin analog and binds to somatostatin receptors on cells of neuroendocrine origin; tumors with somatostatin receptors include carcinoid, pancreatic islet cell tumor, gastrinoma, pheochromocytoma, meningioma, and neuroblastoma
- Patients should be off somatostatin 24 hours to prevent competitive uptake
FDG PET for Oncology

Protocol:

- Patient prep: NPO for 8 hours minimum (nothing except water), check glucose level
- Inject 12 mCi F-18 FDG
- Patient secluded in dark, quiet room for 90 minutes
- Scan from base of skull to mid thighs (6-8 bed stops at 3 minutes per stop)
- CT serves as attenuation correction
- May use either low dose CT or IV diagnostic CT
- Volumen prevents oral contrast artifacts

Pearls:

- Melanoma, sarcomas get whole body scan—do legs separately
- Known false positives: brown fat, infections (pneumonia, abscess), granulomatous processes (Sarcoid, TB, fungal infections), postoperative changes, and even normal distributions such as cecum can be very intense in uptake
- Known false negatives: low grade neoplasms (carcinoid) or neoplasms that do not metabolize glucose (prostate carcinoma)
- Standardized uptake value (SUV) is a semiquantitative value relating intensity of uptake in a lesion to average whole body distribution
- SUV is not standardized at all: may vary with ROI differences, technique (dose, timing of acquisition), and does not prove a finding is malignant
Lymphoscintigraphy

Protocols:
- Use 4 mCi Tc99m Sulfur Colloid (filtered vs unfiltered)
- Inject intradermal / deep over quadrant of lesion
- Image continuously with shielding of injection site
- “Sentinel” node typically appears in minutes
- Mark site on skin

Pearls:
- Filtered SC travels fast but passes through nodes
- Unfiltered SC travels slow but stays in first node
- Dermal injections travel fast
- Deep injections travel slow
- Most important part of injection is to avoid contamination. Do not “clear” syringe by injecting into the air, and make sure dose is completely injected prior to removing needle.
Prostascint

Protocols:

- Inject 7 mCi of In-111 Prostascint
- At 3 days, start vigorous bowel prep
- On day 5, perform planar and SPECT of chest / abdomen / pelvis using medium energy collimator
- Without moving patient, give 30 mCi Tc99m RBCs and repeat SPECT
- Match blood pool and Prostascint slices

Pearls:

- Prostascint is an IgG murine monoclonal antibody that reacts with the cytoplasmic membrane of prostate cancer cell lines
- Planar images help evaluate abnormal mesenteric and abdominal lymph nodes
- SPECT images allow evaluation of asymmetry around large vessels and the prostate bed
- False positives include stool in rectum and colon, focal inflammatory processes, and asymmetric bone marrow distribution
**Radionuclide Therapy**

**Zevelin**
Give IV nonradioactive rituximab
Within 4 hours, give 5 mCi of In-111 for dosimetry
3 scans:  
  Scan 1 at 2-24 hours  
  Scan 2 at 48-72 hours  
  Scan 3 at 90-120 hours (optional)
Confirm uptake in tumor sites
Normal biodistribution includes liver, spleen, and blood pool
Altered biodistribution includes kidney activity and marrow uptake
Lung or bowel activity greater than liver is poor prognostic indicator
Absent blood pool activity = HAMA
Pretreatment evaluation  
  Platelets > 150K = Tx with 0.4 mCi / kg of Y90 Zevelin
  Platelets 100-149K = Tx with 0.3 mCi / kg of Y90 Zevelin
  Always < 32 mCi

**Bexxar**
Block thyroid
IV nonradioactive drug
Give 5 mCi of I-131 Tositumomab
3 scans:  
  Scan 1 at 1 hour  
  Scan 2 at 24-72 hours  
  Scan 3 at 6-7 days
High energy collimator
30 minute whole body scan with dual head camera
Normal biodistribution is blood pool, liver, and spleen
Altered biodistribution includes lung uptake, urinary obstruction, intense liver and spleen activity
Absent blood pool activity = HAMA
Dose of I-131 Tositumomab ranges from 45 – 275 mCi

**Strontium / Samarium**
Not indicated if survival is measured in days or weeks vs months
Check platelets > 100K, WBCs > 4K
Give dose via slow IV infusion
Warn patient about “flare” of increased pain in days immediately following dose
Make sure patients have sufficient narcotics to manage flare
Strontium dose is 4 mCi
Samarium dose is 1 mCi/kg
Thyroid Cancer Therapy

Used only in patients with follicular or papillary carcinoma
   NOT anaplastic or medullary carcinoma (not avid for I-131)
Patient s/p near-total thyroidectomy
Wait 6 weeks, check TSH > 65 IU/dl
Pre-treatment scan using 2-3 mCi I-131 to assess extent of disease
   Some advocate no survey to prevent thyroid stunning
Thyroid manipulation to increase dose delivery of I-131 to metastases
   ▪ Want TSH levels > 30 uU/ml prior to therapy
   ▪ D/C T4 at 4-6 weeks prior to therapy
   ▪ Low iodine diet
   ▪ D/C T3 at 2 weeks prior to therapy
I-131 dose based on extent of metastatic disease:
   ▪ 100 mCi for residual thyroid bed
   ▪ 150 mCi for cervical nodes (local nodal mets do NOT influence survival)
   ▪ 200 mCi for lung / distant metastatic disease
Acute complications of therapy:
   ▪ Sialoadenitis (use hard candies and aggressive hydration)
   ▪ Loss of taste
   ▪ GI symptoms (nausea and vomiting)
   ▪ Thyroid Storm (release of thyroid hormone 2-10 days post therapy)
Chronic complications of therapy
   ▪ NO INCREASED RISK of thyroid tumors and no evidence of reduced fertility or genetic abnormalities in patient's offspring
   ▪ Leukemia (cumulative dose should not exceed 800 mCi)
Post therapy scan at 7 days can detect new lesions in up to 15% of patients
30 minute whole body acquisition (using treatment dose) with pinhole of neck
Followup at 1 year intervals until negative for 2 years, then follow thyroglobulin
   ▪ Rising thyroglobulin level implies presence of functioning mets and will be elevated in 85-90% of patients with mets
Hyperthyroidism Therapy

Need to know labs and clinical history
\[ T_3 \uparrow + T_4 \uparrow + \downarrow \text{TSH} = \text{Graves (in other disorders, TSH may be elevated)} \]
Confirm Graves Disease with RAIU and scan
Pregnancy test for female patients (unless postmenopausal or s/p hysterectomy)
Contraindications to therapy:
- Pregnancy
- Breast feeding
- Severe thyrotoxicosis (use β blockers to prevent thyroid storm)
Consent Issues:
Hyperthyroidism therapy does NOT cause increased risk of cancer and does NOT affect fertility
65-95% chance of developing hypothyroidism, based on dose
15% remain hyperthyroid and may be retreated
Dose depends on RAIU
\[
\text{Dose} = \frac{(\text{Thyroid mass [gms]} \times 80-200\mu\text{Ci/gm})}{\text{Percent uptake}}
\]
Treat empirically with 12 mCi I-131 for Graves
Higher doses for Plummers Disease, MNG, toxic nodular goiter (25mCi)
Results
Maximum effect at 3-4 months
- 60% euthyroid
- 15% remain hyperthyroid (may be retreated)
- 35% hypothyroid (treated with Synthroid)
Pulmonary

V/Q Scan

Protocol:

- Check CXR to verify clear; always compare V/Q scan with current CXR
- Ventilation acquired using 30 mCi Tc99m-DTPA in nebulizer
  - Perform ventilation prior to perfusion
  - Breath for 8 minutes on 12L oxygen
  - Spot posterior chest for 200K (measure time)
  - Do ANT, LAO, RAO, LPO, RPO for equal time
- Perfusion acquired after injecting 8 mCi Tc99m MAA
  - Always inject supine; may image supine or upright
  - Spot posterior chest for 1000K (measure time)
  - Do ANT, LAO, RAO, LPO, RPO for equal time

Pearls:

- First identify whether or not there is a significant perfusion defect, and then use ventilation images and CXR to see if perfusion defect is explained by underlying lung disease; significant defects involve >25% of a segmental defect
- Know basic vascular segmental anatomy, modified PIOPED II criteria
- Differential for V/Q mismatch includes embolus, prior embolus, lymphadenopathy or tumor mass effect, vasculitis, pulmonic stenosis
- “Fissure sign” is oblique linear area of decreased perfusion secondary to pleural fluid tracking in fissure
- “Contour mapping” is seen in lymphangitic carcinomatosis and appears as linear defects outlining bronchopulmonary segments
- “Hot spots” occur due to injection of blood clots inadvertently formed in syringe
- “Stripe Sign” with activity at periphery indicates low probability scan
- “Triple match” in upper lobes is low probability, while in lower lobes it qualifies as intermediate probability
Shunt Study

Protocol:
- Give bolus of 8 mCi Tc-99m MAA
- Immediately scan whole body from top of head to mid-thighs over 10 minutes
- Whole body activity – Lung activity / whole body activity = % shunt

Pearls:
- Typically discovered incidentally as part of V/Q scan
- Relative contraindications to performing this study include pregnancy and pulmonary hypertension
Central Nervous System

Cerebral Perfusion Study

Protocols:
- Give 25 mCi of Tc-99m ECD, patient secluded in quiet room with eyes closed
- Wait 20 minutes
- Acquire SPECT of head using triple head camera

Pearls:
- For detection of seizure focus, during the ictal phase of a complex partial seizure, there is typically hyperperfusion of the affected temporal lobe; ictal exam is more sensitive and specific than inter-ictal scan
- Severity of defects in patients with dementia correlates with severity of patient’s dementia
- DDx for biparietal/temporal defects includes Alzheimer’s dementia, Parkinson’s disease with dementia, bilateral parietal infarcts, and multi-infarct dementia (typically assymetric)
**Diamox Cerebrovascular Reserve Study**

**Protocol:**
- Day 1: low dose scan
  25 mCi of Tc-99m ECD
  Wait 20 minutes, acquire SPECT
- Day 2: Give Diamox 1g IV over 7 minutes
  Inject 25 mCi of Tc-99m ECD at minutes
  Wait 20 minutes, acquire SPECT

**Pearls:**
- Diamox challenge test is used for identifying CNS territory at risk in patients experiencing TIAs or for preoperative evaluation
- Diamox is a carbonic anhydrase inhibitor that causes increased cerebral CO₂ levels which in turn results in vasodilation. In areas of reduced blood flow, where there is already maximal vasodilation (i.e. loss of cerebrovascular reserve), there can be no augmentation of flow
- Areas of limited flow reserve will have decreased tracer activity on the challenge exam when compared to the baseline study
Brain Death Study

Protocols:

- Position camera anteriorly over the head
- Bolus 25 mCi Tc99m DTPA
- Scan at 1 sec / frame for 30 frames
- Do 3 minute anterior spot for sagittal sinus evaluation
- If positive from absent cerebral blood flow, do spot of anterior abdomen for donor evaluation

Pearls:

- Clinical criteria for brain death include absent brain stem reflexes, no spontaneous respiration, and excluding potentially reversible causes such as barbiturates, hypothermia, or metabolic derangements
- Lack of blood flow is diagnostic of brain death and is the result of increased intracranial pressure
- Radionuclide test is not affected by reversible causes listed above
- Carotid arteries should be visualized (indicates adequate bolus), but there is abrupt cut-off of activity at the skull base
- "Hot nose" sign results from increased flow to external carotid circulation
Cisternogram

Protocols:
- Intrathecal injection of 0.5 mCi of In-111 DTPA
- Planar imaging at 2h, 6h, 24h, 48h, 72h as needed
- May do SPECT
- Use low energy all purpose collimator

Pearls:
- Know normal flow pattern of CSF
- Activity is normally seen at basal cisterns between 1 and 6 hours after injection
- Tracer activity should be seen at frontal poles, interhemispheric fissure and Sylvian fissures by 2-6 hours, producing “Neptune’s trident”
- Activity should be at convexities by 12-24 hours
- There should be no activity seen in lateral ventricles since physiologic flow is in opposite direction
CSF Leak

Protocols:

- Pre-weigh and label pledgets
- Perform lumbar puncture and inject 1 mCi In-111 DTPA intrathecally
- Scan at 30 minutes using medium energy collimator to verify intrathecal injection
- Scan at 4 hours to confirm passage to base of skull
- Send to ENT for pledget placement
- Wait 4 hours
- Draw serum sample and pull pledgets
- SPECT of head
- Count and weigh pledgets, and express results as ratio of pledget / serum

Pearls:

- A ratio of nasal to plasma radioactivity greater than 1.3 : 1 is considered positive for a leak
Cardiac Imaging

Rest / Stress Myocardial Perfusion Scintigraphy

Protocols:
- Many protocols (1 day, 2 day, dual isotope)
- Inject 4 mCi Thallium 201 at rest
- Wait 10 minutes and do SPECT (30 stops, 25 sec / stop) 180 degrees RAO to RPO
- Perform adenosine stress using 6 minute infusion at 0.14 mg/kg/min; or
- Perform modified Bruce protocol to 85% targeted heart rate for stress
- Inject 30 mCi T99m Sestamibi, wait 30 minutes, SPECT as above

Pearls:
- Coronary artery “dominance” refers to which coronary artery supplies the LV’s diaphragmatic surface by giving rise to the PDA
- A “critical stenosis” occurs with a 90% cross sectional area reduction and produces ischemia in myocardium served by the artery
- Increased pulmonary activity on a thallium exam is a poor prognostic indicator
- Normal MPS exam is associated with yearly rate of cardiac events of less than 1%
- Post PTCA scans should be delayed for at least 2-4 weeks after procedure (result in false positive for ischemia)
- Left bundle branch block on Bruce protocol stress exams results in reversible septal defect (false positive) due to decreased diastolic blood flow
- Pharmacologic stress tests coronary flow reserve without increasing myocardial oxygen demands
- Sestamibi is a perfusion agent that does not redistribute the way thallium does
Gated Cardiac Blood Pool Scan

Protocol:

- Give 30 mCi of Tc99mTcO4- labeled autologous RBCs
- Image at 45 degree LAO with caudal tilt (best ventricular separation)
- Obtain 600 acceptable beats
- Gate at minimum of 16 frames per cardiac cycle (32 frames for diastolic function)
- If for chemotx only, just acquire LAO for LVEF
- If for other indications (?), add anterior and LT lateral projections

Pearls:

- EF = (ED counts – ES counts) / ED counts – Background
- High background will falsely elevate EF, while low background will falsely lower the calculated EF
Genitourinary

Lasix Renogram

Protocol:
- Inject 10 mCi Tc99m MAG3
- Do posterior flow at 1 sec / frame for 60 frames
- Do posterior function at 10 seconds / frame for 180 frames (30 minutes)
- Lasix 40mg IV given during MAG3 injection or 10 minutes into study
- Have patient void and take spot image at 30 minutes / 1 hour

Pearls:
- Tc99m MAG3 measures effective renal plasma flow (ERPF): total perfusion of the kidney that is available for clearance (80% tubular secretion, 20% GFR)
- Renal scans can be used to measure split renal function, degree of obstruction, evaluate renovascular hypertension and renal transplants (ATN)
- Transplant evaluation includes perfusion (normal perfusion with decreased function suggests ATN), rejection, and complications of transplant such as leak or urinoma
Captopril Renogram (ACE Inhibition Study)

Protocol:
Patient must be well-hydrated and off ACE inhibitors and diuretics
Do post-ACE inhibition study first; if negative, do not need baseline exam
   Give 50mg captopril orally or Enalaprilat IV, constantly monitoring HR/BP
   Give 10 mCi Tc99m MAG3 and perform standard renogram
If abnormal, perform baseline renogram following day

Pearls:
- Criteria for positive exam include asymmetric renal size, increase in time to peak activity, prolonged cortical retention, rising baseline renogram, and nonvisualization of the kidney
- A positive captopril exam is a strong predictor of surgically correctable renovascular hypertension (~90% of patients will demonstrate improved blood pressure following intervention)
- Angiography can demonstrate renal artery stenosis, but gives no physiologic information regarding the presence of renovascular hypertension
- Causes of renovascular hypertension include atherosclerosis, FMD, arteritis, aortic dissection, and neurofibromatosis
Nuclear Medicine Protocols

Nuclear Cystogram

Protocols:
- Patient prep: Insert Foley
- Fill bladder to capacity using sterile saline with 1 mCi of Tc99m Sulfur Colloid
- Image continuously (posterior) at 2 sec / frame for 300 frames in filling and voiding phases
- Position so top of bladder is in field of view
- Take post void 3 minute spots of the kidneys to look for retention

Pearls:
- Bladder filling volume = (age in years + 2) x 30ml
- Gonadal dose from radionuclide cystography is about 1/100th that of standard VCUG
- Clinical indications for radionuclide cystography include followup for patients with known reflux, initial test in females with UTIs, screening asymptomatic siblings, and serial evaluation for patients with neurogenic bladders
Testicular Scan

Protocols:
- Give IV bolus of 20 mCi Tc99mO4-
- Do anterior flow study with shielding around scrotum at 2 sec / frame for 30 frames
- Do 3 minute “static” spot of the scrotum with lead marker on scrotum +/- shielding
- Pinhole collimator used in children

Pearls:
- Exam rarely performed due to ease and ready availability of Doppler ultrasound
- “Nibbin sign” shows vascular activity in ipsilateral iliac artery and is pathognomonic of torsion
- “Delayed torsion” produces a halo of increased activity around testis
References


Williams, Scott. AuntMinnie notes on Nuclear Medicine.


Notes from Gainesville Hotseats Review.