Scintigraphic evaluation of genitourinary and gastrointestinal systems

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Evaluation of the urinary system

- **Tc99m-MAG3**
  - Tubular secretion 100%
- **Tc99m-DTPA**
  - Glomerular filtration 100%
- **Tc99m-DMSA**
  - Cortical binding 40-50%
- **I131-OIH**
  - Tubular secretion 80%
  - Glomerular filtration 20%
- **Tc99m-EC**
  - Tubular secretion
- **I123-OIH**
  - Tubular secretion 80%
  - Glomerular filtration 20%

- **Tc99m-GH**
  - Glomerular filtration
  - Cortical binding 10-15%
Evaluation of the urinary system

- **Tc99m-MAG3**
  - Tubular secretion 100%
  - Blood flow and renal function

- **Tc99m-DTPA**
  - Glomerular filtration 100%

- **Tc99m-DMSA**
  - Cortical binding 40-50%
  - Renal cortex imaging

- **Tc99m-NTA**
  - Tubular secretion

- **Tc99m-GH**
  - Glomerular filtration
  - Cortical binding 10-15%

- **I131-OIH**
  - Tubular secretion 80%
  - Glomerular filtration 20%

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Taylor A.T. JNM 2/18/2014

24-year-old male with urinary symptoms for 6 months (urgency and frequency); request for renal scintigraphy for “pelvic mass, concern for poorly functioning ectopic kidney that may be draining into the prostate.” The most likely diagnosis is:

A. Left kidney hydronephrosis
B. Left side multicystic dysplastic kidney
C. Cross-fused renal ectopia
D. Nonfunctioning right kidney/renal agenesis right side
a. Retrograde cystogram: filling defect within the right aspect of the urinary bladder.
b. MRI: high T1 and intermediate T2 signal intensity structure consistent with proteinaceous cyst (separate right seminal vesicle is not seen)

**Renal agenesis**

- Embryological renal agenesis results from a failure of the proper development of the metanephros
- Associated with many anomalies including
  - Congenital heart disease
  - Seminal vesicle cyst
  - Adrenal agenesis
- Zinner syndrome - triad of right renal agenesis, ipsilateral seminal vesicle cyst, and ejaculatory duct obstruction
Tc99m-DMSA (dimercaptosuccinic acid)
renal cortical imaging

- binds to metalloproteins in functioning proximal tubular cells
- imaging is performed 2-4 hours after injection
- 40% of the injected tracer is bound to the kidneys.
- high resolution cortical images (Pinhole, SPECT)
- low level of urinary excretion is not adequate for assessment of the collecting system and lower urinary tract.
- 5 mCi Tc99m-DMSA, image at 2 hours

The role of 99mTc-DMSA
1. renal scarring or acute pyelonephritis
2. accurate differential renal function
3. congenital anomalies (agenesis, ectopic, fusion, MCDK, pseudomasses (lobulation, Bertin))

Tc99m-MAG3: Quality Control/Pitfalls
Blood flow phase evaluation

Blood flow phase is suggestive of:

A. Normal blood flow phase
B. Renal artery thrombosis
C. Renal vein thrombosis
D. Technical difficulties (infiltrated iv dose)
E. Poor bolus (vascular occlusion)
Blood flow phase **poor bolus** due to systemic-systemic collaterals due to left supraclavicular vein obstruction

Blood flow phase - native kidneys

- Inaccurate results if:
  - poor bolus
  - Extravasation
  - venous occlusion
  - ROI incorrectly placed

- Kidneys seen 1-3 sec after the bolus in the abdominal aorta
Blood flow phase – transplanted kidneys

- Inaccurate results if:
  - poor bolus
  - Extravasation
  - venous occlusion
  - ROI incorrectly placed

Kidney seen 1-3 sec after the bolus in the iliac artery

Parenchymal uptake and clearance of radiotracer

History: patient with continent urinary reservoir; evaluate for obstruction. Foley catheter placed.
Tc99m-Mag3 renogram shows no response to Lasix for left kidney:

A. Partial obstruction of the left kidney collecting system
B. Complete obstruction of the left kidney collecting system
C. Patulous left kidney collecting system
D. Study needs to be repeated
Causes for false positive renogram suggesting obstruction (no response to Lasix):

1. Vesicoureteral reflux
2. Dehydration
3. Renal failure (Lasix dose not adjusted)
4. Full bladder
Tc99m-MAG3: Quality Control/Pitfalls
Parenchymal uptake and phase

- Patient with **neurogenic bladder or continent urinary conduit** (Indiana pouch, neobladder) if possible a Foley catheter in place for the study
- Background correctly placed
- Patient preparation (well hydrated)/voiding before the study) – 2 glasses of water
- Depth of the kidneys

Ref: Taylor A.T. Radionuclides in nephrourology 3/2014

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Another case

57 yo male with bilateral hydronephrosis on CT due to a pelvic mass representing metastatic HCC. Right kidney renogram is consistent with:

A. Right kidney has normal excretion and drainage
B. Right kidney evaluation for obstruction is limited
C. Right kidney acute tubular necrosis
D. Right kidney suspicious for renal artery stenosis
Noncontrast CT (above): mild fat standing and small amount of perinephric fluid collection.
Findings on renogram (prior slide): urine leak with perinephric accumulation suspicious for forniceal rupture.
Management: right kidney nephrostomy tube was placed.

Evaluation for renal artery stenosis
(captopril study)
Baseline study

Blood flow
Given the interval change in the renogram curve, findings are consistent with:

A. High probability for renovascular hypertension (RVH)
B. Intermediate probability
C. Low probability for RVH
D. No evidence of RVH

Abdominal MRA

Slides courtesy of Sana Parsian MD.
ACE inhibitor effects on the renogram on RVH:

**Main effect:**
- reduce GFR (decreased angiotensin 2 level) → decrease tracer uptake in TC99m-DTPA
- reduce urine flow → delayed transit and wash-out in Tc99m-MAG3 (prolonged time to peak and time transit time).

**Preparation:**
- ACE inhibitor should be withdrawn 3-5 days prior to the study (2-3 days captopril)
- Stop ARB and calcium channel blockers, diuretics
- 1 day/2 day protocol

High probability for RVH – unilateral changes after ACI

**For OIH or MAG3**
- Increased 20min/peak captopril by 0.15 (normal less than 0.3)
- Time to peak increased by 2 min or more
- 10% change in relative function from 50/50 to 60/40

**For Tc99m-DTPA**
Reduction in relative uptake more than 10%

Intermediate probability

- Bilateral symmetric changes (hypotension, insufficient hydration, distended bladder)
- Baseline abnormal renogram unchanged after captopril

Low probability

- Normal findings on ACEI renography
- Abnormal baseline that improves
### Evaluation of transplanted kidney

**Normal appearance**

- **Perfusion**: tracer bolus to transplant seen 1-3 sec after the bolus in the abdominal iliac artery
- **Parenchymal uptake**: maximal activity 3-5 minutes
- **Excretion**: ureter/bladder activity 4-8 minutes

### Differential of Allograft Dysfunction

- **Surgical vs. Medical**
- **Prerenal, renal, post-renal**
- **Timeline**
  - Immediate, early, late acute, late chronic
Medical vs. Surgical

MEDICAL
- Rejection
- ATN
- Drug toxicity
- Infection
- Other nephropathy

SURGICAL
- Obstruction
- Vascular complications
- Perinephric fluid collections

Patient status post deceased donor kidney transplant, with new flank pain and creatinine 2.1 (initial creatinine was 3.6). Findings are suggestive of:

1. Renal artery thrombosis
2. Renal vein thrombosis
3. ATN
4. Obstruction
5. Urine leak

Another case

Day 3 posttransplant
Delayed 1 hour images no excretion from the transplanted kidney (unlikely to be obstructed); as expected gallbladder and gut excretion

Biopsy results consistent with ATN

Acute preservation injury and urine leak (4 days posttransplant)
ATN

- most common cause of allograft dysfunction in first FEW weeks
  34% cadaveric, 9% living
- need to exclude other treatable (ie usually surgical) causes of
dysfunction before treatment (dialysis)

Postransplant immediate complications -within a week

- ATN
- Rejection (preformed AB)
- Thrombus - arterial or venous
- Obstruction
- Leak
Renal transplant evaluation in a 75 yo patient s/p renal transplant 2 months ago with increasing creatinine (1.76 → 2.57) new fluid collection on US at the inferior pole.

Fluid Collection DDX:
- Urine Leak / Urinoma (days to weeks)
- Lymphocele (2-4 months)
- First few days:
  - Post-op fluid collection
  - Seroma
  - Hematoma
  - Infection

SPECT/CT images acquired at 90 min
Renal parenchymal dysfunction

- **Acute Tubular Necrosis (immediate- week)**
- **Immunosuppressive Drug Toxicity** (months)
- **Hyperacute Rejection** (minutes-hours)
- **Accelerated Acute Rejection** (1 week)
- **Acute Rejection** (>2 weeks, <3 months)
- **Chronic Rejection** (months)

Parenchymal dysfunction on renogram

- **Acute Tubular Necrosis**
  - Normal perfusion*, delayed cortical clearance, minimal to no excretion*

- **Immunosuppressive Drug Toxicity (Cyclosporine, Tacrolimus)**
  - Normal perfusion delayed cortical clearance, poor excretion

- **Acute rejection / Chronic rejection**
  - Decreased perfusion (shallow upward slope, patchiness) cortical retention, decreased excretion
Early posttransplant complications- 1-12 weeks

- Acute rejection
- Drug toxicity
- Infection
- Recurrent primary disease
- Obstruction

Evaluation of the gastrointestinal system
History: 39 yo male with refractory T cell lymphoma with gallbladder wall thickening on US. NPO for more than 24 hours. HIDA scan first 60 min images are obtained. Which one is the next best step:

1. Administration of CCK- pt on TPN
2. Administration of morphine
3. Administration of cimetidine
4. Administration of glucagon
US- above (1 day prior): gallbladder wall thickening (0.9 cm) and one calculus. No biliary duct dilatation (not shown). Limited evaluation of Murphy’s sign (patient is intubated).

**Diagnosis:** Cystic duct obstruction likely secondary to acute cholecystitis and hepatocellular dysfunction

**Findings:** Delayed blood pool clearance of tracer (cardiac blood pool seen for more than one hour)
- Normal excretion into the biliary tree
- Non visualization of the gallbladder after 1 hour and after 45 min post morphine administration.

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**HIDA scan radiopharmaceuticals**

Tc-99m HIDA scan radiopharmaceuticals travels the same pathway as bilirubin, are subject to competitive inhibition by high serum bilirubin levels.

- **HIDA/Lidofenin (Tc99m- dimethyl iminodiacetic acid –IDA)**
  - Good visualization at bilirubin levels of 5-7 mg/dl

- **DisIDA/Disofenin (Tc99m- diisopropyl IDA)**
  - Good visualization at bilirubin levels approaching 20 mg/dl

- **BrIDA/Mebrofenin (Tc99m- brometriethyl IDA)**
  - greater hepatic extraction and resistance to displacement by bilirubin than disofenin; preferable in patients with poor liver function.
  - Good visualization at bilirubin levels approaching 20-30 mg/dl
Normal HIDA scan?

### Normal appearance of HIDA (1 min/frame 60 min)
- Blood pool: up to 5-10 min
- Common BD: 20 min (100%)
- Gallbladder: 60 min (100%)
- Small intestine: 60 min (80%)

### HIDA 0-30 min
- Normal appearance
- Blood pool: up to 5-10 min
- Common BD: 20 min (100%)
- Gallbladder: 60 min (100%)
- Small intestine: 60 min (80%)

### HIDA 31-60 min
- Normal appearance
- Blood pool: up to 5-10 min
- Common BD: 20 min (100%)
- Gallbladder: 60 min (100%)
- Small intestine: 80%
Procedure

- 5 mCi Tc99m - Mebrofenin if bilirubin less than 2 mg/dL
- NPO for 4 hours
- 1 min/frame for 60 min and RL and LAO to confirm
- If NPO more than 24 hours: CCK 0.02 μg/kg over 60 minutes. Wait 30 minutes and start HIDA
- No gallbladder seen by 60 min: - morphine 0.04 mg/kg (contracts sphincter Oddi) and image for 45 more min
  - delayed 4 hours images
- Gallbladder is seen: CCK 0.02 μg/kg to calculate EF
False- positive for HIDA scan

- Fasting less than 4 hours
- Fasting longer than 24 hours
- Hyperalimentation
- Concurrent severe illness
- Chronic cholecystitis
- Liver dysfunction

Ziessman et al. The requisites. p139

Indications for CCK

Before HIDA Examination
- Empty gallbladder in patient fasting longer than 24 hours
- Diagnose sphincter of Oddi dysfunction*

After HIDA Examination
- Differentiate common duct obstruction from functional causes
- Exclude acute acalculous cholecystitis if gallbladder fills
- Diagnose chronic acalculous gallbladder disease (60 min; EF 38%)**


**Ziessmann HA et al. Sincalide-stimulated cholecintigraphy: a multicenter investigation to determine optimal infusion methodology and gallbladder ejection fraction normal values. JNM 2010. 51; 277- 281.
Another case

Gallbladder not seen at 60 min

“rim sign”

Gallbladder not visualized post 4 mg morphine and 45 min images.

Case courtesy of Behnia Fatemeh MD
US (above): Gallbladder wall thickening, pericholecystic fluid, no stone, no biliary ductal dilatation
Equivocal Murphy’s sign.

Diagnosis: Cystic duct obstruction likely secondary to acute acalculous cholecystitis. Rim sign associated with
increased severity of cholecystitis and with increased complications like perforation.

Findings: Prompt blood pool clearance of tracer
Normal excretion into the biliary tree
Non visualization of the gallbladder for 1 hour
Non visualization of gallbladder after morphine administration
Tracer activity in the liver adjacent to the gall bladder fossa consistent with a “RIM SIGN”

Another case
54 yo male with history of diffuse large B-cell lymphoma in remission presenting with fever, abdominal
pain and diarrhea. **No cholelithiasis on ultrasound.** Which one is the correct answer:

1. GB filling essentially exclude acute cholecystitis.
2. There is hepatic parenchymal dysfunction.
3. Findings are suspicious for cholangitis.
4. The cystic duct is patent.
CT: edema of the gallbladder wall with mucosa enhancement
US: diffuse wall thickening 7 mm, positive Murphy’s sign, no stones or sludge. The gallbladder is distended.

Postsurgical path report: acute and chronic cholecystitis with serositis

If acalculous cholecystitis is suspected and gallbladder fills, CCK iv is indicated to demonstrate that EF is low (normal EF exclude acalculous cholecystitis). Sensitivity of HIDA scan for acute acalculous cholecystitis is aprox 80% (95%-98% for acute calculous cholecystitis).

Acute acalculous cholecystitis (AAC)

• 5-15% of acute cholecystitis
• critical ill patients or elderly patients
• cystic duct may not be obstructed and gallbladder wall inflammation caused by infection, ischemia or toxemia
• sensitivity of HIDA scan for acute acalculous cholecystitis is aprox 80% (95%-98% for acute calculous cholecystitis).
• Cholecystitis can be excluded if the gallbladder contracts normal after CCK. If it does not contract, the cause could be acute or chronic acalculous cholecystitis
• Early filling of the gallbladder (within the first 30 min) excludes the diagnosis of acute calculous cholecystitis, but with delayed filling after morphine, the false-negative rate may be as high as 20%.

37 yo male with abdominal pain and hematochezia. Focus of uptake in the left upper quadrant most likely represents:

A. Large bowel bleeding  
B. Small bowel bleeding  
C. Meckel diverticulum  
D. Additional images are necessary to characterize this focus

Fused Tc99m-pertechnetate SPECT/CT image (above): focus of increased radiotracer in the left upper quadrant corresponds to urine in the left renal pelvis.

Additional images lateral and obliques view or SPECT/CT images may be helpful to differentiate from urinary tract activity.
Meckel’s diverticulum

• 5-10 mCi Tc99-pertechnetate iv
• Cimetidine: increased uptake of the radiotracer activity secondary to the inhibition of the release from gastric mucosa. Dose is 20mg/kg orally for two days prior to the study
• Pentagastrin: increases the rapidity, duration and intensity of uptake. (not available in the USA)
• Glucagon: gastrointestinal paralytic agent.
• Lateral and oblique views or SPECT/CT useful to differentiate from urinary tract activity
Meckel’s diverticulum

- 2%–3% of the population
- incomplete atrophy of the omphalomesenteric duct

**Complications**
- peptic ulceration with hemorrhage
- diverticulitis
- intestinal obstruction from diverticular inversion
- intussusception
- volvulus
- torsion
- inclusion of the diverticulum in a hernia
- formation of enteroliths;

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**Tc99m-pertechnetate Meckel’s diverticulum**

- Intestinal activity may appear simultaneously with the gastric and heterotopic gastric activity or later in the course of the scan
- SPECT has been reported to demonstrate a positive Meckel diverticulum when results from conventional planar imaging are negative

**False-positive results:**
- gastric or small intestinal duplication
- heterotopic gastric mucosa in otherwise normal small intestine
- ulcerative or inflammatory processes that cause substantial intestinal hyperemia
- GU
- Vascular – hemangioma, angiodysplasia

The study below was most likely performed for evaluation of:

1. Metastatic carcinoid
2. Hemangiomas
3. Metastatic thyroid cancer lesions
4. Posttraumatic sequelae

The study below was most likely performed for evaluation of:

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4. Posttraumatic sequelae
Splenosis

Tc99m-sulfurcolloid study (prior slide): foci of uptake intrathoracic and intraabdominal (left upper quadrant) corresponding to soft tissue nodules seen on CT in a patient with splenectomy post prior gun shot wound 33 years ago. NECT (above): well-circumscribed soft tissue nodules in the left upper quadrant, left side pleural-based nodules, paramediastinal.

Thoracic splenosis

- Disseminated autotransplantation of splenic tissue following traumatic disruption of the spleen.
- On CT multiple well-circumscribed, homogeneous, noncalcified nodules with similar attenuation to normal splenic tissue
- Asymptomatic in most cases
- Can be characterized with Tc99m-sulfurcolloid and Tc99m heat-damaged RBC (higher sensitivity)
- Often asymptomatic
Tc99m-sulfurcolloid

- Colloidal particles sequestered in the reticuloendothelial system
- Biodistribution: Liver > Spleen > Bone marrow >> other (lung, stomach)
- Clinical role:
  - distribution of the reticuloendothelial system in cirrhotic patients
  - splenosis
  - past: FNH characterization, acute GI bleeding

Expected bone marrow biodistribution: Liver > Spleen > Bone marrow

79 yo with metastatic ampullary adenocarcinoma to the liver
78 y/o female with solitary 5 cm segment 6/7 HCC in the setting of CTP-A5 NASH related cirrhosis, being planned for definitive external beam radiation.

Bone marrow scintigraphy in a patient with hemophagocytic syndrome.
Viable marrow in the tibia bilaterally and distal epiphyseal region of bilateral femurs.
The findings presented below are consistent with:

1. Rapid gastric emptying
2. Delayed gastric emptying
3. ROI incorrect placed
4. Normal study

Causes for rapid gastric emptying:
- cyclic vomiting syndrome
- diabetes mellitus
- Zollinger-Ellison syndrome
- iatrogenic vagal nerve injury during fundoplication procedures
- irritable bowel syndrome
Normal gastric emptying study

Standardized gastric emptying (Tougas) protocol:
- Blood sugar check for diabetics
- NPO overnight or 6 hours fasting

1 mCi Tc99m-sulfurcolloid bound to:
- 4 oz egg substitute
- 2 slices of white bread
- strawberry jam (30 g)
- water (120ml)
- meal ingested 10-15 minutes

Patient with Whipple procedure for ampullary adenocarcinoma presenting with nausea, vomiting, early satiety.

Endoscopy demonstrating stenosis of the body of the stomach and subsequent balloon dilation.
33 yo women with prior bariatric surgery Roux-en-Y gastric bypass and scleroderma/Sjogren syndrome.

1. Normal gastric emptying
2. Delayed gastric emptying
3. Rapid gastric emptying (dumping syndrome)
4. Incorrect placing of region of interest
5. Gastric emptying may be mildly delayed

Consensus Recommendations for Gastric Emptying Scintigraphy: A Joint Report of the American Neurogastroenterology and Motility Society and the Society of Nuclear Medicine

Consensus Recommendations for Gastric Emptying Scintigraphy: A Joint Report of the American Neurogastroenterology and Motility Society and the Society of Nuclear Medicine


66 year-old male with lower GI bleeding

Issues Requiring Further Investigation for GES

1. Optimization of the specific time points used for imaging and interpretation:
   A. Use of 0.5- or 1-h result for detection of rapid gastric emptying.
   B. Use of 3-h result compared to 2- and 4-h results for detection of delayed GE.
   C. Use of multiple time points (2- and 4-h) versus single 2- or 4-h values and further understanding of the clinical meaning of discordant results between 2- and 4-h scans.

2. Need for normal data on other meals:
   A. Use of different composition solid meals with different calorie/fat challenges.
   B. Need for alternative meals for patients unable to tolerate eggs, allergic to eggs, or with gluten sensitive enteropathy.

3. Need for glycemic control and management of diabetic patients:
   A. Assessment of glucose in diabetic patients prior to the test: glucose and HbA1c.
   B. Management of hyperglycemic patients on the day of test.
   C. Administration of insulin and oral hypoglycemic agents.
   D. Need for monitoring postprandial glucose.

4. Value of monitoring symptoms during the time of study.

5. Development of a scale to assess severity of delayed gastric emptying.

6. Need for database of "normal" values for postprandial surgery patients.

7. Clinical value of characterization of proximal and distal gastric function:
   A. Regional analysis of gastric emptying (separate antral and fundal measurements).
   B. Dynamic antral contraction studies.
   C. Fundal accommodation studies with SPET.

8. Other quantitative measurements:
   A. Curve fitting.
   B. Lag phase measurements.
   C. Use of total abdominal counts.

9. Industry software development:
   A. Need for industry to develop commercial acquisition and processing protocols that support these consensus recommendations.
Findings are consistent with:

A. Upper GI bleeding (stomach)
B. SVC obstruction with collaterals
C. Technical error for the first set of images and no evidence of bleeding
D. Lower GI bleeding
GI bleed originating near splenic flexure.
Large photopenic defect in the left upper quadrant.
Metastatic melanoma invading the splenic flexure of the colon.
Progression of disease:

There is a heterogeneously enhancing, centrally necrotic mass initially centered on the left aspect of the anterior renal fascia. The mass progressively grows and extrinsically invades the medial aspect of the descending colon. Foci of gas are present within the mass on the final axial image, suggesting associated ulceration. The coronal image reveals multiple colonic diverticula near the splenic flexure.

Another case
71 yo F with h/o jejunal AVMs s/p previous small bowel resection admitted with recurrent GI bleeding.

Selective SMA angiogram involving multiple jejunal branches. Small areas of vascular malformations visualized, in region of surgical staple line/anastomosis.

Tc99m-RBC scintigraphy

- Patient’s own RBCs are labeled with Tc99m and given intravenously
  - Administered activity: 20-30 mCi
- Site of active bleeding is identified by accumulation and movement of labeled RBCs within the bowel lumen
  - Focus of increased activity
  - Activity increases in intensity over time
  - Activity changes in location over time, but conforms to intestinal anatomy
- Radiotracer transit may be anterograde or retrograde
  - Frequent images (every minute) will increase accuracy of localization
- Bleeding rates as low as 0.1-0.35 mL/min may be detected
Discussion

- **Causes of Upper GI Bleeding:**
  - Esophageal varices
  - Gastric and **duodenal** ulcers
  - Gastritis
  - Esophagitis
  - Mallory-Weiss tear
  - Neoplasm

- **Causes of Lower GI Bleeding:**
  - Angiodysplasia
  - Diverticula
  - Neoplasms
  - Inflammation
  - Meckel's diverticulum

- **False positives:**
  - Bladder
  - Vascular structures
    - (varices, AVM, grafts)
  - Ostomies
  - Inflammation
  - Penile uptake
  - Free pertechnetate
    - Consider imaging the thyroid and salivary glands

Pitfalls

- Excretion of the radiotracer from stomach not an indication of GI bleeding
- Pelvic activity is likely representing penile venous uptake. Obtain lateral view.
- Stomach activity due to free TC99m-pertechnetate not always appears diffuse/homogeneous. Check for thyroid uptake and urinary bladder
Free Tc99m- pertechnetate (thyroid visualized, high amount of free Tc99m- pertechnetate in the bladder)

Thank you!