RENAL TUBULAR SECRETION STUDY

(Tc-99m-MAG3)

Overview

- The Renal Tubular Secretion Study images Tc-99m-MAG3 as it passes through the vascular system, renal tubular cells, tubular lumens, and collecting system. This series of images allows the sequential evaluation of renal perfusion, renal clearance by tubular secretion, renal parenchymal transit time, and passage of urine through the renal collecting system. In addition, the study provides high contrast images for evaluation of renal anatomy.

Indications

- Evaluation of renal perfusion and function (1).
- Evaluation of renal trauma.
- Diagnosis of renovascular hypertension (2).
- Detection and evaluation of renal collecting system obstruction (3-5).
- Evaluation of renal transplants.

Examination Time

- 45 minutes.

Patient Preparation

- The patient should hydrate by drinking at least one large glass of water 30 minutes prior to the study.
- The patient should void before beginning the study.

Equipment & Energy Windows

- Gamma camera: Large field of view.
- Collimator: Low energy, high resolution, parallel hole.
- Energy window: 20% window centered at 140 keV.
- Computer.

Radiopharmaceutical, Dose, & Technique of Administration

- Radiopharmaceutical: Tc-99m-mercaptoacetyltriglycine (Tc-99m-MAG3) (6-9).
- Dose: 10 mCi (555 MBq).
- Technique of administration: Oldendorf method.

Patient Position & Imaging Field

- Patient position: Supine.
- Imaging field: All of kidneys and bladder.

Acquisition Protocol (10,11)

- Position the camera under the table for POST images.
- Acquire serial 3 second analog images for approximately 30 seconds.
- Acquire 1 minute analog images beginning at 1, 3, 5, 10, 15, and 20 minutes.
- In addition to routine analog images, acquire simultaneous digital images:
  1. Acquire 1 second serial digital images using a 128 x 128 matrix for 60 seconds.
  2. Acquire 30 second serial digital images using a 128 x 128 matrix for 19 minutes beginning at 60 seconds.
- Have the patient void at the end of the study to significantly reduce the gonadal radiation dose (12).

Protocol Summary Diagram

Data Processing

- Place regions of interest over the cortex of each kidney (excluding the calyces) and lateral to or around each kidney for background subtraction (13):
  - ❑ Place a region of interest over the adjacent aorta.
- Generate 20 minute renal cortex and background curves.
- Subtract the background curves from the corresponding renal cortex curves (Be sure curves are normalized for area, i.e. per pixel, before subtraction.) (13).
- Display curves with "Time" on the X-axis and "Counts" on the Y-axis.
- The perfusion portion of the time-activity curve should be on an expanded scale compared to the delayed portion of the curve; this may be done either in one graph, if possible, or by using 2 separate graphs.

Optional Maneuvers

- Imaging a transplanted kidney (14):
  1. The patient is positioned supine.
  2. Images are acquired in the ANT projection.
  3. The field of view includes the transplanted kidney and bladder (usually imaging the entire pelvis will accomplish this).
  4. The acquisition and quantification is otherwise the same as for native kidneys.

- Diuretic washout renal study (3,15-17):
  1. Hydrate the patient:
     - ❑ Oral fluids: Up to 1,500 mL over 30 minutes prior to the study for adults (18).
     - ❑ Intravenous fluids: Give fluids prior to and during the study (19,20):
       - i tell the patient to drink fluids prior to the study.
       - ii give an intravenous infusion of 0.9% sodium chloride at a rate of 10 mL/kg of body surface area over 30 minutes prior to the injection of the radiopharmaceutical.
       - iii during the study infuse 0.225% sodium chloride and 3.75% dextrose at maintenance levels, e.g. 2-8 years: 60-80 mL/kg/day.
  2. Catheterize the bladder in neonates (3).
  3. Perform the routine Tc-99m-MAG3 renal study with digital acquisition for quantitation.
  4. At 10 minutes after injection of the radiopharmaceutical, inject 1 mg/kg of furosemide intravenously over 1 minute. [Some recommend a maximum of 40 mg per patient while others do not (15).]
     - ❑ Inject furosemide at 20 minutes (3).
     - ❑ Inject furosemide at the time of injection of the radiopharmaceutical (19).
  5. Continue acquiring images for an additional 20 minutes:
     - ❑ An additional post gravity-assisted drainage image has been recommended, especially in post pyeloplasty patients (21).
  6. Place regions of interest around the renal pelvis and calyces on each side. (Background subtraction is not essential.)
  7. Display curves with “Time” on the X-axis and “Counts” on the Y-axis.
  8. The perfusion portion of the time activity-curve should be on an expanded scale compared to the delayed portion of the curve; this may be done either in one graph if possible or by using 2 separate graphs.
  9. Normal halftime clearance is approximately 10 minutes; abnormal is over 20 minutes; and between 10 and 20 minutes is often considered indeterminate (3,21).
  10. Urinary extravasation following administration of the diuretic in diuretic renography has been reported as a rare complication (22).

- Angiotensin converting enzyme (ACE) inhibitor renal study (17,23-28):
  1. Interfering medications:
     - a) ACE inhibitors and diuretics may decrease the accuracy of the test. (Discontinue for 2-3 days.)
     - b) discontinue calcium antagonists (24).
     - c) angiotensin II receptor antagonists may be continued (26).
  2. With the patient supine, administer an ACE inhibitor (25):

- ❑ Enalaprilat: 0.04 mg/kg intravenously infused over 5 minutes. (Enalaprilat has a higher incidence of hypotension so an intravenous line with normal saline is suggested.)
- ❑ Captopril: 50 mg orally. (Since food in the gastrointestinal tract delays absorption, the patient should fast for 4 hour prior to the study if captopril will be used.)

3. Record the patient's blood pressure every 15 minutes for 1 hour.
4. Timing of radiopharmaceutical injection:
   - > Enalaprilat: Inject Tc-99m-MAG3 10 minutes from the end of the enalaprilat infusion.
   - > Captopril: Inject Tc-99m-MAG3 60 minutes after ingestion of the captopril.
5. Additional quantitative measurements beyond those in the routine quantitative renal study may be performed (27).
6. If the ACE inhibitor renal study is abnormal, a baseline Tc-99m-MAG3 renal study should be performed later when the patient has been off ACE inhibitors for at least 2 days (4,25).

- Quantitation of renal tubular function in terms of % renal uptake of the injected dose without blood or urine sampling (10,11,29,30):
  1. This approach is valid for adults with normal cardiac output and normal vascular volume.
  2. Use a 5 mCi dose of Tc-99m-MAG3 and a low energy, high resolution collimator (8,29).
  3. Before injecting the dose obtain a 1 minute count of the syringe with the gamma camera by placing it 30 cm in front of the center of the camera (10,31).
  4. Acquire a routine quantitative renal study (see above).
  5. Obtain an analog image of the injection site to detect infiltration (11).
  6. Obtain a 1 minute count of the residual radiopharmaceutical in the syringe, again with the syringe 30 cm in front of the center of the camera.
  7. Place regions of interest around both kidneys and below both kidneys for background.
  8. Determine the counts in the 4 regions of interest from 2 to 3 minutes post injection.
  9. Calculate the depth of each kidney based on the patient's height, weight, and age (10,32-34).
  10. Calculate the global and fractional right and left renal tubular function using the Renal Tubular Function Worksheet (see below).

- Quantitation of effective renal plasma flow (ERPF) with blood sampling (35-37).

Principle Radiation Emission Data - Tc-99m (38)

- Physical half-life = 6.01 hours.

Radiation	Mean % per disintegration	Mean energy (keV)
Gamma-2	89.07	140.5

Dosimetry - Tc-99m-MAG3 (11,39)

Organ	rads/10 mCi	mGy/370 MBq
Bladder wall		
4.8 hour void	4.8	48.0
Ovaries		
4.8 hour void	0.26	2.6
Testes		
4.8 hour void	0.16	1.6
Kidneys	0.14	1.4
Total body	0.07	0.7
Liver	0.04	0.4

Effective dose	rems/10 mCi	mSv/370MBq
Whole body	0.26	2.6

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Normal Findings

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RENAL TUBULAR FUNCTION (% UPTAKE) WORKSHEET

Nuclear Medicine Department

Institution ______________________

Patient name______________________________________ ID______________ Date___________

Referring physician____________________ Weight______(kg) Height______(cm) Age_____(yr)

NOTE: Many nuclear medicine computers have software that performs one or more of the steps below automatically.

STEP 1 Calculate the net injected dose from the syringe images:

pre injection (cts) - post injection (cts) = net injected dose (cts)

__________(cts) - __________(cts) = __________(cts)

STEP 2 Calculate the renal depth of both kidneys using the method of Taylor:

[151.3 x weight (kg) ÷ height (cm)] + 0.22 age (yr) + 0.77 = right kidney depth (mm)

[151.3 x _____(kg) ÷ _____(cm)] + 0.22 x _____(yr) + 0.77 = _____(mm)

[161.7 x weight (kg) ÷ height (cm)] + 0.27 age (yr) + 0.7 = left kidney depth (mm)

[161.72 x _____(kg) ÷ _____(cm)] + 0.27 x _____ (yr) + 0.7 = _____(mm)

STEP 3 Calculate the percent uptake of the injected dose in each kidney at 2 to 3 minutes using the equation:

$$\frac{[A-B] \times P \times 100\%}{[e \exp -\mu Y] \times D} = U\ (\%)$$

Where: U = percent uptake (%)
A = counts per pixel right or left kidney (cts/px)
B = counts per pixel corresponding background (cts/px)
P = pixels in kidney region of interest (px)
e = natural log = 2.718 (no units)

μ = attenuation coefficient for Tc-99m = 0.0153 (1/mm)
Y = kidney depth (mm)
D = net counts for syringe containing dose (cts)
exp = exponent

Right kidney:

$$\frac{[\_\_\_\_\_\_(\text{cts/px}) - \_\_\_\_\_\_(\text{cts/px})] \times \_\_\_\_(\text{px}) \times 100\%}{[2.718 \exp -0.153\ (1/\text{mm}) \times \_\_\_\_(\text{mm})] \times \_\_\_(\text{cts})} = \_\_\_\_\%\ \text{uptake}$$

Left kidney:

$$\frac{[\_\_\_\_\_\_(\text{cts/px}) - \_\_\_\_\_\_(\text{cts/px})] \times \_\_\_\_(\text{px}) \times 100\%}{[2.718 \exp -0.153\ (1/\text{mm}) \times \_\_\_\_(\text{mm})] \times \_\_\_(\text{cts})} = \_\_\_\_\%\ \text{uptake}$$

STEP 4 Add the percent uptakes of the two kidneys together to obtain the global percent uptake (a measure of renal clearance):

right (% uptake) + left (% uptake) = global (% uptake)

_______(% uptake) + _______(% uptake) = _______(% uptake)

Technologist___________________________

NOTES