RENAL GLOMERULAR FILTRATION STUDY

(Tc-99m-DTPA)

Overview

- The Renal Glomerular Filtration Study images Tc-99m-DTPA as it passes through the vascular system, renal glomeruli, renal tubular lumens, and collecting system. This series of images allows the sequential evaluation of renal perfusion, renal clearance by glomerular filtration, 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 (1-3).
- Diagnosis of renovascular hypertension (4).
- Detection and evaluation of renal collecting system obstruction (5,6).
- Evaluation of renal transplants (7,8).

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: With renal anaysis application.

Radiopharmaceutical, Dose, & Technique of Administration

- Radiopharmaceutical: Tc-99m-diethylenetriaminepentaacetic acid (Tc-99m-DTPA) (9).
- Dose: 15 mCi (555 MBq).
- Technique of administration: Oldendorf method.

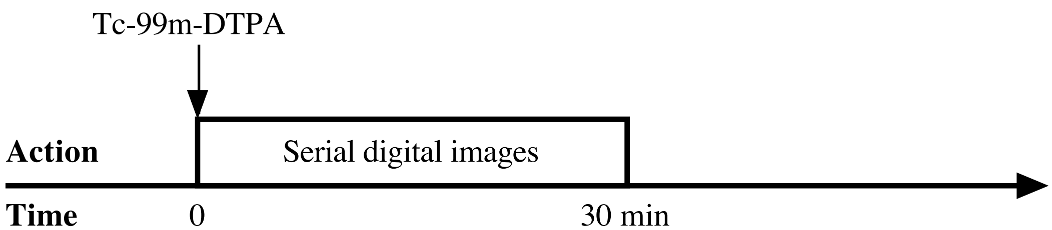
Patient Position & Imaging Field

- Patient position: Supine.
- Imaging field: All of the kidneys and bladder, if possible.

Acquisition Protocol

- Position the camera under the table for POST images.
- Acquire serial digital images (4):
  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 29 minutes beginning at 60 seconds.
- Have the patient void at the end of the study to significantly reduce the gonadal radiation dose (10).

Protocol Summary Diagram



Data Processing

- Display serial 3 second images for 48 seconds for visual evaluation of perfusion.
- Display 1 minute analog images beginning at 1, 3, 5, 10, 15, 20, 25, and 30 minutes for visual evaluation of clearance parenchymal transit, excretion, and anatomy.
- Place regions of interest over the cortex of each kidney (excluding the calyces) and lateral to or around each kidney for background subtraction (11,12):
  - ❑ Place a region of interest over the adjacent aorta.
- Generate 30 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.) (11).
- 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 (8):
  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.

- Angiotensin converting enzyme (ACE) inhibitor renal study (4,13-16):
  1. Chronic administration of ACE inhibitors and diuretics may decrease the sensitivity of the test (15):
     - ❑ Stop ACE inhibitors and diuretics 3-5 days prior to the study.
  2. With the patient supine, administer an ACE inhibitor (14,17):
     - ❑ <u>Enalaprilat</u>: 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.)
     - ❑ <u>Captopril</u>: 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:
     - > <u>Enalaprilat</u>: Inject Tc-99m-DTPA 10 minutes from the end of the enalaprilat infusion.
     - > <u>Captopril</u>: Inject Tc-99m-DTPA 60 minutes after ingestion of the captopril.
  5. Additional quantitative measurements beyond those in the routine quantitative renal study may be performed (13,16).
  6. If the ACE inhibitor renal study is abnormal, a baseline Tc-99m-DTPA renal study should be performed later when the patient has been off ACE inhibitors for at least 2 days (4,14).

- Quantitation of glomerular filtration rate - without blood or urine sampling (18-22):
  1. This approach is valid for adults with normal cardiac output and normal vascular volume.
  2. Use a 3 mCi dose of Tc-99m-DTPA and a medium energy collimator (18).
     - ❑ a dose attenuation syringe shield may be used to allow larger doses and a low energy high resolution collimator without significant dead time count losses (23).
  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.
  4. Acquire a quantitative renal study (see above); if only GFR is desired, the study may be terminated at 3 minutes.
  5. Obtain an analog image of the injection site to detect infiltration.
  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 (24-26).
  10. Calculate the global and fractional right and left GFR using the Glomerular

Filtration Rate Worksheet (see below).

- Renal function (GFR) may be monitored in real time: A small radiation detector strapped to the arm measures the disappearance of Tc-99m-DTPA from the extracellular space (27).

Principle Radiation Emission Data - Tc-99m (28)

- Physical half-life = 6.01 hours.

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

Dosimetry - Tc-99m-DTPA (10,29)

Organ	rads/15 mCi	mGy/555 MBq
Bladder wall		
2 hour void	1.73	17.3
4.8 hour void	4.05	40.5
Kidneys	1.35	13.5
Ovaries		
2 hour void	0.17	1.7
4.8 hour void	0.23	2.36
Testes		
2 hour void	0.11	1.1
4.8 hour void	0.16	1.6
Whole body	0.09	0.9

Effective dose	rems/15 mCi	mSv/555MBq
Whole body	0.27	2.7

References

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Normal Findings

> Kass EJ, Fink-Bennett D: Contemporary techniques for the radioisotopic evaluation of the dilated urinary tract. Urol Clin N Am 17:273-289, 1990.

> Dey HM, Hoffer PB, Lerner E, et al: Quantitative analysis of the technetium-99m-DTPA captopril renogram: Contribution of washout parameters to the diagnosis of renal artery stenosis. J Nucl Med 34:1416-1419, 1993.

GLOMERULAR FILTRATION RATE 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) + 0.70 = left kidney depth (mm)

[161.72 x _____(kg) ÷ _____(cm)] + 0.27 x _____ (yr) + 0.70 = _____(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:

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

Left kidney:

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

STEP 4 Calculate the glomerular filtration (GFR) rate for each kidney using the equation:

Right kidney: U (%) x 9.75621 - 6.19843 = GFR (mL/min)

_____(%) x 9.75621 - 6.19843 = ______(mL/min)

Left kidney: U (%) x 9.75621 - 6.19843 = GFR (mL/min)

_____(%) x 9.75621 - 6.19843 = ______(mL/min)

STEP 5 Add the glomerular filtration rates for the two kidneys together to obtain the global GFR:

right GFR (mL/min) + left GFR (mL/min) = global GFR (mL/min)

_______(mL/min) + _______(mL/min) = _______(mL/min)

Technologist__________________________