# Renal Scintigraphy – Reporting Document


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# Chapter 1: Introduction

Renal scintigraphy offers the opportunity to get a wide spectrum of information about renal function, but the radiopharmaceutical and procedure needs to be tailored to the patient's pathology and clinical question to extract the maximum benefit from this procedure.

The radiopharmaceuticals available for assessment of kidneys can be grouped into 3 broad categories:

1. Radiopharmaceuticals filtered by the glomerulus
2. Radiopharmaceuticals secreted by the renal tubules
3. Radiopharmaceuticals retained by the renal tubules (Table 1).

**Table 1. Radiopharmaceuticals available for renal scintigraphy(1).**

| Mechanism | Radiopharmaceutical | Comment |
|---|---|---|
| Glomerular Filtration | $^{99m}$Tc-Diethylenetriaminepentaacetic Acid (DTPA) | Commonest renal radiopharmaceutical in general use for imaging and GFR measurement by plasma sampling |
| | $^{51}$Cr-Ethylenediaminetetraacetic Acid (EDTA) | Used for GFR measurement by plasma sampling |
| | $^{125}$I-Iothalamate | Used for GFR measurement by plasma sampling, cannot be used for imaging |
| Tubular Secretion | $^{123}$I- and $^{131}$I-Orthoiodohippurate (OIH) | use supplanted by $MAG_3$ |
| | $^{99m}$Tc-mercapto acetyl tri glycine ($MAG_3$) | Highly protein bound with high extraction fraction (~50%), preferred over DTPA in cases of renal obstruction and impairment of function. Used to calculate effective renal plasma flow (ERPF). Sometimes, gallbladder and bowel activities may cause artifacts and difficulties in interpretation. |
| | $^{99m}$Tc-L,L Ethylenedicysteine (EC) | Extraction even higher than $MAG_3$, widely used in some countries |
| | $^{99m}$Tc-(CO3)Tricarbonylnitriloacetic | Advantages over $MAG_3$ include no gallbladder or bowel activity |

| | | |
|---|---|---|
| | Acid (NTA) | |
| Cortical retention | $^{99m}$Tc-Dimercaptosuccinic Acid (DMSA) | Primarily used in paediatrics to evaluate relative function, pyelonephritis and renal scarring. |
| | $^{99m}$Tc-Glucoheptonate (GH) | Cortical retention as well as excretion |

## Chapter 2: Common Indications/ Applications

The field of renal nuclear medicine encompasses a wide array of scintigraphic applications which can be divided to four major groups (Table 2):

- Dynamic renal imagining (Renal physiology and function, morphology Urinary tract obstruction, Renovascular hypertension, Evaluation of transplanted kidney)
- Measuring renal function (ERPF, GFR)
- Renal Cortical imaging (evaluating renal cortex)
- Radionuclide Cystography (Evaluation of vesicoureteral reflux)

**Table 2. Common indications of radionuclide scintigraphy in Nephrourology (2).**

| | |
|---|---|
| Renal physiology and function | Acute and chronic renal failure<br>Determine relative renal function in patients with asymmetric renal disease<br>Evaluate the vascular supply to the kidneys in patients with renal trauma, dissecting aneurysm and other disorders<br>Determine renal morphology and function in patients with allergy to x-ray contrast media |
| Renal Morphology | Pre-surgical evaluation<br>Congenital anomalies<br>Evaluation of masses |
| Assessment of obstruction | Ureteropelvic or ureterovesical obstruction<br>Post-surgical evaluation of a previously obstructed system<br>Distention of pelvicalyceal system as a etiology of back pain |
| Assessment of renovascular hypertension | In patients with abrupt onset or severe hypertension<br>Hypertension resistant to medical therapy in a compliant patient<br>Abdominal or flank bruits<br>Unexplained azotemia in an elderly hypertensive patient<br>Worsening renal function during therapy with ACE inhibitors<br>Grade 3 or 4 hypertensive retinopathy<br>Occlusive disease in other vascular beds<br>Onset of hypertension in under age 30 or over age 55 |

| | |
|---|---|
| Evaluation of transplanted kidney | Baseline evaluation of transplanted kidney<br>Evaluation of Acute Tubular Necrosis (ATN), acute and chronic rejection.<br>Assessment of vascular obstruction.<br>Confirmation of urine leakage, hematoma, lymphocele and other surgical complication |
| Evaluating the renal cortex | Acute pyelonephritis<br>Renal scarring<br>Renal mass evaluation<br>Solitary or ectopic renal tissue<br>Horseshoe kidneys |
| Evaluation of vesicoureteric reflux | Detection and follow up of VUR in children |

# Chapter 3: Dynamic Renal Imaging

## 3.1 Evaluation of renal physiology and morphology

$^{99m}$Tc-DTPA, $^{99m}$Tc-EC and $^{99m}$Tc-$MAG_3$ are the preferred radiopharmaceuticals with recommended dose range of 2-6 mCi (70-210 MBq) in adults. In children, $^{99m}$Tc-$MAG_3$ is recommended at a dosage of 50 µCi/kg and a minimum dose of 1 mCi.(5)

### 3.1.1 Introduction:

Dynamic renal scintigraphy gives valuable information about renal perfusion, total and differential function and presence of any outflow obstruction.

### 3.1.2 Indications (No contraindication):

1. Evaluation of acute and chronic renal failure.
2. Relative renal function in patients with asymmetric renal disease.
3. Evaluation of vascular supply to the kidneys in patients with renal trauma, dissecting aneurysm and other disorders.
4. Renal morphology and function in patients with allergy to x-ray contrast media.
5. Pre-surgical evaluation.
6. Congenital anomalies.
7. Evaluation of masses.

### 3.1.3 Patient preparation:

The patient should be well hydrated and drink about 500ml (two large glasses) of water just before tracer injection. Also, voiding before starting imaging is recommended as it is essential for reducing effect of full bladder on renal drainage and lessens the needs to void during acquisition.

Review clinical history, imaging (ultrasound, prior radionuclide or other imaging), make note of any known renal anomaly (duplex, ectopic, malformed or hydronephrotic kidneys).

In patients who have been referred for follow up scan, previous report and images should be available for comparison.

### 3.1.4 Imaging:

Supine position with the camera below the table is preferred in most cases. In some situation like transplant kidney, camera should be above the table to acquire anterior images. Both anterior and posterior images should be acquired in horseshoe and ectopic kidneys for accurate assessment of function. Note that the best resolution will not possible unless the patient has been positioned as close to the collimator face as possible.

After injecting the radiopharmaceutical, images should be acquired for about 30 minutes with 2 seconds per view for the first minute for evaluation of perfusion followed by one minute per view for the remainder of the study to evaluate cortical uptake, transit as well as excretion. In all patients, prevoid, post void and delayed images (static views with the same duration as the last frame i.e. 1 minute are indicated for evaluation of tracer excretion, omitting bladder effect, evaluation of residual bladder volume and any possible vesicoureteral reflux. This is especially important in patient with tracer retention in renal pelvis.

Diuretic renography involves the injection of furosemide during the radionuclide renal study. Furosemide injection can be given simultaneously with the radiopharmaceutical (F+0 Protocol), the second method is looking at the renogram curve at 20 minutes and if the curve is abnormal giving furosemide and continuing the study for another 30 minutes (F+20). The third method is to inject furosemide 15 minutes before the radiopharmaceutical injection (F-15 protocol). If there is no mechanical obstruction, the diuresis will increase the flow to the extent that it overcomes the stasis in the dilated patulous system and the washout curve shows a steep decline. It is essential however, that the renal function is normal and there is no dehydration because both these situations can confound the curve.

### 3.1.5 Furosemide dose(1, 4, 6)

Children: 1mg/Kg in infants, 0.5 mg/kg in children>1 year up to maximum 20mg.

Adults: based on creatinine level:

| Creatinine level (mg/dl) | Furosemide dose (mg) |
|---|---|
| 1 | 20 |
| 1.5 | 40 |
| 2 | 60 |
| 3 | 80 |

Regions of interest (ROIs) are placed around the kidneys and aorta for generating time activity curves (TAC). Renal ROIs can be placed around the whole kidneys or just the cortical areas if there is pelvic retention of the radiopharmaceutical.

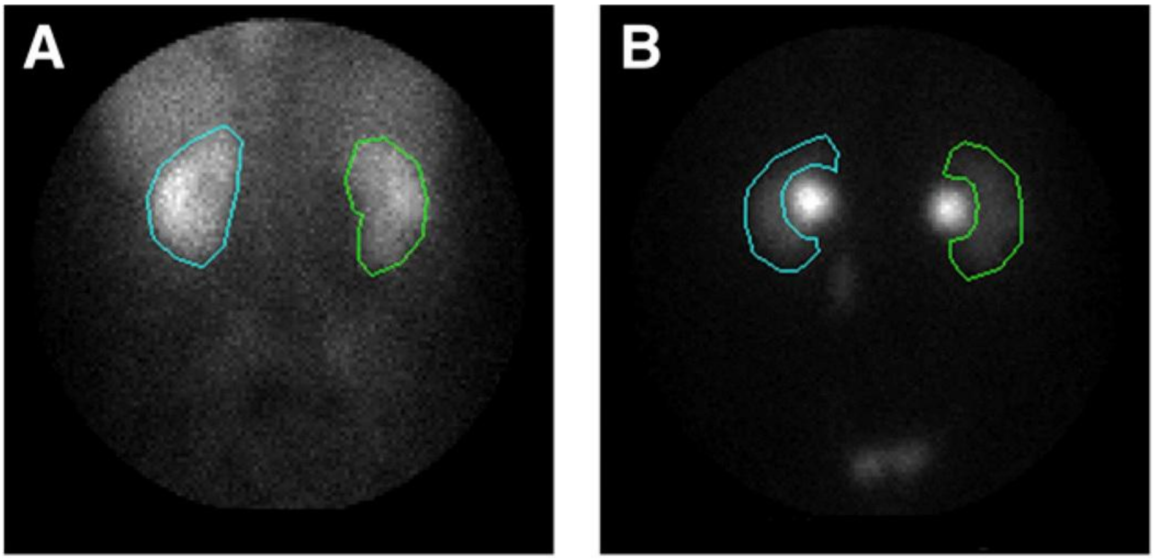



Figure1. A. Whole-kidney ROI on image 2-3 minutes after radiotracer injection. B. Cortical (parenchymal) ROI on image 19-20 minutes after injection.

(Image © IAEA Paediatric Renal Scan, Sri Lanka, 2015)

### 3.1.6 Reporting:

Before processing, image data of dynamic renal scintigraphy should be first checked for:

- Motion
- Sufficient number of counts
- Tracer extravasation
- Appearance of activity in the heart (quality of bolus)

Position of patient (patient should be lying flat), kidneys should be centred over the field of view (FOV).

After reviewing raw images and processing them, description and interpretation of images and diuretic renogram can be accurately performed.

### 3.1.7 Normal findings:

Renal perfusion should appear simultaneously with the appearance of activity in the aortic bifurcation with peak renal activity being similar to the aorta. There should be no delay in renal perfusion peak more than 2-4 seconds compared to aorta peak.

Both kidneys should show symmetrical uptake. Delay in uptake or reduction in intensity suggests abnormal perfusion.

Peak cortical activity should occur within 3-5 minutes of injection and the activity should decline to 50% of the peak within 8-12 minutes ($T_{1/2}$).

$T_{1/2}$ refers to the time from peak activity to half of peak activity, or with diuretic renography, the time to half of activity after furosemide injection, a $T_{1/2}$ of less than 10 minutes is considered normal.

Differential function is calculated by summing the counts from the whole kidney between 2-3 minutes. Care must be taken to not include any retained activity in the renal pelvis. Differential function should be the same (50:50) but range of up to 45:55 is considered within normal limits too.

### 3.1.8 Abnormal findings:

Perfusion: If both the aortic flow and renal flow curves are flattened, this might be due to poor injection technique (Non-bolus injection).

Delayed perfusion (>4 seconds) or decreased perfusion is considered abnormal.

Function: Renal uptake normally peaks in the first 2-3 minutes after injection, pelvicalyceal system should be seen in the first 5 minutes and bladder should be seen in the first 10 minutes. Renal washout normally is done in less than 10 minutes after diuretic injection. $T_{1/2}$ of less than 10 minutes is normal, $T_{1/2}$ > 20 minutes suggests obstructed system, 10-20 minutes $T_{1/2}$ is equivocal.

No extension in imaging time is needed for an F-15 or F+0 protocols if the pelvic system shows non-obstructive dilatation.

Post micturition image is crucial in interpretation of obstruction. A complete washout in post-micturition image rules out any obstruction even if the $T_{1/2}$ was abnormal.

### 3.1.9 Pearls & Pitfalls:

Many factors can influence the results and several pitfalls are known (1, 3); these are summarized in table 3.

**Table 3. Pearls and pitfalls in diuretic renal scan.**

| Pitfall | Effect |
|---|---|
| Inadequate hydration | Causes tracer retention in the kidneys as well as the PCS and ureters |
| Delayed ureteral transit caused by diclofenac | Diclofenac, and possibly other nonsteroidal anti-inflammatory drugs (NSAIDs), and prostaglandins have been shown to inhibit spontaneous ureteric contraction, prolong the transit time, and |

| | |
|---|---|
| | delay the time to peak height of the renogram curve of $^{99m}$Tc-$MAG_3$ in healthy individuals. |
| ACE inhibitors | ACE inhibitors will cause a reduction in GFR in kidneys with a significant RAS. Drug history should include list of drugs, especially for hypertension |
| Furosemide (diuretics) | If the patient is on diuretics, there might be volume depletion and the patient will need additional hydration or larger doses of furosemide to prevent blunting of renogram. |
| Failure to have patient void before study | Full bladder might delay upper urinary tract emptying |
| Dose extravasation | Poor bolus due to extravasation or venous obstruction in the injected extremity can lead to inaccurate camera-based clearance measurements and result in an abnormal study with delayed uptake and washout.<br>Injection into a limb with venous obstruction should be avoided, positioning the arm at a 90° angle to the body will minimize the likelihood of axillary retention of the tracer. A short 30 to 60 sec image of the injection site at the conclusion of the study is a useful and a recommended quality control procedure. The degree of extravasation or infiltration can be estimated by dividing the counts/min at the site of infiltration by the counts/min injected. |
| Error in recording patient's height, weight, or dose injected | Renal depth and attenuation of activity is calculated from patient's height and weight and inaccurate values will influence accuracy of results |
| Patient motion resulting in spurious quantitative indices | If the patient moves, the ROI might not be limited to the cortex and also unintentionally include the renal pelvis leading to spurious results |
| Failure to use urinary drainage catheter for patients with urinary diversions | If free drainage is stopped, reflux might occur giving abnormal results |
| Insufficient dose of furosemide to obtain adequate diuresis in kidney with reduced function | With impaired renal function, furosemide dose needs to be increased to avoid indeterminate or false positive results |
| Failure to obtain post void kidney image to evaluate drainage | Post void images are essential to ascertain that the bladder has indeed been emptied so that the effect of backpressure does not confound the results and also to calculate residual urine volume |
| Use of whole-kidney ROI to evaluate washout rather than ROI limited to dilated collecting system | Can lead to an abnormally prolonged $T_{1/2}$ and misleading values for parenchymal function. |
| Use of parenchymal ROI reference values as standard for whole-kidney ROI measurements of T½ or 20-min/maximum count ratio | ROIs should be optimized for the information sought; pelvic ROIs can be used to assess drainage/obstruction of the kidneys |

| | |
|---|---|
| Measurement of relative function during 1 to 3 min post injection period in patients with severely impaired renal function and delayed urine excretion | Relative function should be assessed just before radiopharmaceutical leaves the kidney. In impaired renal function, this might be delayed till 13-14 minutes and the study should be similarly optimized. |

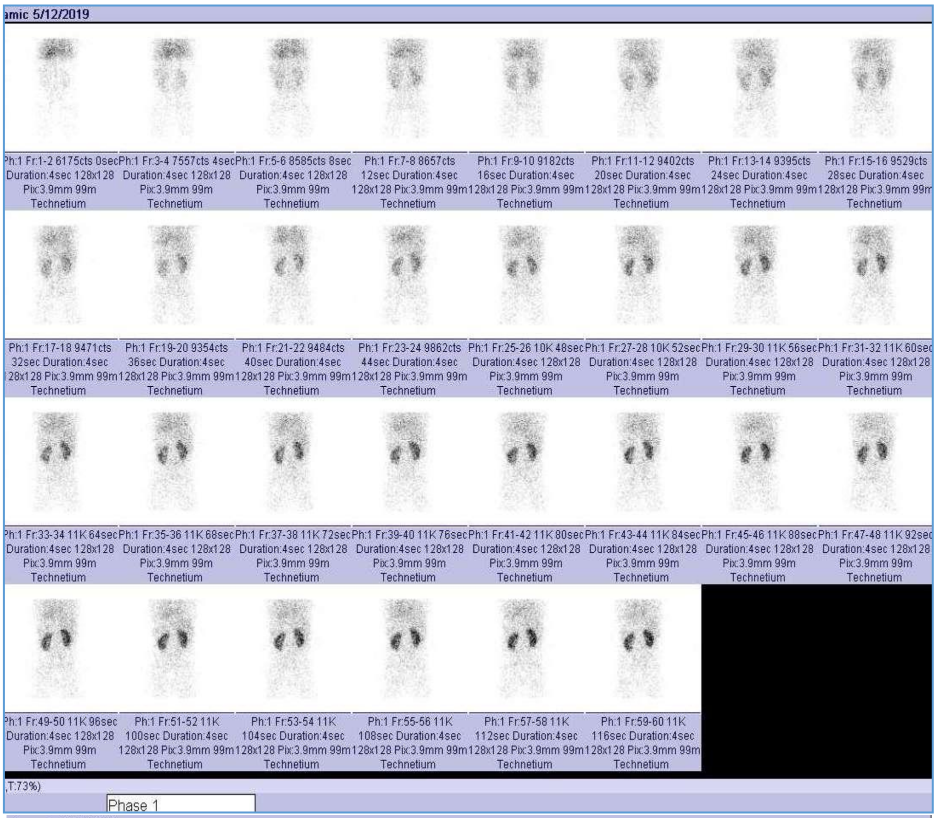
### 3.1.10 Reporting a normal dynamic renal scan (Example)

**Indication:**
The patient is a 4.5-year-old boy, referred for assessment of bilateral hydronephrosis.

**Clinical History:**
A 4.5 year old boy with history of bilateral antenatal hydronephrosis on ultrasonography (US). Recent US showed right kidney is 75mm in size and left kidney is 74mmin size with normal cortical echogenicity and thickness in both kidneys but hydronephrosis of left pelvicalyceal system.

**Procedure:**
The patient received additional hydration, which consisted of about 100 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 2mCi of $^{99m}$Tc-EC, scanning was performed in two dynamic phases from both kidneys in posterior view. Diuretic (8mg of Inj. Lasix) was injected intravenously 18minutes after tracer injection (16th frame of functional imaging). After review of raw data and image processing, two manual ROIs were drawn around both kidneys and background subtraction was performed using peri-renal semilunar ROIs. Images were reviewed in two perfusion and function phases. Also, post-void image and renal curve were assessed.

Figures below show perfusion phase, function phase, post-void image and renal curve, respectively.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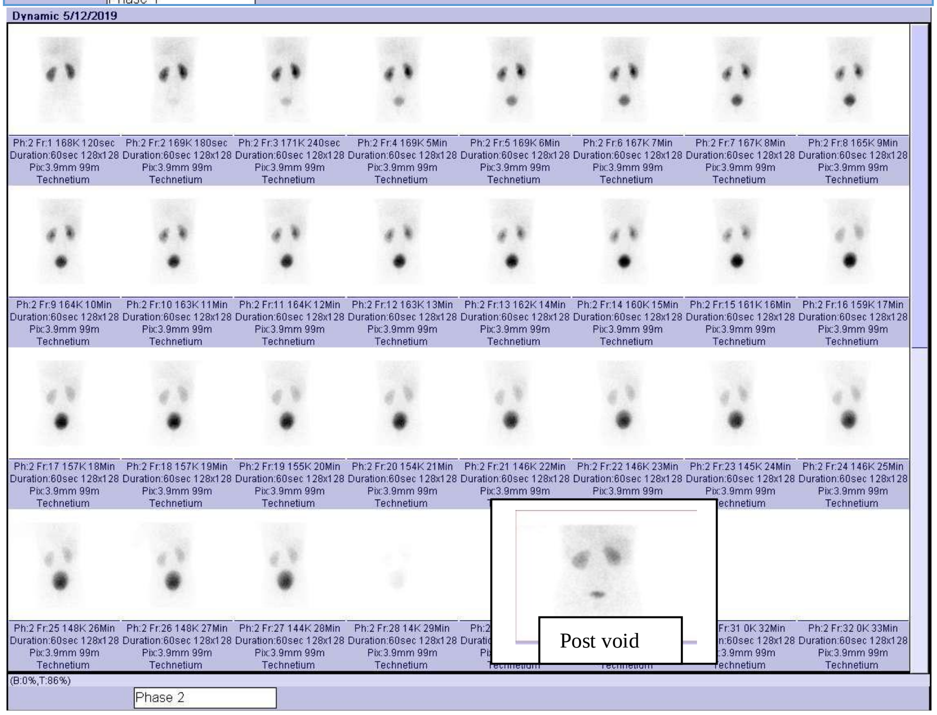
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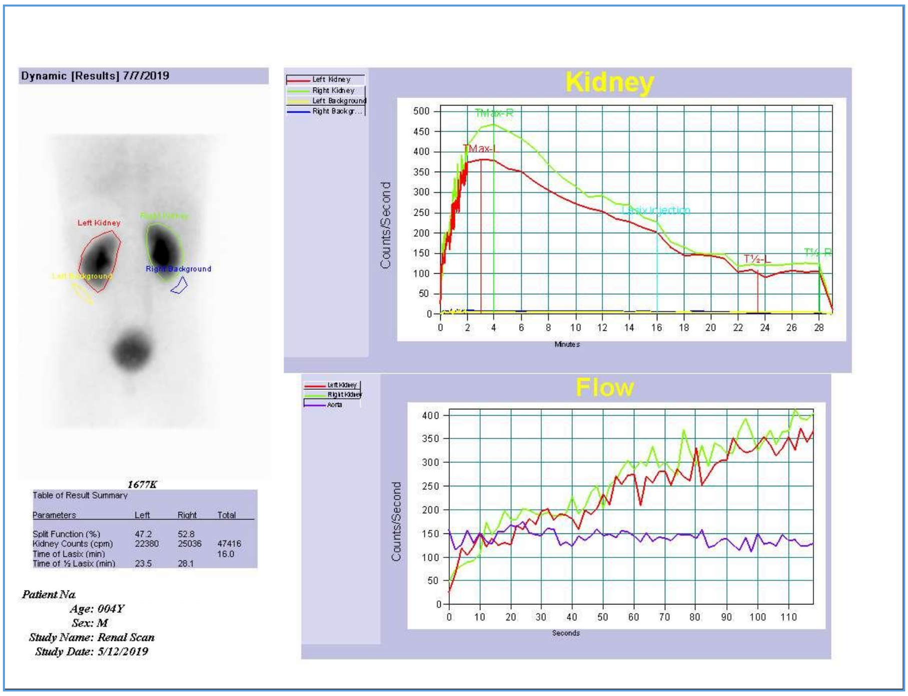
Post void
Phase 2




**Findings**

Both kidneys showed normal perfusion and initial tracer uptake with good excretion, even before lasix injection.

**Impression:**

***Both kidneys:***

Normal perfusion and function with normal tracer drainage.

***Split renal function:***

Right kidney: 53%

Left kidney: 47%

## 3.2 Evaluation of renal outflow obstruction *(7)*

### 3.2.1 Introduction:

Most useful in distinguishing obstructed from non-obstructed dilatation of the collecting system (Causes of non obstructive dilatation incl ude infection, VUR, mega ureter and recent mechanical obstruction).

### 3.2.2 Indications:

- Confirm or rule out ureteropelvic/ ureterovesical obstruction.
- Post-surgical evaluation of a previously obstructed system.
- Serial evaluation of stenotic system
- Determining etiology of back pain (distention of pelvicalyceal system).

**Patient preparation:** *(The same as discussed above)*

- Well hydration and voidingbefore starting imaging are mandatory.
- Review previous imaging, especially if a renal scan has been done previously, this knowledge will enable a more accurate assessment of renal function and

put into perspective the abnormalities noted.

- Summarize relevant urological procedures, drain or stent placement. This knowledge is essential for accurate reporting of the renal scan findings.
- Ensure that the bladder has been emptied immediately prior to the study to facilitate renal drainage.

#### 3.2.3 Imaging:

Dynamic acquisition of 1-2 second images for 1 min. ("vascular" phase), starting immediately after administering radiopharmaceutical. It is followed by 10-15 second images for about 5 min. (functional uptake cortical transit), and then 20-30 sec. images for about 20 min. (excretion phases), with a total scan time of 20-30 min. All of the functions actually occur concurrently but these are the times when one or the other dominates. A post-micturition post-erect image, for the same duration as the last frame of the renogram is frequently indicated clinically. Acquire an image of the injection site to assess any infiltration.

Posterior images with the patient supine are generally acquired but anterior images will also be needed in cases suspected to have horseshoe kidneys. If there is retention of radiopharmaceutical in the renal pelvis, erect images can be acquired.

Furosemide should be injected based on recommended standard dose and protocols.

#### 3.2.4 Reporting:

- Comment on the quality of the study and cite any problems that might have affected the quality (patient movement, injection site infiltration, etc.)
- Note if additional hydration was done to avoid radiopharmaceutical retention in the kidneys or ureters. Timing of Furosemide injection should be mentioned.
- Report the relative uptake of the two kidneys.
- Describe the relative size and shape of the kidneys.
- Qualitatively describe the renogram curves.
- Note any retention of radiopharmaceutical in the renal pelvis, ureters, etc. and if this was with or without furosemide and the time of clearance if present.
- Note time to peak (T max), understand that this might be prolonged in obstruction as well with impaired function.
- Describe kidney drainage after voiding.
- If the bladder fails to empty after voiding, this must be reported as this might represent hitherto unrecognized pathology (prostatic enlargement, neurogenic bladder, diabetic cystopathy, increased risk of reflux nephropathy).
- If there is flank pain after furosemide injection, this must be reported as this supports the presence of obstruction.
- The report should state if evidence of obstruction is present, absent or if this is inconclusive.
- The language should be as unambiguous and concise as possible.
- Give differential diagnosis if appropriate.
- Recommendations for further workup if appropriate.

### 3.2.5 Reporting a dynamic renal scan with an outflow obstruction (Example)

**Indication:**

The patient is a 3-year-old boy, referred for evaluation of obstruction in left ureteropelvic junction.

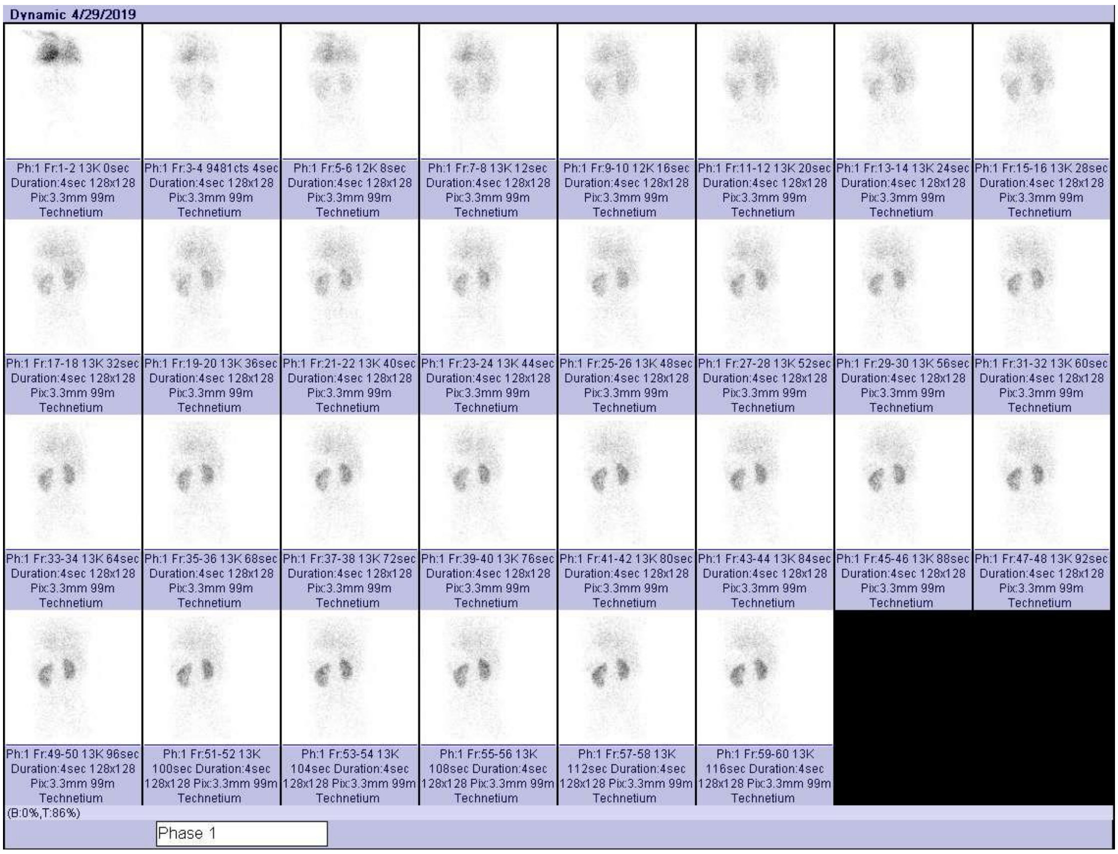
**Clinical History:**

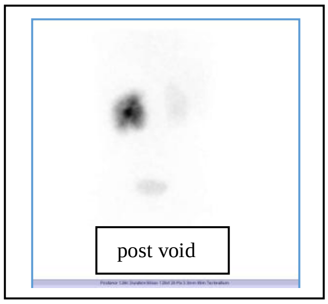
A 3 year old boy with abdominal pain for one month. Ultrasonography has showed normal right kidney and hydronephrotic left kidney (grade III) without any evidence of dilatation in the left ureter.

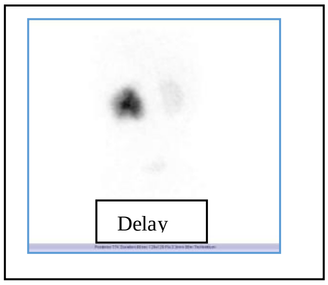
**Procedure:**

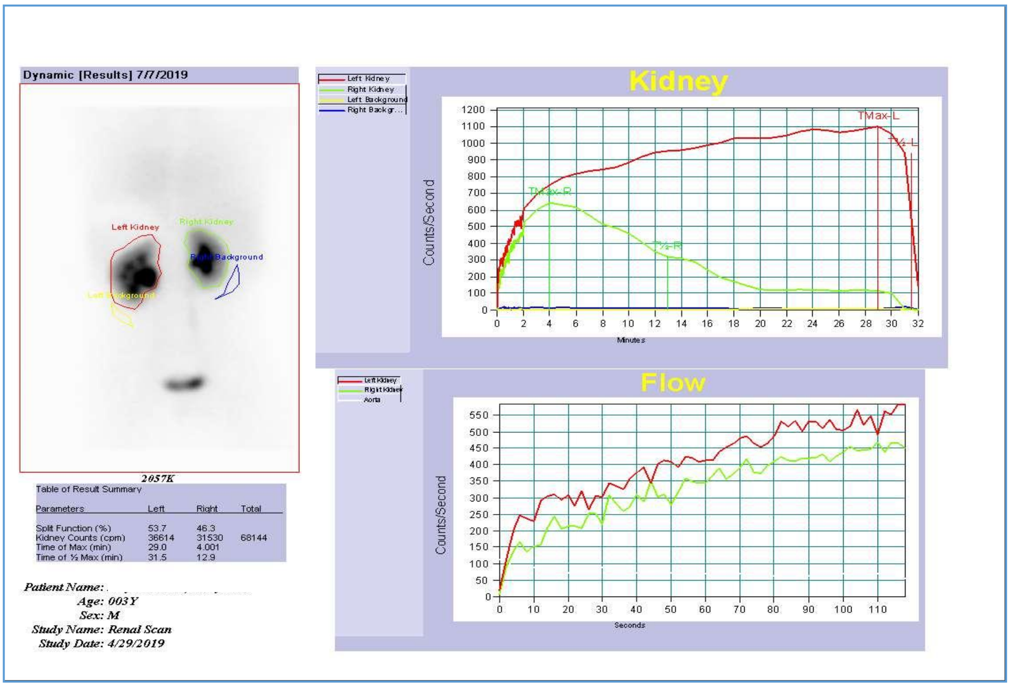
The patient received additional hydration, which consisted of about 100 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 2mCi of $^{99m}$Tc-EC, scanning was performed in two dynamic phases for both kidneys in posterior view. Diuretic (8mg of lasix) was injected intravenously 15 minutes after tracer administration (in 13th frame of functional imaging). After review of raw data and image processing, two manual ROIs were drawn around both kidneys and background subtraction was performed using peri-renal ROIs. Images were reviewed in two perfusion and function phases. Also, post void and delayed image as well as renal curve were evaluated.

Figures below show perfusion phase, function phase, post-void and delayed images and renal curve, respectively.




**Findings:**

The study was of good quality. The right kidney showed normal perfusion and tracer uptake with normal excretion, even before lasix injection. The left kidney showed normal perfusion and initial tracer uptake with tracer accumulation in dilated pelvicalyceal system and poor excretion, even after lasix injection. On post void and delayed images, no tracer washout was noted from left PC system.

***Split renal function:***

Right kidney: 46.3%

Left kidney: 53.7%

**Impression:**

*Right kidney:* Normal perfusion and function without obstruction.

*Left kidney:* Normal perfusion and function with dilated PC system and no tracer excretion suggesting obstructive disease at the UPJ level.

## 3.3 Evaluation of reno-vascular hypertension *(3, 8-10)*

### 3.3.1 Introduction:

Although Gadolinium enhanced MR Angiography is the most accurate non-invasive modality for detection of renal artery stenosis of more than 50%; captopril renogram has considerable sensitivity. Captopril renography is used in many centers as a screening test in patient with appropriate a priori probability.

99m Tc MAG3 (or 99m Tc-EC) is the preferred radiopharmaceutical.

25 mg Captopril, orally is the preferred ACE inhibitor but Enalapril (40ug/kg in over 3-5 minutes) can also be used.

### 3.3.2 Indication:

Evaluation of renovascular hypertension in patients who are suspected to have renal artery stenosis including:

- Abrupt onset or severe hypertension
- Resistant hypertension to medical therapy in a compliant patient
- abdominal or flank bruits
- unexplained azotemia in an elderly hypertensive patient
- worsening renal function during therapy with ACE inhibitors
- grade 3 or 4 hypertensive retinopathy
- occlusive disease in other vascular beds
- onset of hypertension in under age 30 or over age 55 years

### 3.3.3 Patient preparation:

The patient should be on an empty stomach with the last solid meal at least 4 hours before the test.

The patient needs to be well hydrated before beginning the test. One protocol suggests 7 ml/kg of water one hour before the test.

If the patient is already on an ACE inhibitor for hypertension, these should be substituted with other medication 2-5 days before the test.

If the patient is on chronic diuretic use, these should also be discontinued for 4-5 days, though adequate hydration might cancel any effect of long term diuretic use.

The effect of other antihypertensive drugs on renal study is not very well understood and it might not be necessary to withhold all antihypertensive medication except ACE inhibitors.

Some patients might become hypotensive and an IV line should be established in high risk patients (history of carotid disease, stroke, myocardial infarction, transient ischemic attack and angina).

Blood pressure and pulse should be recorded every 10-15 minutes after captopril administration.

### 3.3.4 Imaging Protocol:

A single day or a two-day protocol can be used.

In the two-day protocol, the post Captopril study is done first. If this is normal, the pre-captopril study is unlikely to contribute anything more and the study should be terminated at this stage.

In the single day study, baseline renal scan with 1 mCi of $^{99m}$Tc-$MAG_3$ is done. Renogram is generated using a large field of view (LFOV) gamma camera, time activity curves are generated and imaging continued for 30 minutes.

After the baseline study, 25mg of Captopril is given orally and the patient is instructed to drink more water (300-500ml).

A second larger dose of $^{99m}$Tc-$MAG_3$ (5-10 mCi) is used for the post Captopril study. This is done one hour after administering Captopril; the larger dose serves to overwhelm the remaining counts from the first study.

To avoid artifacts and false positive results, standard doses of furosemide should be used at exactly the same time, in each pre and post captopril phase. Renogram and renal scan are acquired in the same manner as previously.

After the test, the patient should not be allowed to go home unless the standing blood pressure is at least 70% of the baseline BP and the patient is completely asymptomatic

### 3.3.5 Reporting:

Like all renal scintigraphic studies, reviewing raw data for evaluation of image quality and patient movement is necessary.

Describe all steps of procedure and imaging protocol and note that imaging protocol was the same in both phases.

Describe perfusion, function and tracer excretion of each kidney in two phases, separately.

Note the renal curves and compare them between two phases.

Determine RVH likelihood based on patient's history, visualization of dynamic images (perfusion, function) and analysing renogram of each kidney considering which tracer had been injected.

### 3.3.6 Diagnostic criteria:

The following findings represent a positive study for renovascular hypertension using MAG3 or EC:

- Unilateral retention of radiopharmaceutical after Captopril intake.
- Change of 0.15 in the 20 minute-to-maximum ratio.
- Change of >10% relative uptake in the affected kidney

If the patient has an abnormal pre-Captopril scan with reduced renal function that does not change with captopril administration, it is suggestive of an intermediate probability of renal artery stenosis.

Tc-99m DTPA can also be used in a manner similar to $MAG_3$, the criteria for a positive test include:

- Reduction in relative uptake greater than 10% after ACE inhibitor administration indicates high probability for renovascular hypertension.
- 10% decrease in calculated glomerular filtration rate of the

ipsilateral kidney after ACEI administration.

- Marked unilateral parenchymal retention after ACEI administration compared to baseline study also represents high probability for renovascular hypertension.

### 3.3.7 Reporting a Captopril renal scan in suspected renovascular hypertension (Example)

**Indication:**

The patient is a 25-year-old woman who presented with new onset of hypertension two weeks ago.

**Clinical History:**

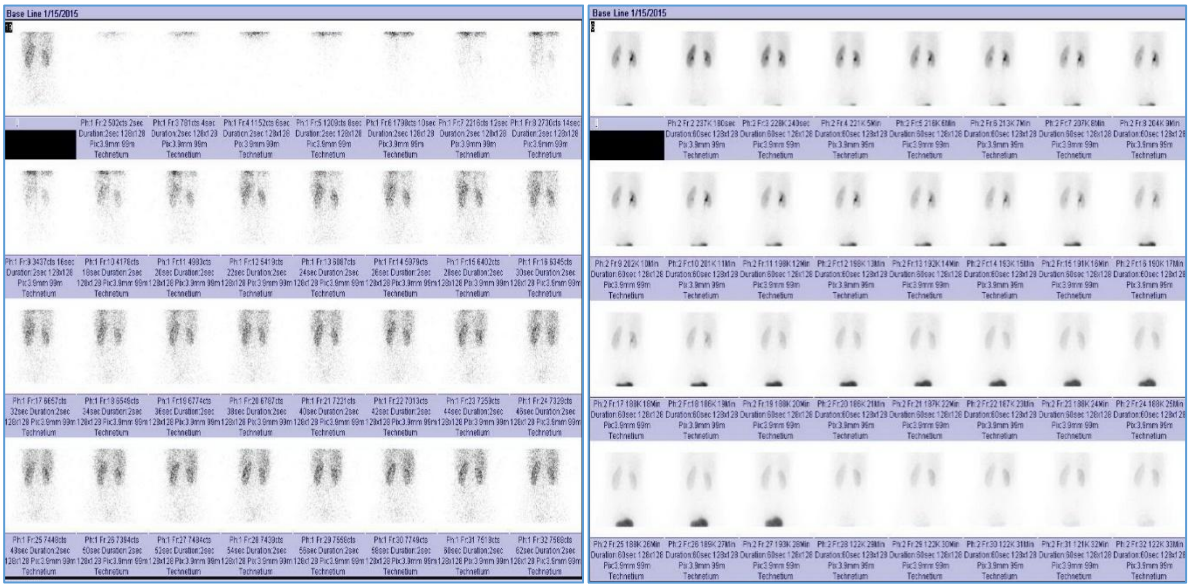
A 25 y/o woman with new onset of hypertension two weeks ago.

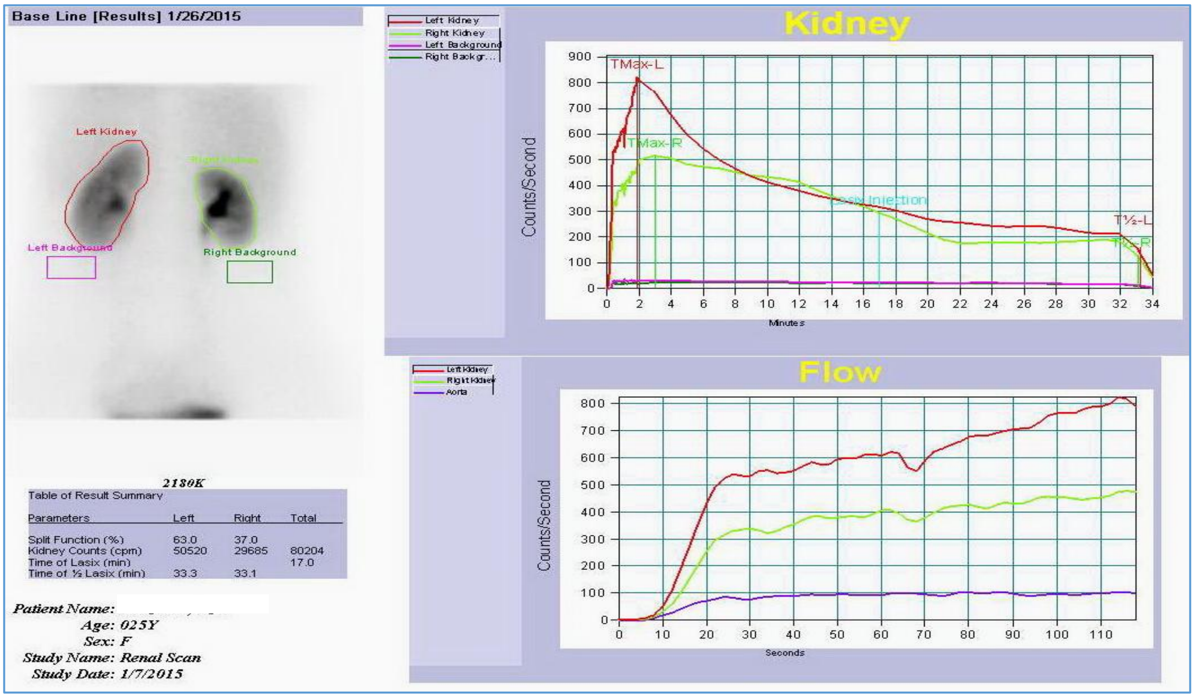
Sonography: Left kidney is normal in size(124 mm)and right kidney is small in size (91 mm).

**Procedure:**

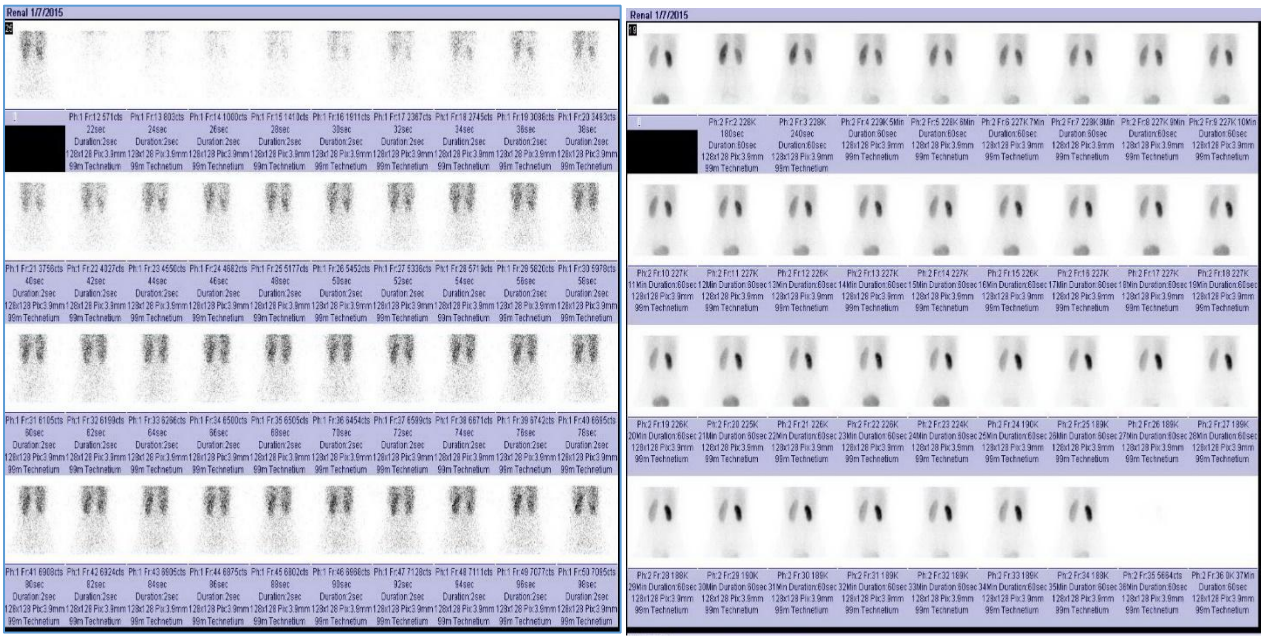
The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. One hour after administration of 25mg captopril, 5mCi of $^{99m}$Tc-EC_was injected and renal scanning was performed in posterior view in two dynamic phases (Note; 99mTc-Ec could also have been used if departmental policies so dictated). Another day, immediately after intravenous injection of 5mCi of $^{99m}$Tc-EC , scanning was performed in two dynamic phases from both kidneys in posterior view. Diuretic (40mg of lasix) was injected intravenously 15minutes after tracer administration (in 13th frame of functional imaging) in both baseline and post-captopril sets of imaging. After review of raw data and image processing, two manual ROIs were drawn around both kidneys and background subtraction was performed using peri-renal ROIs. Images were reviewed in two perfusion and function phases. Also, using another software, kidney and background ROIs has been drawn and baseline/post-capto renograms were compared.

Figures below show pre-captopril perfusion phase, function phase and renal curve, respectively.




Figures below show perfusion and function phases and renal curve of post-captopril renal scan.



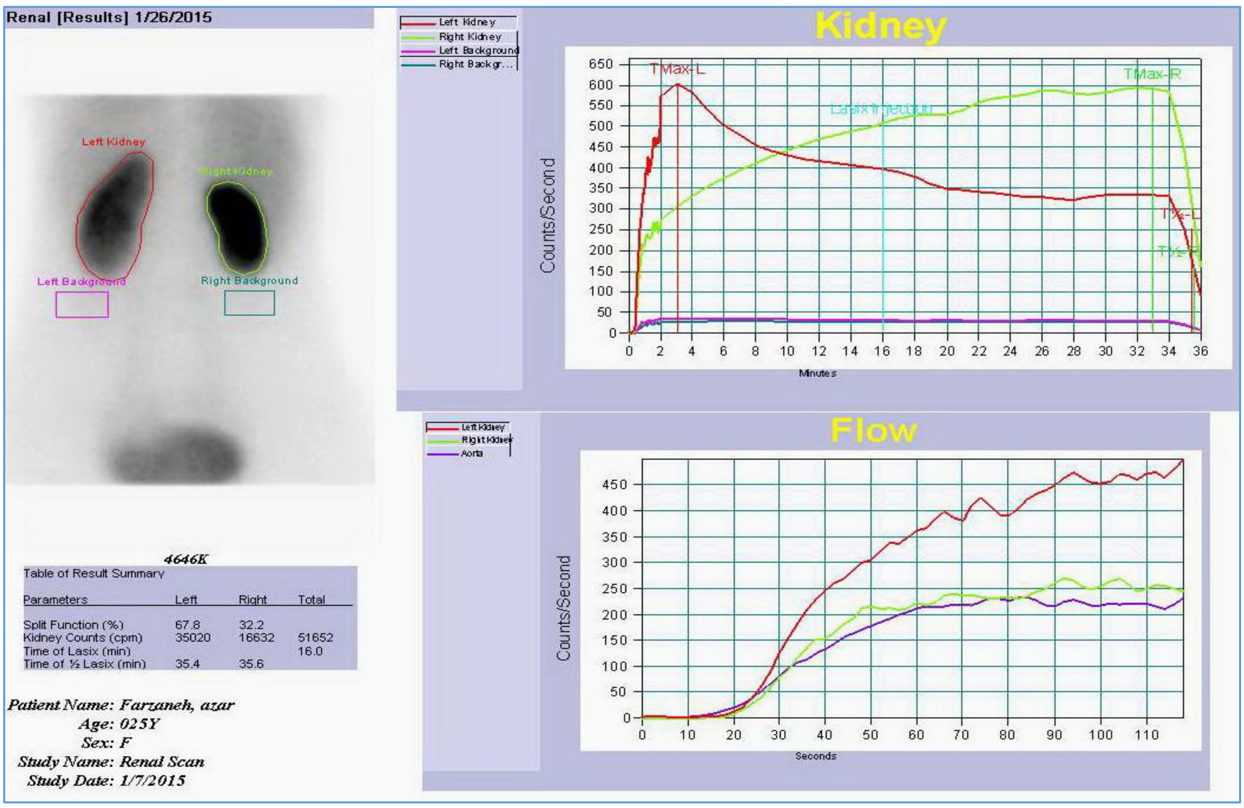
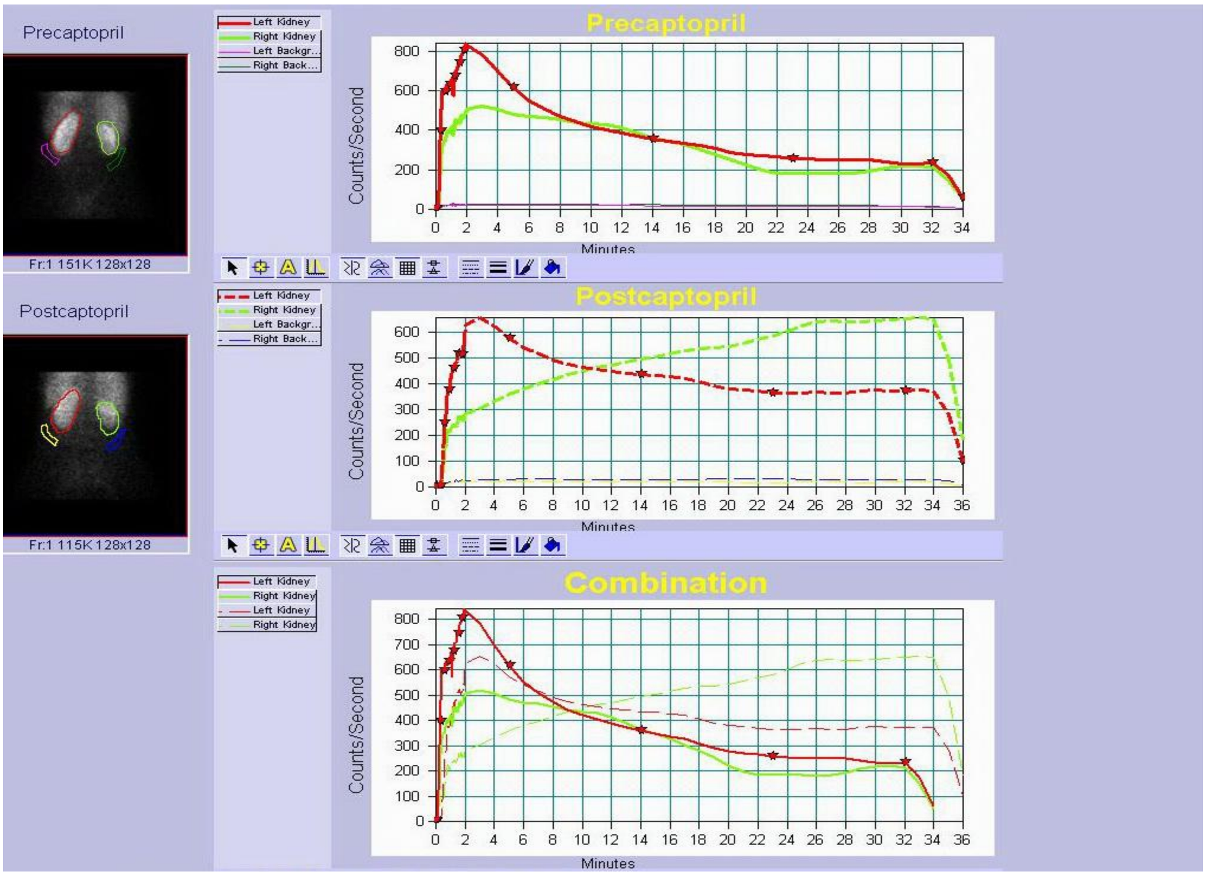




Figure below compares pre-captopril and post-captopril renograms and confirm significant changes in right kidney.




**Findings:**

The study was of good quality. The baseline scan showed normal perfusion and initial tracer uptake of both kidneys with good tracer washout.

The post-captopril scan showed normal perfusion and initial tracer uptake of the left kidney with prompt tracer excretion, even before lasix injection. The right kidney showed slightly decreased perfusion and function with no tracer excretion from renal cortex to pelvicalyceal system. After lasix injection, more tracer accumulation with no excretion was noted in the right renal cortex.

**Result:**

Right kidney: Small sized with normal perfusion and function and good excretion in baseline set. Mild decreased perfusion and function with cortical retention was noted in the post-captopril scan.

Left kidney: Normal perfusion and function without urinary obstruction in both sets.

**Impression:**

The scan findings suggest high probability for RVH in the right kidney.

Baseline scan split function:
Right kidney: 37%
Left kidney: 63%

Post-captopril split function:
Right kidney:32%
Left kidney: 68%

## 3.4 Evaluation of renal transplant *(11, 12)*

### 3.4.1 Introduction:

Renal transplant scintigraphy can evaluate transplanted kidney as baseline study immediately after transplantation, or later for evaluation of complications.

### 3.4.2 Indications:

- Baseline evaluation of transplanted kidney
- Evaluation of parenchymal failure (ATN, acute and chronic rejection).
- Assessment of vascular or mechanical failure (arterio-venous obstruction, ureteral obstruction and other surgical complications like urine leakage, hematoma, lymphocele)

### 3.4.3 Patient preparation: *(The same as discussed above, in physiology and morphology)*

1. Good hydration and voiding before starting are mandatory.
2. Review previous imaging, especially if a renal scan has been done previously, this knowledge will enable a more accurate assessment of renal function and put into perspective the abnormalities noted.
3. Summarize drug history and relevant urological procedures. This knowledge is essential for accurate reporting of the renal scan findings
4. Ensure that the bladder has been emptied immediately prior to the study to facilitate renal drainage.

### 3.4.4 Imaging:

Detector is positioned anteriorly over the pelvis to image the renal transplant instead of the usual posterior lumbar region position for native kidneys.

Patient must be well hydrated as dehydration might mimic allograft dysfunction or obstruction.

Bolus injection (5-10 mCi of $^{99m}$Tc-MAG$^3$ or $^{99m}$Tc-EC) followed by 15 second images for 30 minutes to evaluate parenchymal radiotracer uptake and clearance. Good bolus injection (small volume, fast) is mandatory for accurate assessment of perfusion.

Dynamic acquisition of 1-2 second images for 1-2 min. (perfusion phase), starting immediately after radiopharmaceutical administration. It is followed by 30-60 sec images for about 30 min. (function phase), with a total scan time of 20-30 min. If there is retention of radiopharmaceutical in the renal pelvis, erect images can be acquired.

### 3.4.5 Reporting:

**Normal renal transplant study:**

The perfusion images is utmost important in interpretation of transplant renal scan. The transplanted kidney should peak immediately after abdominal aorta or Iliac artery peak with at least the same intensity.

Prompt uptake and homogeneous distribution of the radiotracer should be seen in the kidney.

There should be free flow of radiotracer into the drainage system with no retention at the end of the study.

If no spontaneous excretion is noted, diuretic injection is in the form of furosemide may be administered 10 minutes after injection of radiotracer to exclude outflow tract obstruction.

A normal transplant renogram demonstrates a rapid upslope followed by the cortical concentration which contains the peak of the curve.

Photopenic areas or tracer activity in peri-transplant region should be noted.

### 3.4.6 Complications:

Acute tubular necrosis (ATN) and acute allograft rejection are the most common early complications of transplant.

- ATN typically displays normal or mildly reduced perfusion but delayed uptake and excretion of tubular secretion agents like Tc-99m $MAG_3$. This is followed by progressive accumulation of radiotracer in the renal cortex.
- Rejection is seen typically as decreased perfusion, decreased uptake and delayed excretion.

There may be considerable overlap in the findings of ATN and acute rejection and it might not always be possible to differentiate between the two. However, reduced perfusion favours a diagnosis of Acute rejection.

Post-transplant fluid collections: These can accumulate immediately after the procedure or be delayed for several months. These collections can be significant due to the potential to exert a mass effect. They might be due to a hematoma, seroma, abscess, urinoma or lymphocele. Collections appear as peri-renal photopenic or hot areas on scintigraphy. Interpretation of nuclear medicine scans needs to be done in the context of the clinical presentation and time of occurrence:

Abscess: Associated with fever and raised inflammatory markers.

Hematoma, seroma and urinoma usually accumulate within the first few days of surgery. Hematoma and seroma do not show tracer activity and appear as photopenic areas. Urinoma might go from a photopenic area on an early scan to intense activity on delayed scan if the leak is significant. In slow leaks urine flow might be inadequate to accumulate activity during the course of the study and even on delayed scans.

Lymphoceles typically occurs several months after surgery and appear as photopenic areas which might show slight filling in on delayed scans.

Vesicourinary reflux: Can often be an incidental finding, picked up as a "double peak" on a renogram. An indirect cystogram can be confirmatory.

Obstruction can occur anywhere but commonly at the ureteric anastomosis with the urinary bladder, it is easy to diagnose this on a renal scan/renogram using persistent retention of activity proximal to the obstruction.

### 3.4.7 Reporting a dynamic renal scan for evaluation of renal transplant – Normal transplanted kidney

**Indication:**

The patient is a 49-year-old man, referred for baseline transplanted kidney assessment.

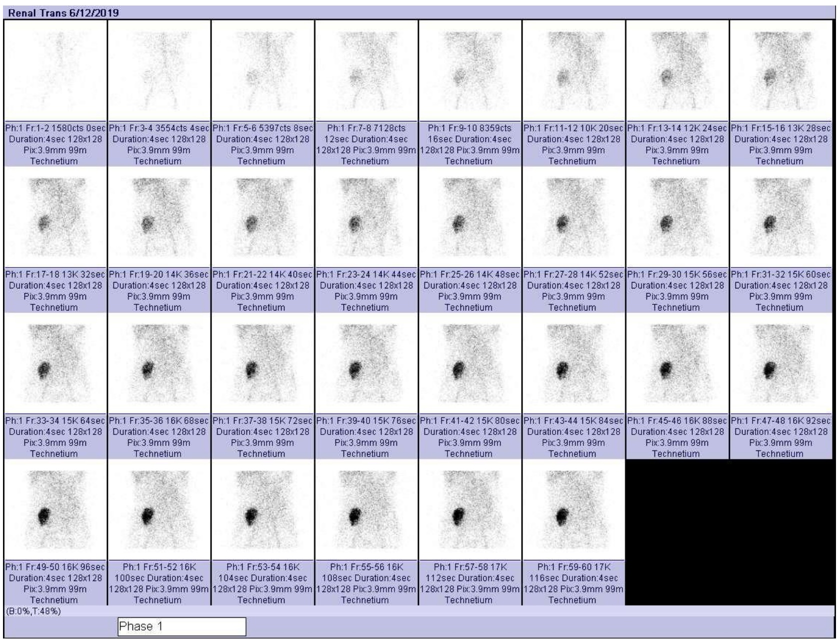
**Clinical History:**

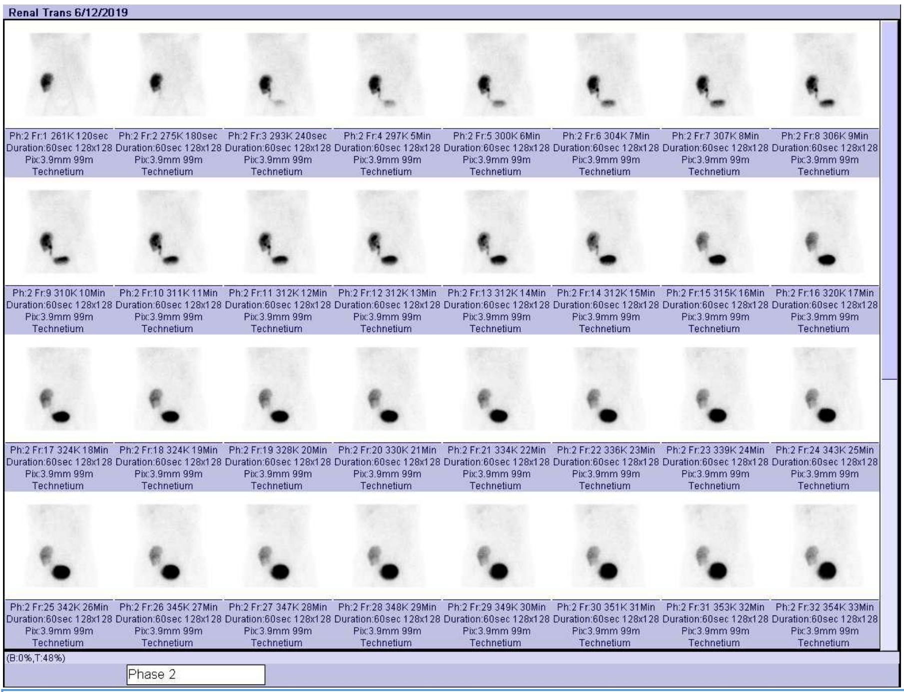
A 49 Y/O man with history of kidney transplantation from patient cadaver, 3 days ago. Ultrasonography revealed transplanted kidney of 110×48mm size with normal echogenicity and minimal fluid collection around the kidney.

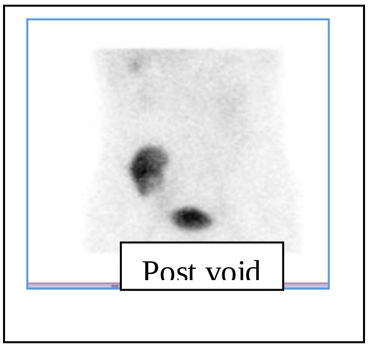
**Procedure:**

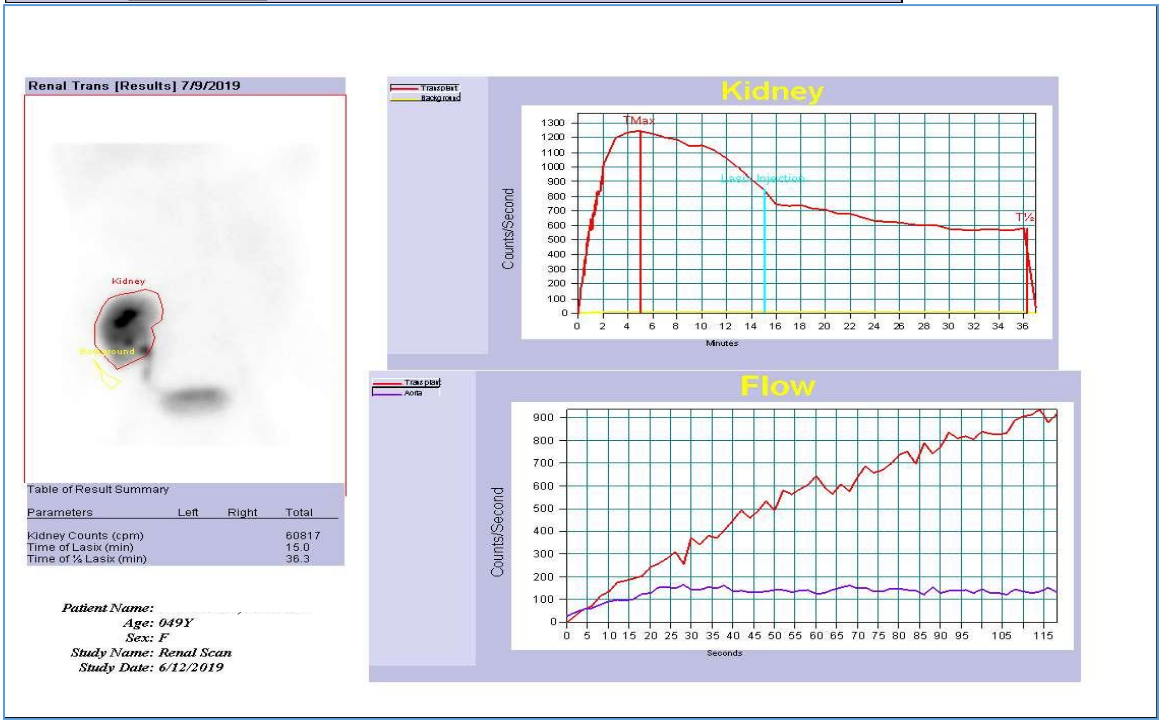
The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 5 mCi of $^{99m}$Tc-EC, scanning was performed in two dynamic phases from transplanted kidney in anterior view. Diuretic (70mg of lasix) was injected intravenously 19minutes after tracer administration (in 17th frame of functional imaging). After review of raw data and image processing, manual ROI was drawn around kidney and background subtraction was performed using peri-renal ROI. Images were reviewed in two perfusion and function phases. Post void image and renal curve were also assessed.

Figures below show perfusion phase, function phase, post-void image and renal curve, respectively.






**Findings:**

The study was of good quality. The transplanted kidney was located in the right hemi-pelvis. The scan shows normal perfusion of the transplanted kidney with normal initial tracer uptake, on time peak, fairy good excretion and good response to lasix injection.

**Impression:**

Normal renal transplant scintigraphy.

### 3.4.8 Reporting a dynamic renal scan for evaluation of renal transplant – Acute rejection

**Indication:**

Referred for evaluation of transplanted kidney.

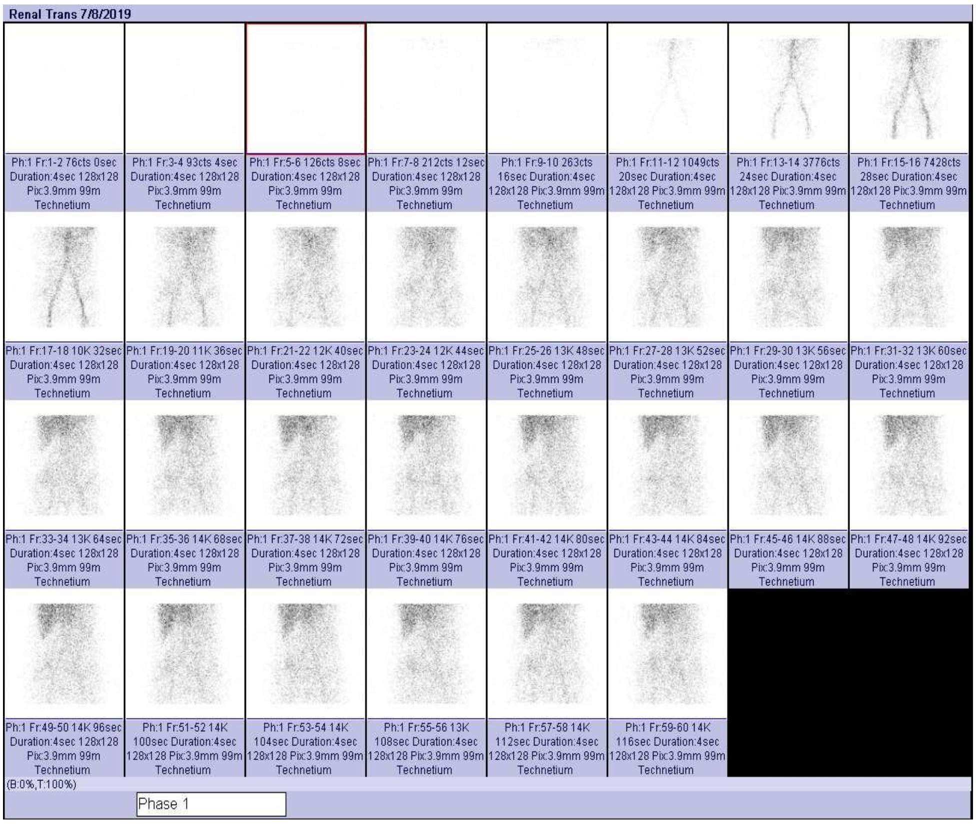
**Clinical History:**

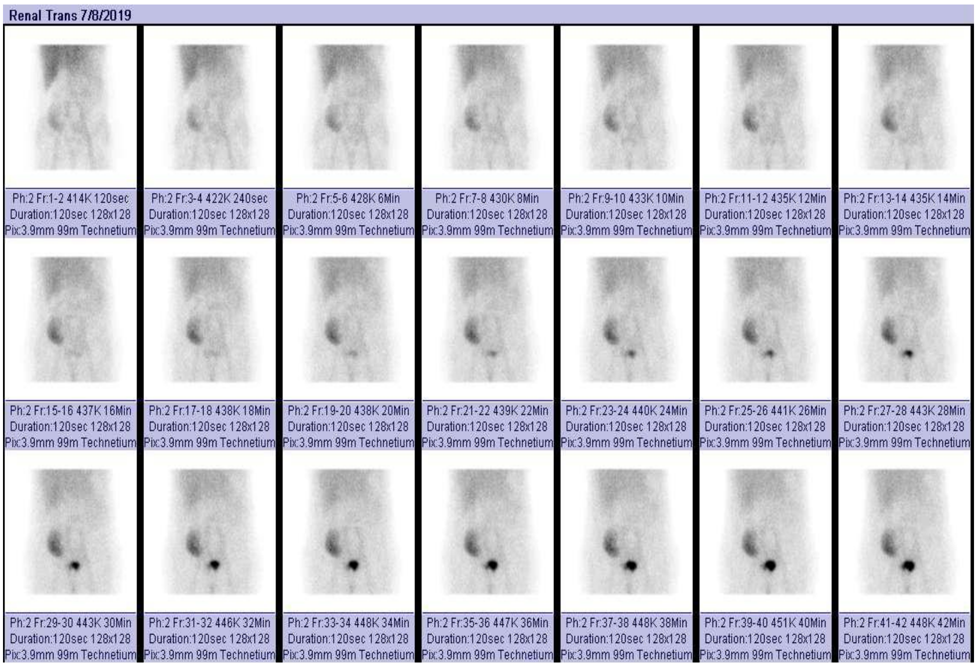
A 33 Y/O woman with history of ESRD since 5 years ago who has received renal transplant 2 months ago. Laboratory tests showed increasing trend of serum creatinine since 10 days ago from 1.63 to 4.8. Now, she is under pulse steroid therapy.

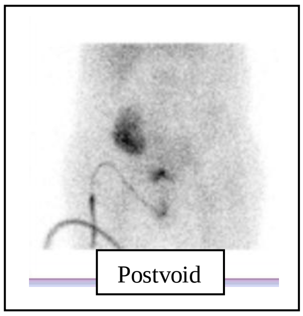
**Procedure:**

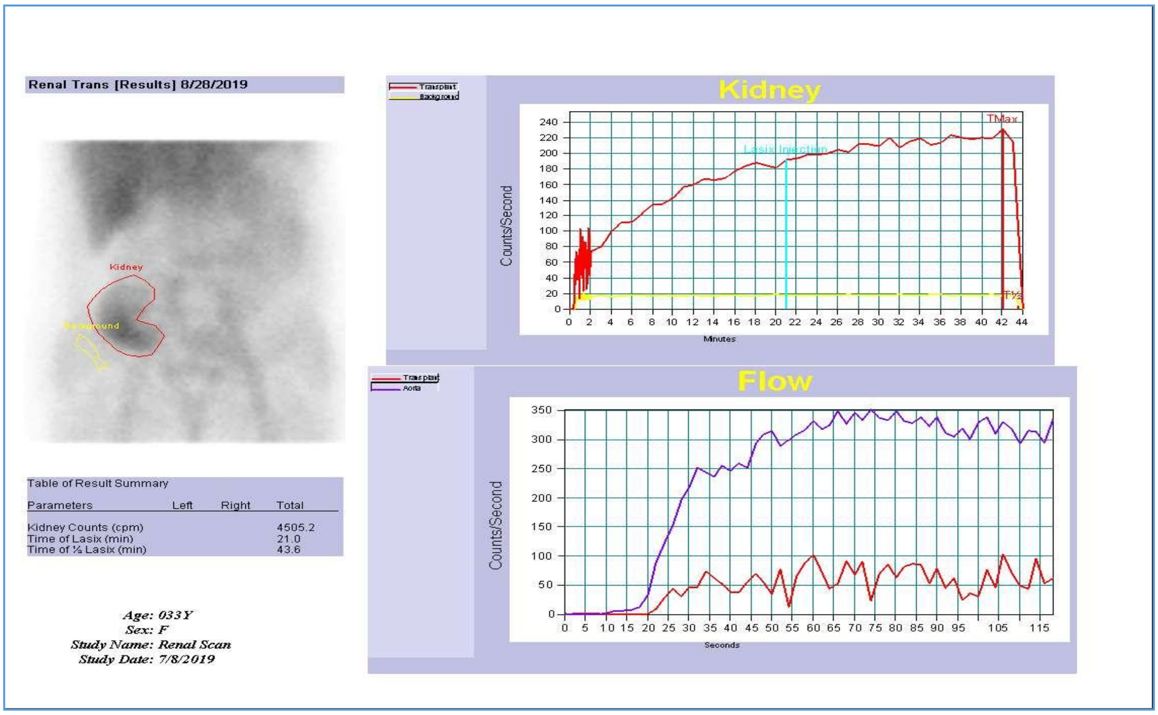
The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 10mCi of $^{99m}$Tc-EC, scanning was performed in two dynamic phases from transplanted kidney in anterior view. Diuretic (40mg of lasix) was injected intravenously 23 minutes after tracer administration (in 21th frame of functional imaging). After review of raw data and image processing, manual ROI was drawn around transplanted kidney and background subtraction was performed using peri-renal ROI. Images were reviewed in two perfusion and function phases. Also, Post void image and renal curve were assessed.

Figures below show perfusion phase, function phase, post-void image and renal curve, respectively.






**Findings:**

The study was of good quality. The transplanted kidney was located in the right hemi-pelvis and showed decreased perfusion and initial tracer uptake with cortical retention, even on post-void image. Background activity was also increased.

**Impression:**

Decreased perfusion and function of transplanted kidney with cortical retention suggests acute rejection.

### 3.4.9 Reporting a dynamic renal scan for evaluation of renal transplant – Chronic rejection

**Indication:**

Evaluation of transplanted kidney.

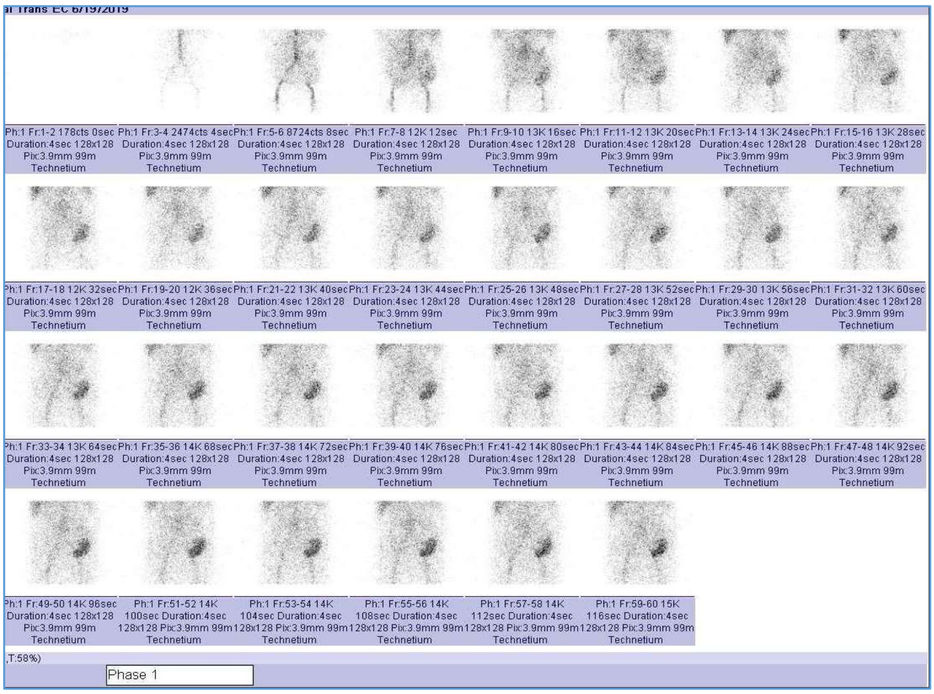
**Clinical History:**

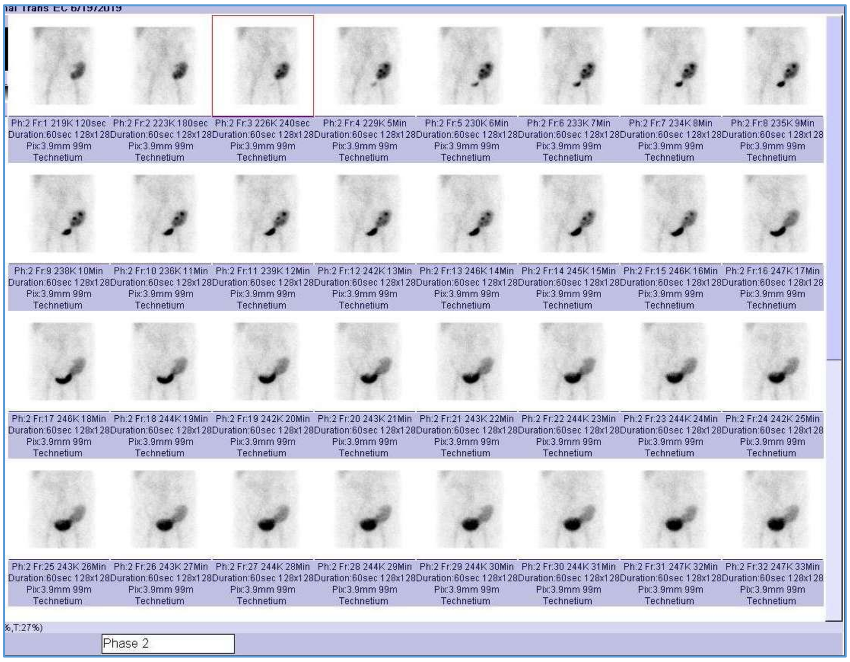
A 23 Y/O man with history of kidney transplantation from non related live donor, 5 years ago. He had serum creatinine level of 1.3mg/dl which has been increasing for the last 2 weeks to 2.64. Ultrasonography revealed 113×52mm transplanted kidney with normal echogenicity and no hydronephrosis and normal flow of renal artery and vein (RI:0.78).

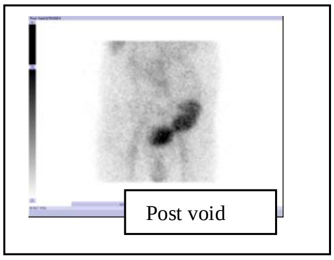
**Procedure:**

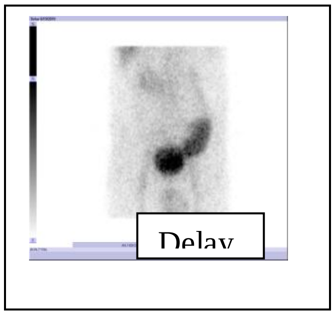
The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 10mCi of $^{99m}$Tc-EC, scanning was performed in two dynamic phases from transplanted kidney in anterior view. Diuretic (70mg of lasix) was injected intravenously 17 minutes after tracer administration (in 15th frame of functional imaging). After review of raw data and image processing, manual ROI was drawn around kidney and background subtraction was performed using peri-renal ROI. Images were reviewed in two perfusion and function phases. Post void image and renal curve were also assessed.

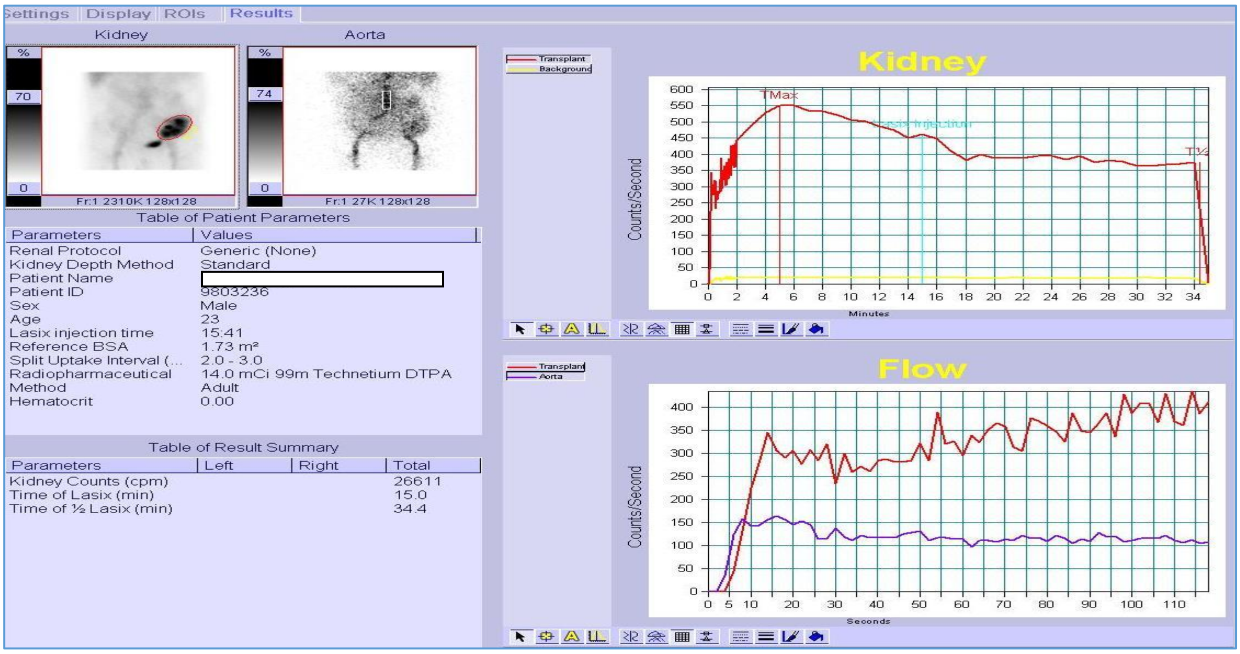
Figures below show perfusion phase, function phase, post-void and delayed images and renal curve, respectively.






**Findings:**

The study was of good quality. The small transplanted kidney is located in the left hemi-pelvis The scan showed mildly decreased perfusion of transplanted kidney, decreased initial tracer uptake with mild cortical retention and partial excretion after lasix injection.

**Impression:**

Small transplanted kidney with mildly decreased perfusion, function and decreased excretion suggest chronic rejection.

## 3.5 Evaluation of absolute renal function -GFR (Glomerular Filtration Rate), ERPF (Effective Renal Plasma Flow) and Renal Clearance *(1, 4, 13)*

The gold standard non-radionuclide methods for accurate measurement of ERPF and GFR are cumbersome, inconvenient and time-consuming. They require a continuous infusion of nonradioactive special material like inulin or PAH to reach steady state blood concentration and multiple blood and urine sampling. Not only are these procedures problematic for patients but they also are unreliable in some conditions like severely decreased renal function or acute onset of renal disease.

Nuclear medicine methods for measuring absolute renal function can be divided to two sub-groups: Plasma sample clearance and camera-based clearance.

***Plasma sample method:*** Simplified techniques of this method involve taking one or two blood sampling after IV injection of radiotracer. $^{99m}$Tc-$MAG_3$ is the tracer of choice for ERPF evaluation. ERPF can be estimated by measuring $^{99m}$Tc-$MAG_3$ renal clearance, using the injected dose and one blood sampling 45 minutes after injection. For GFR, $^{99m}$Tc-DTPA is preferred and GFR can be calculated by measuring dose of injection and tracer concentration in two blood samples, obtained 1-4 hours after intravenous tracer injection. Although plasma sampling methods may be relatively accurate in patients with normal volume of distribution, they are associated with a great deal of errors in particular condition such as: ascites, large effusion and marked edema. In this situation which is not uncommon in renal disease patients, tracer can diffuse into extra vascular fluid spaces and as a result, calculated ERPF can be overestimated. Because of these probable errors, the necessity of plasma sampling and numerous difficulties in process, camera-based technique are more popular.

***Camera-based clearance:*** These methods seems to be more performable and reproducible than blood or urine sampling techniques.

***Camera-based method:***

### 3.5.1 Introduction:

Gamma camera techniques for GFR estimation are considered somewhat less accurate, but easier to perform and more reproducible than invitro measurements. Camera-based method of renal function assessment has been introduced as method of choice in estimation of GFR, ERPF and renal clearance for each kidney. The principles of this method is based on the fact that the kidneys are vascular organs and normally receive 20-25% of cardiac output and initial tracer accumulation in the kidney can indicate the amount of renal clearance, by estimation of either glomerular filtration or tubular excretion.

### 3.5.2 Indications

To determine total as well as split GFR, ERPF and renal clearance more rapidly and reproducibly than blood sampling methods in

Voluntary kidney donors and before using high toxicity drugs with significant renal excretion.

As a baseline data and for follow up in patients with one kidney impairment.

Patients at the extremes of age and body mass, significant abnormal muscle mass like amputation or paralysis.

Patients with special diets with low or high creatinine intake (vegetarians or supplementary diets) or severe malnutrition.

### 3.5.3 Patient Preparation:

The patient should be aware of arriving well hydrated and drinking about 500ml (two large glasses) of water just before tracer injection. Also, voiding before starting images is recommended.

Review clinical history, ultrasound data and previous radionuclide and other imaging, make note of any known renal anomaly (duplex, ectopic or hydronephrotic kidney).

In patients who has been referred for follow up scan, recording all previous data and images is necessary to compare.

### 3.5.4 Imaging:

Similar imaging techniques with different radiotracers with no requirement to urine or blood sampling have been developed for measuring several parts of renal function. The most popular and available camera-based radiotracers include: $^{99m}$Tc-DTPA for GFR, $^{131}$I-OIH for ERPF and $^{99m}$Tc-$MAG_3$ for ERPF estimation.

To determine the accurate dose of injection, the syringe should be counted before and after tracer injection at the same distance from the detector.

Renal depth is usually estimated using a nomogram based on patient's height and weight. So, recording height and weight before imaging is essential.

Supine position with the camera below the table is preferred. Note that best resolution will not be possible unless the patient has been positioned as close to the collimator face as possible.

For GFR evaluation, dynamic scanning from abdomino-pelvic area should be performed in posterior view for 6 minutes after IV injection of 1.5 mCi of $^{99m}$Tc-DTPA. The same protocol should be used for ERPF measurement after IV injection of 0.5 mCi of $^{131}$I-OIH.

For determining renal clearance, 10mCi of $^{99m}$Tc-$MAG_3$ should be injected intravenously and imaging with similar protocol continues up to 30 minutes.

### 3.5.5 Pearls & Pitfalls:

1. Compared to non-scintigraphic methods, camera based method can determine differential function of each kidney using each kidney's percentage of tracer uptake.

2. These methods are highly reproducible and can be used in a patient for follow up.

3. On the other hand, these camera-based methods are only reliable in patients with only single kidney abnormality.

In bilateral renal dysfunction, although GFR is calculated lower than normal range, differential renal function may be estimated in normal limits and warrants more attention to image qualities and patient history.

3. Strict adherence to protocol is mandatory for these techniques because of multiple sources of errors.

Estimation of renal depth and background correction are the main two parts of procedure to obtain exact percentage of injected tracer entering to each kidney. These are two common causes of technical errors and should be avoided by careful measurements.

4. Due to different mechanisms of renal radiotracers, $^{99m}$Tc-$MAG_3$ is extracted more than twice as efficiently as compared to $^{99m}$Tc-DTPA. Therefore

activity needed is higher in $^{99m}$Tc-DTPA scans and should be considered in image interpretation.

5. There is a wide range of normal variants which should be recognised.

#### 3.5.6 Reporting:

Quality of perfusion, function, and tracer excretion of each kidney should be described.

Calculated total and individual GFR, ERPF and renal clearance should be noted.

### 3.5.7 Reporting Renal Function Assessment – Decreased GFR

**Indication:**

Evaluation of differentiatial glomerular filtration rate.

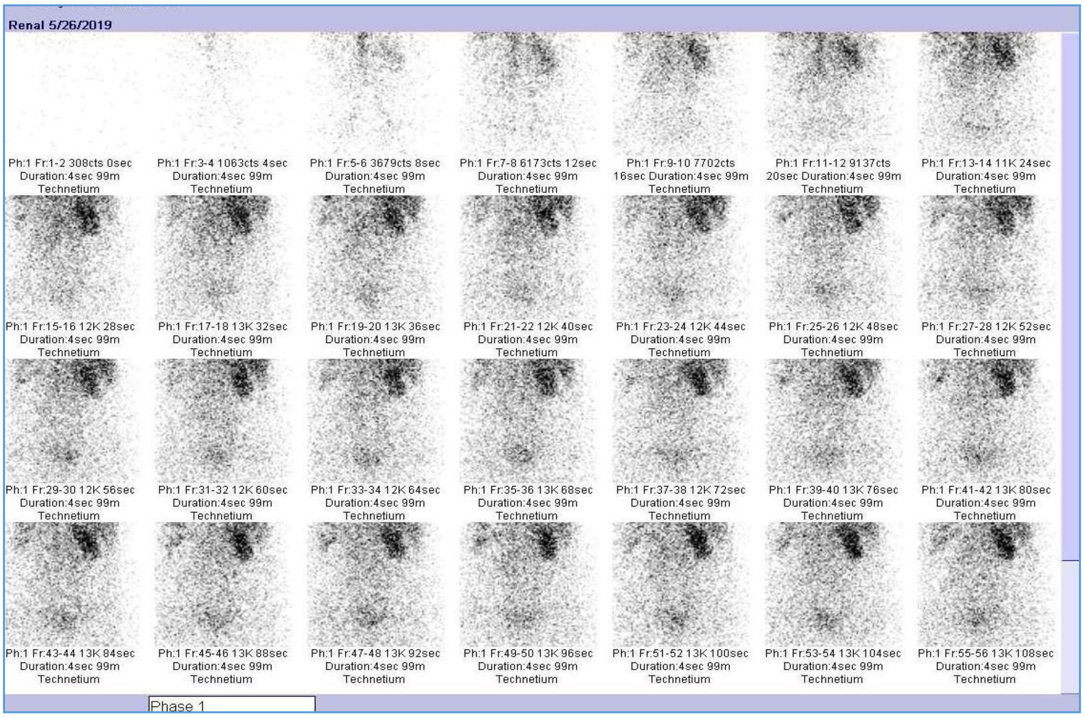
**Clinical History:**

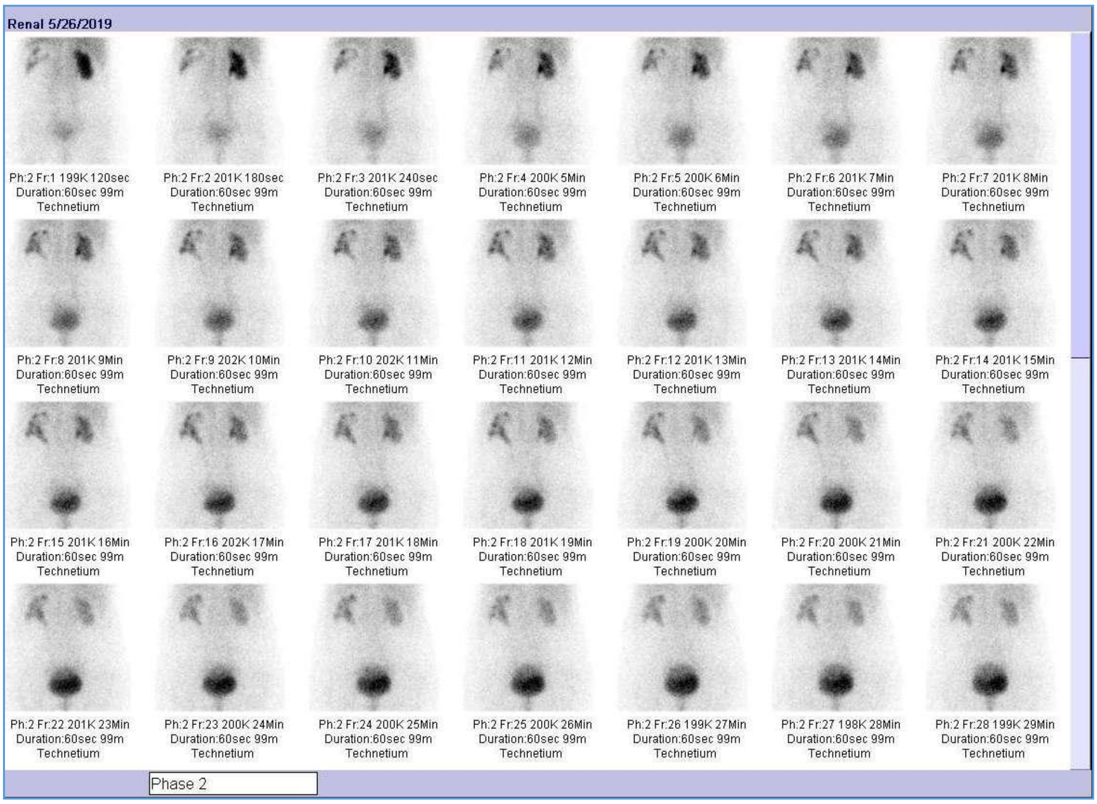
A 39 Y/O female with history of renal stone, lithotripsy and surgery in the left kidney. The patient has been recently admitted due to pyelonephritis. Recent ultrasonography showed normal right kidney and non-visualized left kidney.

**Procedure:**

The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. Immediately after intravenous injection of 7mCi of $^{99m}$Tc-DTPA, scanning was performed in two dynamic phases from both kidneys in posterior view. According to GFR imaging protocol, static pre-injection and post-injection images were obtained from the syringe, and patient weight and height were recorded. Diuretic (32mg of lasix) was injected intravenously at 19 minutes after tracer injection (17th frame of functional imaging). After review of raw data and image processing, two manual ROIs were drawn around both kidneys and background subtraction was performed using peri-renal ROIs. Images were reviewed in two perfusion and function phases. Also, renal curve and calculated GFR were interpreted.

Figures below show perfusion and function phase as well as renal curve and calculated GFR.





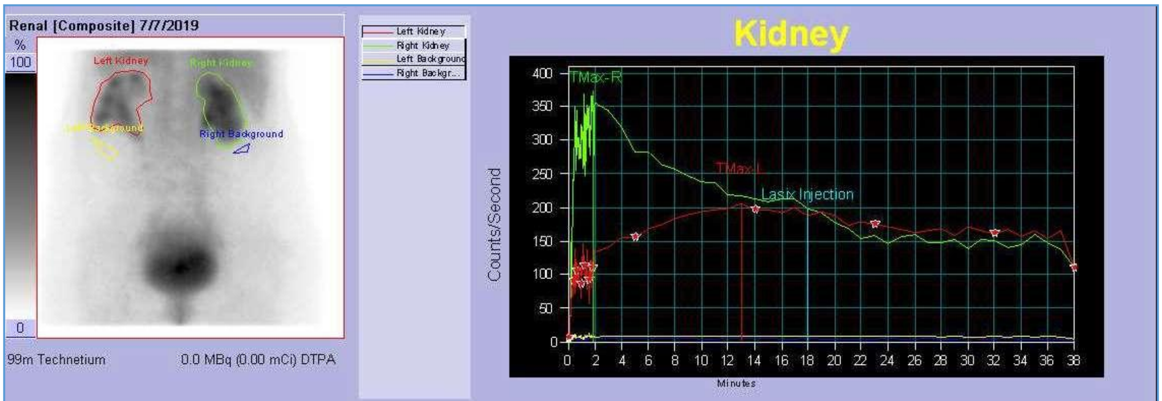




Table of Result Summary

| Parameters | Left | Right | Total |
|---|---|---|---|
| Split Function (%) | 27.4 | 72.6 | |
| Kidney Counts (cpm) | 20917 | 55544 | 76461 |
| Kidney Depth (cm) | 6.235 | 6.277 | |
| Uptake (%) | 1.656 | 4.397 | 6.053 |
| GFR (ml/min) | 14.4 | 38.2 | 52.6 |
| Normalized GFR (ml/min) | | | 53.6 |
| GFR Low Normal (ml/min) | | | 82.0 |
| Mean GFR (ml/min) | | | 106.0 |
| Time of Lasix (min) | | | 18.0 |

**Findings:**

The study was of good quality. The right kidney showed normal perfusion and initial tracer uptake with normal excretion. The left kidney showed decreased perfusion and initial tracer uptake and poor tracer excretion, even after lasix injection. Measurement of total GFR using gamma camera-based technique was done. GFR of the right kidney was estimated 38.2 ml/min and in the left kidney was 14.4ml/min.

**Impression:**

Right kidney: Normal glomerular function with normal perfusion and function without obstruction.

Left kidney: Moderately impaired glomerular function with decreased perfusion and function and no renal activity reduction (tracer excretion).

Total GFR based on gamma camera measurements: 52.6ml/min

Right kidney GFR: 38.2 ml/min

Left kidney GFR:14.4 ml/min

# Chapter 4: Renal Cortical Imaging

## 4.1 $^{99m}$Tc DMSA Scan

$^{99m}$Tc-DMSA is the preferred radiopharmaceutical for renal cortical imaging.

Appropriate dose (5mCi/185MBq) according to local guidelines and patient age/size should be used and a minimum activity of 15MBq should be administered for adequate counts.

### 4.1.1 Introduction:

$^{99m}$Tc-DMSA scintigraphy has been recommended as the best technique for renal cortex assessment, especially in patients with urinary tract infections. Despite the low extraction efficiency of this tracer by the kidneys, imaging after 2 or 3-hours following injection (due to cortical retention) leads to adequate images enabling evaluation of the functioning renal cortex with low background. (Some tracer is excreted in the urine).

### 4.1.2 Indications:

Detection of renal parenchymal abnormalities

Assessment of the kidney in the acute phase of a Urinary Tract Infection (UTI) (Acute pyelonephritis)

Assessment of the kidney for detection of scarring in the late phase, 4 to 6 months following a UTI

Confirmation of non-functional multicystic kidney

Congenital abnormalities like solitary kidney, ectopic kidney, duplex kidney, small kidney, dysplastic kidney, horseshoe kidney, solitary kidney etc.

Differential renal function estimation – particularly when kidneys may be lying at different depths (a low-lying or malrotated kidney).

Localisation of poorly functioning kidney

Assessment of renal function in the presence of an abdominal mass

Detection of residual functioning renal tissue following direct trauma

#### 4.1.3 Patient Preparation:

No specific preparation is required, but hydration is recommended.

The date of last UTI should be recorded, if present and whether the patient is on prophylactic antibiotics.

Review clinical history, ultrasound data and previous radionuclide and other imaging, make note of any known renal anomaly (duplex, ectopic or hydronephrotic kidney).

#### 4.1.4 Imaging:

Imaging should be started 2-3 hours after tracer injection, In patients with significant hydronephrosis, delayed imaging (4 to 24 hr) or furosemide injection may be useful .

Posterior and both posterior oblique views are essential. Note that best resolution will not be possible unless the patient has been positioned as close to the collimator face as possible.

High/ultra-high resolution or pinhole collimator is required for best spatial resolution.

Image for at least 300K counts or use a present time of about 5 minutes if using standard collimators. For pinholes use 100-150k counts/image.

There is no consensus on any advantages of SPECT imaging over planar imaging.

For calculating relative function, attenuation correction is not done except in case of anteriorly displaced ectopic kidney in which geometric mean of anterior and posterior counts is better.

#### 4.1.5 Pitfalls:

1) Renal cortical scan cannot differentiate between acute and chronic pyelonephritis. A permanent defect 6 months after the last UTI suggests a cortical scar.

2. A recent UTI may cause temporary decreased uptake or focal defect and a follow-up DMSA scan after 4-6 month is recommended.

3. In infants under 3-6 months of age, the diagnosis of renal scars is difficult due to renal immaturity. Imaging should be delayed, if possible.

4. There is a wide range of normal variants which should be recognised.

5. Hydronephrosis with tracer retention in the PC system can affect image interpretation and overestimate Differential renal function.

#### 4.1.6 Reporting:

The position, relative size and overall morphology of the functioning renal tissue should be described.

The DRF and method of calculation (posterior view only or geometric mean) should be reported.

#### 4.1.7 Normal findings and variants:

Normal split renal function is between 45-55%. Obstruction might give rise to a falsely high value on the obstructed side due to tracer retention.

Renal contours are generally rounded, but flattening does not necessarily represent a lesion and the lateral aspect of the left kidney can be flattened due to splenic impression.

In very young children, the kidneys might appear triangular with flattening of lateral sides.

Kidneys might appear slender with a short transverse axis in the posterior view; this is usually due to renal rotation.

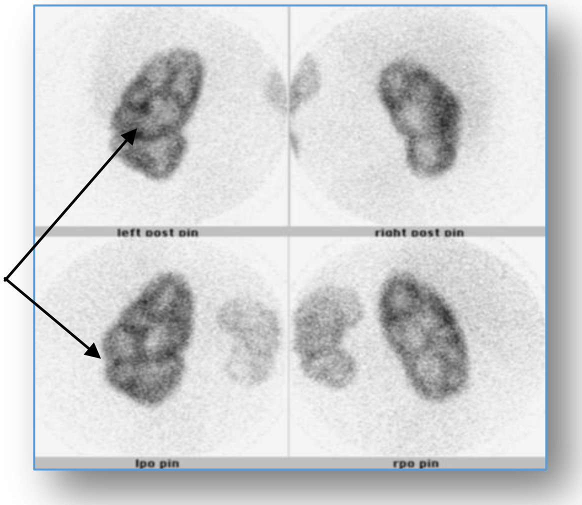
One pole might be narrower giving the pear shaped kidney.

The upper pole can appear artifactually hypoactive, because of liver or splenic attenuation.

Columns of Bertini might be variable in the kidneys and cause difficulty in interpretation as the areas between the columns might appear relative hypoactive on a DMSA scan.

Fetal lobulation should be kept in mind while reporting because of the potential to mimic scars.

Figure shows columns of Bertini in $^{99m}$Tc-DMSA views of a 6-week-old boy.




$^{99m}$Tc-DMSA scan shows flat superolateral of upper pole of the left kidney in an 11 Y/O girl

#### 4.1.8 Abnormal findings:

Number, size and location are important parameters that point to an abnormality/defect.

It is not always possible to differentiate between acute transient lesions that will resolve with time and more permanent lesions.

Polar hypoactive lesions with preserved contours and indistinct margins are likely to heal.Local deformity of contour usually points to a permanent lesion. If a lesion is found, imaging must be repeated after 6 months to confirm permanent squeal.

Diffuse reduced uptake may be seen in a kidney with a UTI.

### 4.1.9 Reporting $^{99m}$Tc-DMSA scan – Normal Scan

**Indication:**

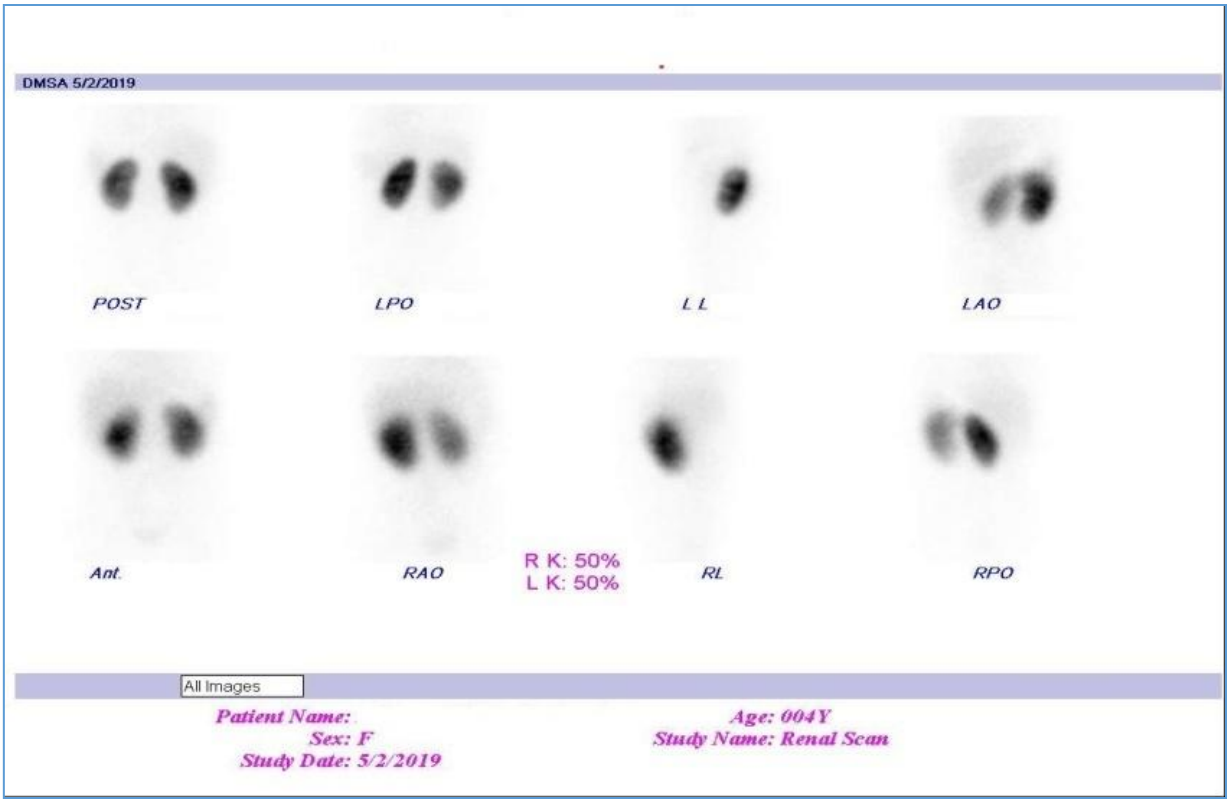
A 4.5-year-old patient referred for evaluation of cortical function and differentiated renal function.

**Clinical History:**

A 4.5 Y/O girl with history of recurrent UTIs and grade II right VUR confirmed in VCUG 4 months ago. Now, urine analysis showed no abnormality and she is under prophylactic antibiotic therapy.

**Procedure:**

The patient received additional hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. 2mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of 2 mCi of $^{99m}$Tc DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**

The study was of good quality. Both kidneys had normal size, located in the normal renal location, with uniform tracer uptake. No focal zone of decreased activity was noted throughout both kidneys. Differential renal function analysis using global uptake, geometric mean, manual ROI determination and no background subtraction showed 50% of total renal function in the right.

**Impression:**

Both kidneys: Normal sized, with no cortical defect.

DRF: Right kidney=50%

Left kidney=50%

### 4.1.10 Reporting $^{99m}$Tc-DMSA scan – Non-functioning left kidney:

**Indication:**
The patient is a 4.5-year-old female referred for renal function assessment.

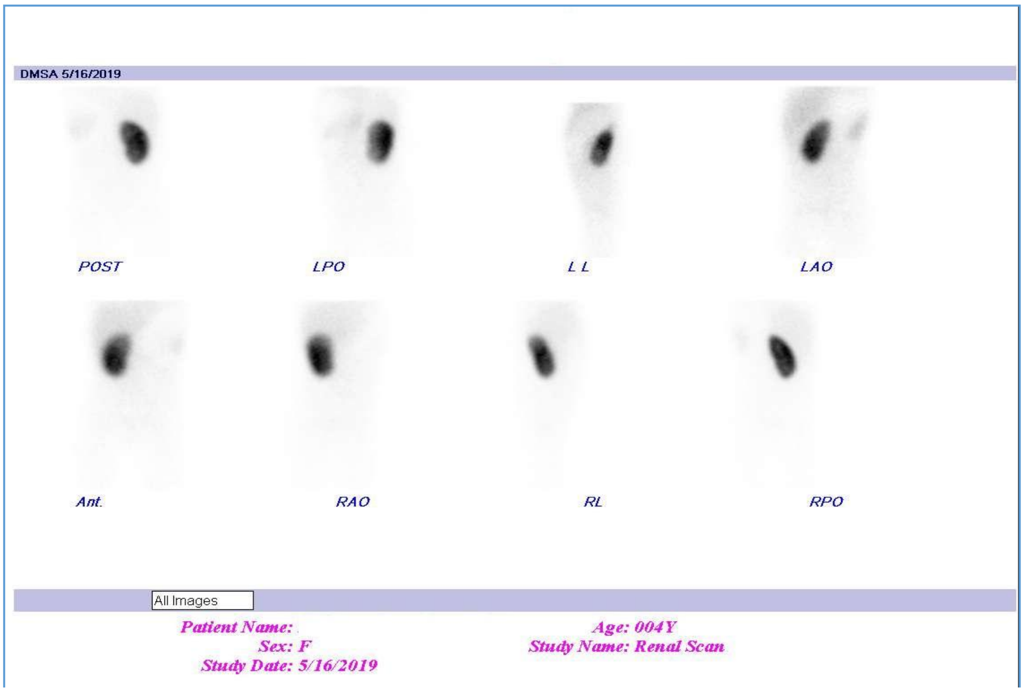
**Clinical History:**
A known case of single right kidney (left kidney agenesis) with moderate VUR.

DMSA 4 years ago: normal right kidney and non-visualized left kidney.

DRC 3 years ago: Moderate VUR in the right side.

US 3 months ago: normal right kidney (size: 96mm, cortical thickness: 14mm), non-visualized left kidney.

**Procedure:**
The patient received hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. 2mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of 2 mCi of Tc-99m-DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**
The study was of good quality. Right kidney had normal size, located in the normal location with uniform tracer uptake. No focal zone of decreased activity was noted throughout the right kidney.

Left kidney is not seen. Due to non-visualized left kidney, differential renal function could not be calculated.

**Impression:**
Right kidney: Normal sized with good function and no evidence of cortical defect.

Left kidney: Non-visualized, suggesting left renal agenesis

### 4.1.11 Reporting $^{99m}$Tc-DMSA scan – Ectopic kidney:

**Indication:**

Referred for localization of left kidney and evaluation of renal cortical function.

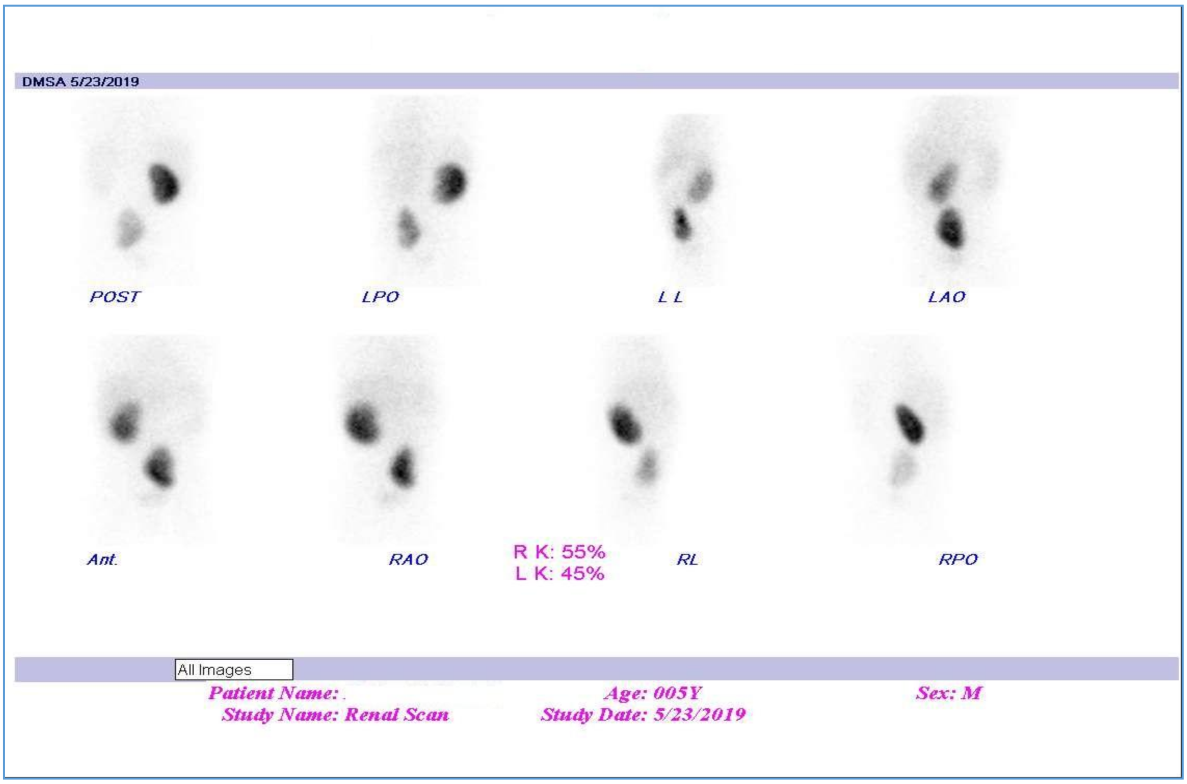
**Clinical History:**

A 5 Y/O boy with history of abdominal pain for the last 3 months

US 1 month ago: Non-visualized left kidney in normal location and normal right kidney.

**Procedure:**

The patient received hydration, which consisted of about 200 ml drinking water, before injection and in waiting room before imaging. 2mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of Tc-99m-DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**

The study was of good quality. Right kidney had normal size, located in the normal renal location, with uniform tracer uptake. No focal zone of decreased activity was noted throughout the right kidney. Left kidney was visualized in the pelvic cavity with malrotation, it showed relatively uniform tracer uptake with no focal zone of decreased activity. Differential renal function analysis using global uptake, geometric mean, manual ROI determination and no background subtraction showed 55% of total renal function in the right.

**Impression:**

Right kidney: Normal sized, with no cortical defect.

Left kidney: Malrotated ectopic kidney with no cortical defect. (Pelvic kidney)

DRF: Right kidney=55%

Left kidney=45%

### 4.1.12 Reporting $^{99m}$Tc-DMSA scan – Horseshoe kidney:

**Indication:**

Localization of right kidney and evaluation of cortical function.

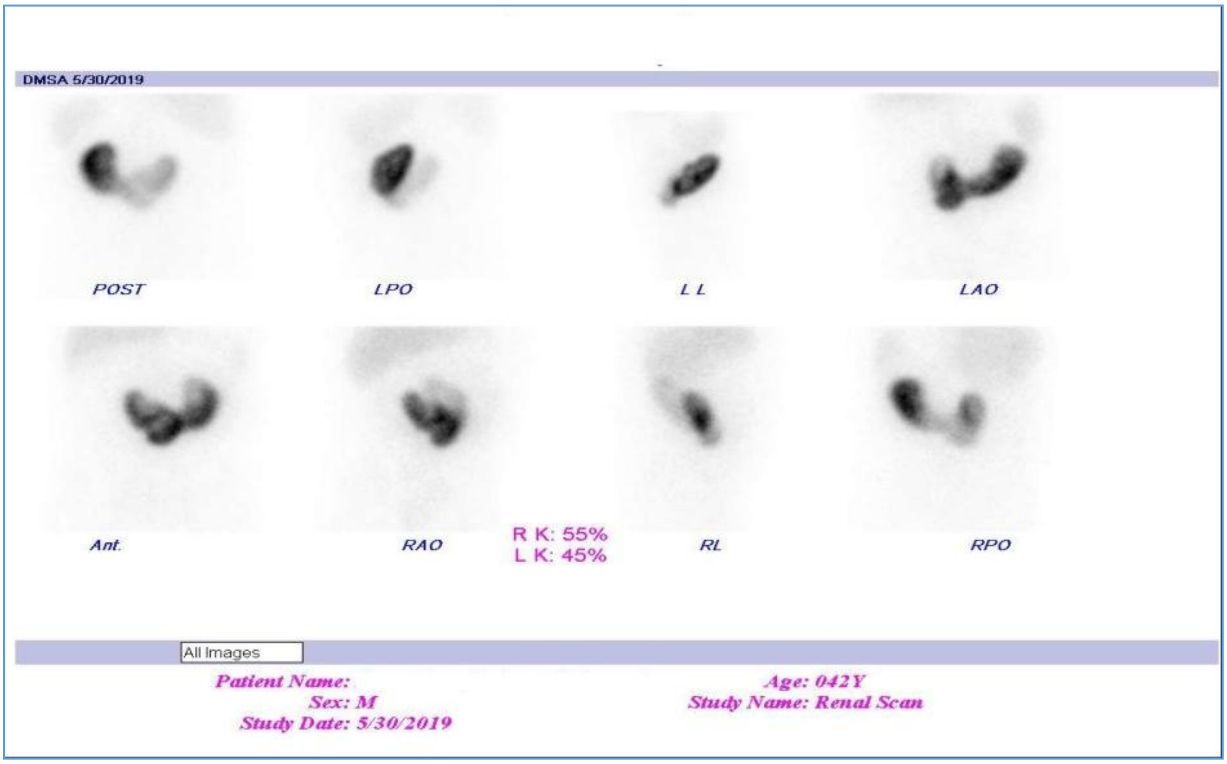
**Clinical History:**

A 42 Y/O man with history of renal stone in the left side and non-visualization of right kidney.

US 1 month ago: Non-visualized right kidney in the normal location and normal left kidney with a 4mm stone in the lower pole and no hydronephrosis.

**Procedure:**

The patient received additional hydration, which consisted of about 500 ml drinking water, before injection and in waiting room before imaging. 3mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of Tc-99m-DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**

The study was of good quality. Both kidneys located in mid abdomen and fused in lower pole (Horse shoe kidney). The right renal moeity was normal sized, anteriorly positioned with diverted axis and homogenously decreased tracer uptake throughout the kidney. The left renal moeity showed normal size, with uniform tracer uptake. Differential renal function analysis using global uptake, geometric mean, manual ROI determination and no background subtraction showed 37% of total renal function in the right.

**Impression:**
Horseshoe kidney.

Right moeity: Normal sized, anteriorly located with deviated axis and relatively decreased cortical function.

Left moeity: Normal sized with no cortical defect.

DRF: Right kidney=37%

Left kidney=63%

### 4.1.13 Reporting $^{99m}$Tc-DMSA scan – Cortical defect:

**Indication:**

History of bilateral VUR referred for evaluation of cortical function and comparison of differentiated renal function with previous DMSA.

**Clinical History:**

A 2.5 Y/O girl with history of VUR confirmed 2 years ago.

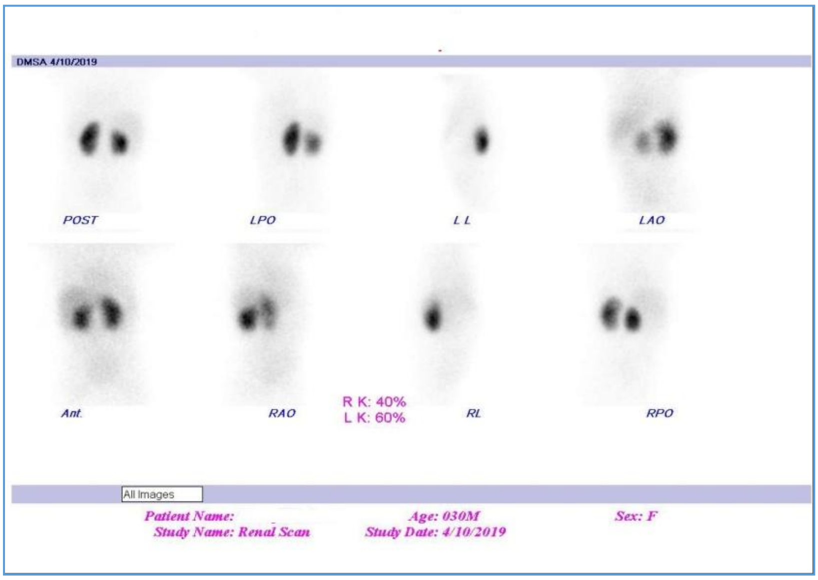
DMSA scan 2 years ago: Two cortical defects in the upper and lower pole of the right kidney and normal left kidney (DRF in right side=43%)

US 3 months ago: Small right kidney (54mm) with dilated PC system and 13mm cortical thickness. Normal sized left kidney (70mm) with dilated PC system and 13mm cortical thickness.

DRC 1 month ago: Severe VUR on the right side and moderate VUR on the left side.

**Procedure:**

The patient received additional hydration, which consisted of about 100 ml drinking water, before injection and in waiting room before imaging. 1mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of Tc-99m-DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**

The study was of good quality. The right kidney was small in size, with two cortical defects in the upper and lower poles. The left kidney was normal sized with regular borders and homogenous tracer uptake throughout the kidney. Differential renal function analysis using global uptake, geometric mean, manual ROI determination and no background subtraction showed 40% of total renal function in the right.

**Impression:**

Right kidney: Small with two cortical defects in the upper and lower poles.*

Left kidney: Normal sized, with no cortical defect.

DRF: Right kidney=40%

Left kidney=60%

*Compared to previous $^{99m}$Tc- DMSA scan, right kidney function has remained stable.

#### 4.1.14 Reporting $^{99m}$Tc-DMSA scan – Global cortical loss and multiple cortical defects:

**Indication:**

The patient is a 45-year-old male, referred for evaluation of cortical function and differential renal function, especially of the left kidney.

**Clinical History:**

A 45 Y/O man with previous history of renal stones and recent right flank pain.

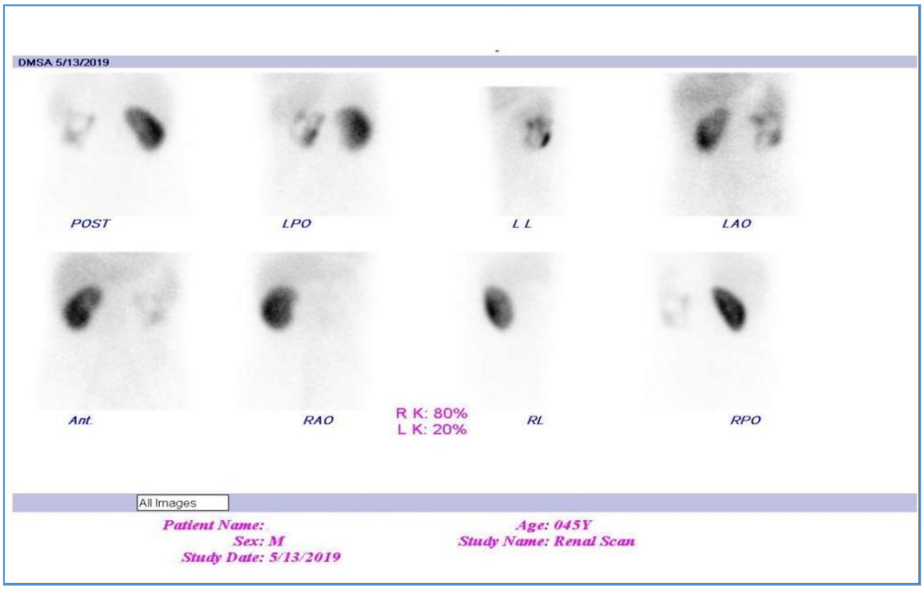
US 2 months ago: normal right kidney with a 4mm stone in the middle calyces. Left kidney showed dilated PC system with decreased cortical thickness.

IVP 1 month ago: Normal right kidney function with normal ureter and non-functioning left kidney.

BUN=21 and Cr=1.1

**Procedure:**

The patient received additional hydration, which consisted of about 500 ml drinking water, before injection and in waiting room before imaging. 3mCi of $^{99m}$Tc-DMSA was injected intravenously and the patient voided before the procedure. 3 Hours after IV injection of 3 mCi of Tc-99m-DMSA scanning was performed in routine spot views (anterior, posterior, right and left posterior oblique, right and left anterior oblique, right and left lateral views).




**Findings:**

The study was of good quality. The right kidney had normal size, located in the normal renal bed, with uniform tracer uptake. The left kidney was relatively normal sized with decreased tracer uptake and multiple zones of absent activity throughout the kidney. Differential renal function analysis using global uptake, geometric mean, manual ROI determination and no background subtraction showed 72% of total renal function in the right.

**Impression:**

Right kidney: Normal sized, with no cortical defect.

Left kidney: Relatively normal in size with global cortical loss and multiple cortical defects.

DRF: Right kidney=72%

Left kidney=28%

# Chapter 5: Direct Radionuclide Cystography – Evaluation of vesicoureteral reflux: (4, 16)

### 5.1.1 Introduction:

The incidence of vesicoureteral reflux is approximately 1 to 2% in children, but in patients with UTI, this rate increases to 22-55%. Direct radionuclide cystography (DRC) has higher sensitivity and lower radiation dose compared to contrast Cystography. It has been introduced as the method of choice for detection and follow up of VUR. 20-40 MBq of $^{99m}$Tc-DTPA(preferred),$^{99m}$Tc-colloid or pertechnetate in 500 ml normal saline can be used. The appropriate volume for bladder filling should not exceed than what is calculated by the formula: (age in year+1)×30

### 5.1.2 Indications:

Detection of VUR after UTI.

Follow up of known VUR during prophylactic or therapeutic antibiotic/bacteriostatic prescription.

VUR screening in siblings of children/parents with proven VUR.

Evaluation of surgical or endoscopic treatment's result.

Detection of VUR in transplant kidneys.

Detection of VUR in patients with bladder dysfunction like neurogenic bladder in serial assessments.

### 5.1.3 Contraindications:

There are no significant contraindications. However, note that:

The first catheter cystogram in boys should be obtained by a radiological micturating Cystography to visualize the urethra and rule out posterior urethral valve.

Children should not be catheterized during the active phase of UTI.

### 5.1.4 Patient Preparation:

Aseptic catheterization with using clean weighed diaper for children.

A single dose of oral prophylactic antibiotic has been suggested.

In children with severe VUR, intravenous antibiotic treatment may be mandated.

### 5.1.5 Imaging:

Filling phase: Posterior dynamic imaging should be performed in supine position during slow filling of bladder with diluted radiotracer until the bladder capacity reach to standard volume or the patient shows urge to void or no more saline can be entered to the bladder.

Voiding phase: Similar to filling phase in posterior view and supine position for infants. In toilet trained co-operative patient, voiding phase should be performed in sitting position in front of a vertical collimator.

Review of cine images is essential for detecting mild VURs. Also, compressed dynamic images may create more accurate reports.

### 5.1.6 Pitfalls:

In patients with pelvic or low-lying kidneys and dilated lower ureter, VUR may be missed.

### 5.1.7 Reporting:

Reviewing cinematic and compressed images as well as raw images on the monitor screen can result in more precise report with less false negative rate. If there is no patient movement during dynamic imaging, increasing activity in the ureter or renal PC system indicates vesicoureteral reflux.

All VURs are not seen in both filling and voiding phases. VURs can be intermittent due to episodes of bladder contraction, only active or just passive. On the other hand, interpreters should be aware of high noise in image, which sometimes may mimic reflux pattern.

Three score DRC grading system is used for accurate guidance for clinicians:

Mild: The tracer only reaches up to ureter (Grade I in radiological VCUG).

Moderate: Tracer can be visualized in ureter and renal pelvis with no dilatation (Grade II and III in VCUG).

Severe: Tracer accumulation in dilated PC system or tortuous ureter (Grade IV and V in VCUG).

### 5.1.8 Reporting normal direct radionuclide cystography

**Indication:**

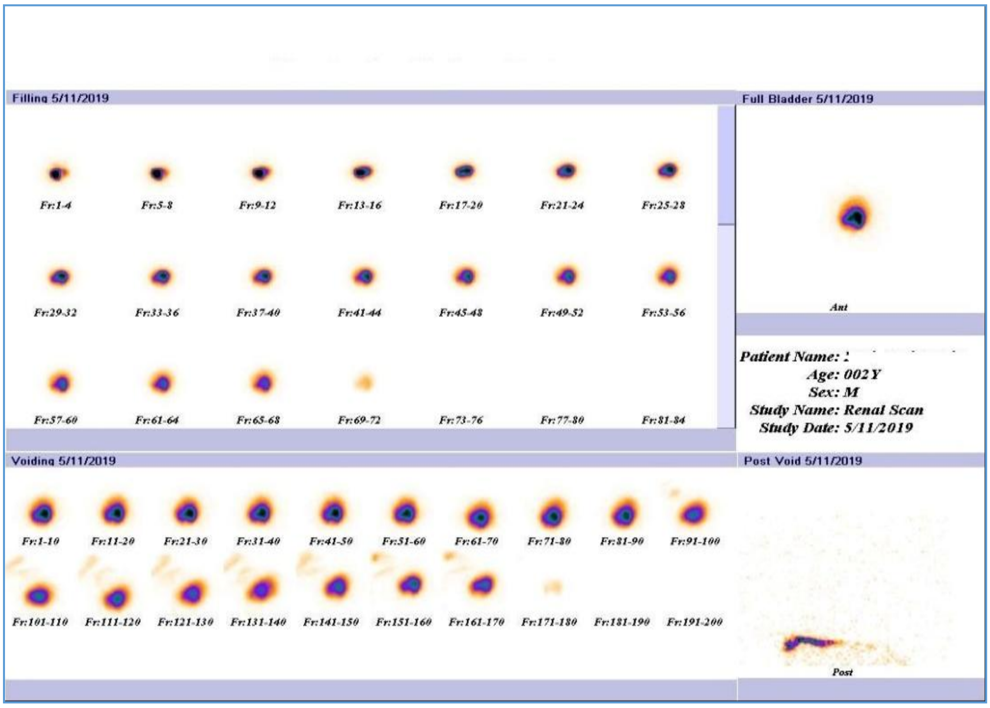
The patient is a 2-year-old male referred for VUR evaluation, follow up scan.

**Clinical History:**

The patient is a known case of recurrent pyelonephritis and left severe VUR which was confirmed in previous VCUG 1 year ago. Now, he is under prophylactic antibiotic therapy with Cephalexin.

**Procedure:**

Under aseptic conditions, bladder catheterization and drainage with a small Foley catheter for bladder emptying was performed. The patient was not toilet trained, so a double disposable nappy was put in place to avoid contamination. The patient placed on the imaging table and the catheter was connected to a bottle of normal saline. When free flow of saline was established to the bladder, 1mci of $^{99m}$Tc-pertechnetatewas injected into the catheter. Then scanning in the filling, full bladder (130cc), voiding and post-void phases were obtained.




**Findings:**

The study was in good quality. The scan showed normal shaped bladder with no abnormal activity in both ureter and pelvicalyceal systems.

**Impression:**

Normal radionuclide cystography.

### 5.1.9 Reporting DRC: severe left VUR

**Indication:**

The patient is a 6 year old female with history of bilateral VUR referred for follow up scan to decide about next management (continuing AB therapy or surgery).

**Clinical History:**

A known case of VUR who was under prophylactic antibiotic therapy. After discontinuing of treatment, an episode of UTI was happened.

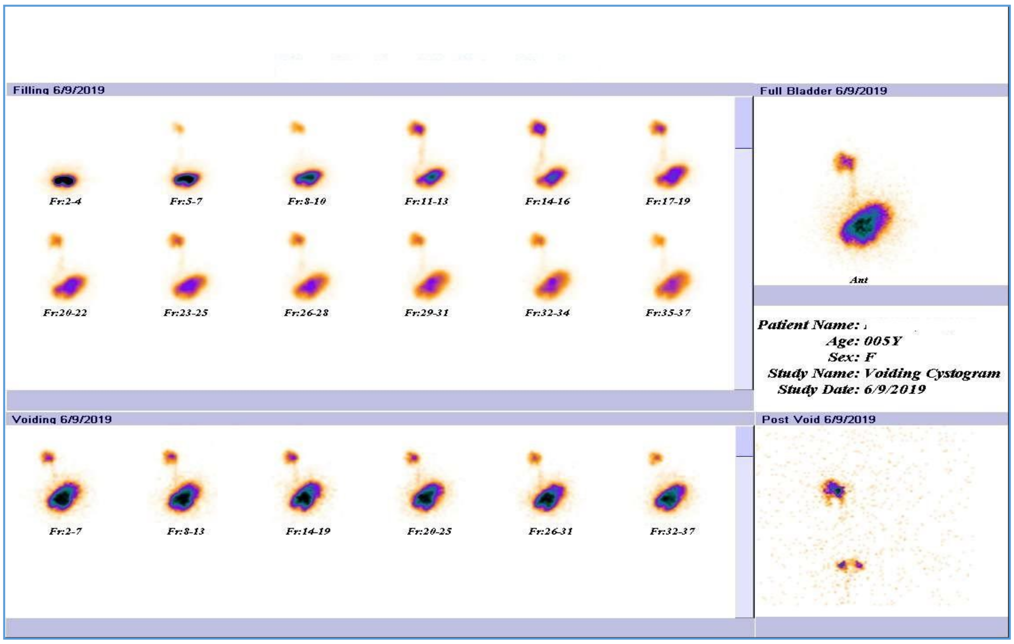
Previous VCUG 5 years ago showed bilateral (VUR grade V in left and grade II in right side).

DRC 2 years ago indicated severe left VUR.

Recent ultrasonography showed normal sized kidneys (right:93mm and left: 90mm) with normal cortical thickness ( right:10mm and left:9mm)

**Procedure:**

Under aseptic conditions, bladder catheterization and drainage with a small Foley catheter for bladder emptying was performed. The patient placed on the imaging table and the catheter was connected to a bottle of normal saline. When free flow of saline was established to the bladder, 1mci of $^{99m}$Tc-pertechnetate? was injected in to the catheter. Then scanning in the filling, full bladder (250cc), voiding and post-void phases were obtained.




**Findings:**

The study was in good quality. The scan showed normal shaped bladder with abnormal activity in the tortuous left ureter and dilated left PC system starting from the filling phase, at the bladder volume of 40cc. No abnormal activity was noted in the right ureter and pelvicalyceal system.

**Impression:**
Severe vesicoureteral reflux on the left side.

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