Genitourinary Tract

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8.1 Dynamic Renal Scintigraphy

Clinical Indications [1]

- Children with a dilated urinary tract, to exclude obstruction.
- Renal transplant evaluation.
- Suspected renal arterial and venous thromboembolic disease.
- Suspected renal trauma.
- Renal length/volume asymmetry at ultrasound (US).

Pre-Exam Information

- History of a recent urinary tract infection (UTI)? If so, when was the last episode?
- Does the child have an ectopic kidney?
- Can the child void on demand? Is the patient toilet trained?
- Is this a baseline or follow-up investigation?
- What are the US results?
- Has the serum creatinine been tested? What is the value?

Study Protocol for Dynamic Renography [2]

Patient Preparation

- Oral hydration is encouraged before arrival and may be sufficient in most situations.
- Place IV line to inject the radiopharmaceutical and furosemide and intravenous (IV) fluids if required.
- IV hydration (volume expansion) is more reliable in diagnosing questionable cases of urinary obstruction.
- IV hydration in patients with no cardiovascular contraindication is suggested to reduce the incidence of false-positive results. The suggested volume is 15–20 ml/kg two-thirds of which should be given prior to furosemide administration. The slow administration of fluid is continued during the remainder of the study.
- Assess bladder status.
- Toilet-trained children should be encouraged to urinate before positioning them on the bed.

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Z. Bar-Sever et al. (eds.), *A Practical Guide for Pediatric Nuclear Medicine*,
https://doi.org/10.1007/978-3-662-67631-8_8

Radiopharmaceutical, Administered Activity, Mode of Delivery

Radiopharmaceutical:

- [^{99m}Tc]-mercapto-acetyl-triglycine (MAG3) or [^{99m}Tc]-ethylene dicysteine (EC) are preferred as being tubular agents.
- Alternative: [^{99m}Tc]diethylene-triamine pentaacetate (DTPA), a glomerular radiotracer.

Activity:

- MAG3: 3.7–5.55 MBq/kg (0.10–0.15 mCi/kg), with a minimum dose of 15 MBq (0.40 mCi).
- DTPA: 20–196 MBq (0.5–5.3 mCi)

Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

Reference to national regulation guidelines, if available, should be considered.

Acquisition Protocol

Patient Positioning

- Supine with the camera in the posterior position
- Double check with a marker that the whole abdomen and pelvis (from xiphoid to symphysis pubis and lateral margins of the abdomen) are in the field-of-view (FOV) before starting the acquisition.
  - If there is a history of an ectopic kidney, ensure that it is in the FOV and acquire, whenever possible, anterior view images contemporary and in addition to posterior views and calculate the differential renal function (DRF) from the geometric mean of anterior and posterior renal counts.
  - Patients with renal transplants will be acquired in the anterior view.

Acquisition parameters

Two acquisition protocols based on the timing of furosemide (F) administration can be used:

- F-0 protocol: The radiopharmaceutical and furosemide are injected together, followed by at least 20 mins of dynamic imaging at 10–15 s/frame, matrix 128 × 128, size-appropriate zoom.
- F + 20 or F + 30 protocol: Following tracer administration, dynamic images are acquired as above for 20 or 30 mins, respectively. Furosemide is then administered, and the second set of post-furosemide dynamic images is acquired for 20–30 mins.
  - The pre- and post-furosemide dynamic images can be obtained as a single continuous acquisition or two separate acquisitions. In this second case, placing the child vertically for 5–10′ may allow the kidney to empty enough, at physician's judgement, to avoid furosemide administration and shorten the scan time.
  - Whenever the pelvis is not full after 20 or 30 mins furosemide administration should be delayed until the pelvis is filling up.
- The furosemide dose across all ages is 1 mg/kg with a maximum dose of 40 mg.
- The first minute of acquisition in both protocols can be acquired with a fast frame rate of 1–2 s/frame to allow evaluation of kidney perfusion.
- A "late" image is mandatory to complete the study in both protocols if drain-

age is inadequate at the end of the post-furosemide dynamic sequence.
  - It is typically acquired at least 45 mins from the start of the study.
  - It should be acquired after the patient empties his bladder, unless there is a bladder catheter in place, and after he has been in a vertical position for at least 10–15 mins.
  - It can be acquired as a static image or as a short sequence of dynamic images for 2 mins which will allow more straightforward incorporation of this data into the renogram if desired.
- Alternatively, a 1-min static image can be acquired at the end of the post-furosemide dynamic sequence while the patient is supine, followed by a second static image with similar acquisition parameters after the patient has been in the erect position for 10–15 mins.

Dynamic Renogram Study Processing and Interpretation [3, 5]

Study Processing

- Check for movement. DRF calculations should be interpreted with caution in the presence of motion.
- Accepted methods for DRF calculations are:
  - Integral method using the area-under-the-curve (AUC) is preferred because it is less sensitive to patient's motion.
  - the Rutland Patlak method.
- Methodology:
  - Draw renal regions-of-interest (ROIs) around the visible renal parenchyma being careful not to "cut" the kidney and not to include the collecting system. Large ROIs containing the yet unfilled pelvis are not acceptable for the DRF calculation.
  - For MAG3 studies, the ROI is constructed on the 60–120 s summed image.
  - For DTPA, the ROI is constructed on the 120–180 s summed image.

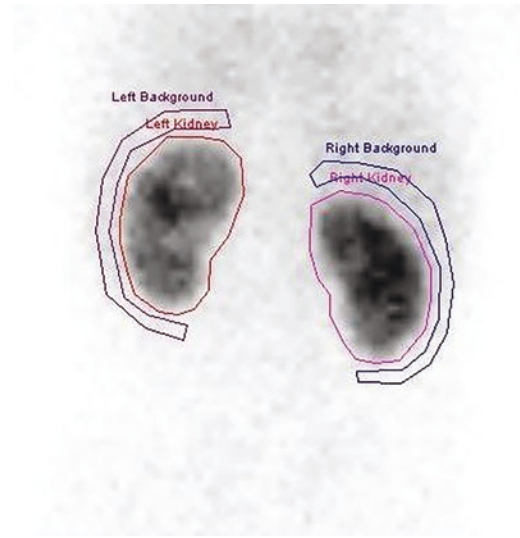


Fig. 8.1 Example of kidneys (red line for the left and pink for the right kidney) and background (purple on the left and blue on the right) ROIs

- Background ROIs should sample activity originating in the liver and spleen. The recommended background ROI has to be inside the body outline, is perirenal, semilunar, "C"-shaped, and samples activity surrounding both upper and lower poles (Fig. 8.1).
- The Rutland Patlak method requires an additional ROI drawn around the heart (blood pool), or, if the heart is not in the FOV, the spleen can be used.

Renogram Processing Quality Control

It is advised to perform the following quality assurance steps, mainly in infants and children with impaired renal function: Process the renogram more than once to check for reproducible values. (i.e., within 4%), modifying size and location of the background ROIs or the time interval selected for the calculation.

Processing the Diuretic Response

- The ROI used for the construction of the drainage curve and for analysis and calculation of semiquantitative parameters:
  - Should be positioned on the summed images showing the maximal dilatation of the collecting system.

  - Should include the entire collection system. In cases of hydroureteronephrosis, both the ureter and the pelvis should be included.
  - If there is suspicion of concomitant ureteropelvic junction (UPJ) obstruction, a second ROI covering only the pelvis should be placed.
- Many centers utilize a semi-quantitation technique to measure the clearance/diuretic T1/2 of the tracer over a 20–30 min period post-diuretic administration, defined as the time at which the TAC decreases to half of its maximal activity.
- Guidelines on diuresis renography in children recommend using the normalized residual activity (NORA) index for a semiquantitative assessment of drainage calculated as the decay corrected, post-diuretic residual kidney counts divided by the 1–2 mins parenchymal counts [4].
  - This ratio normalizes the residual activity to the parenchymal function of the kidney.
  - Typical time points for NORA calculation include the end of the post-furosemide dynamic sequence and, most importantly, the late, post-micturition, post-gravity-assisted image.

Study Interpretation

- Assess the technical quality of the study as good or poor including whether there is excessive patient movement or interstitial and not IV injection of the radiopharmaceutical.
- Describe the images and renogram curves including:
  - The tracer uptake in each kidney at 1–2 mins after the beginning of the study and the appearance of the kidneys on these images.
  - With MAG3, which is a cortical agent, assesses for the presence of cortical defects, for signs of duplications of the excretory system (see Sect. 8.2) and if there are abnormal renal positions or shapes.
  - Measure DRF.
  - Assess the clearance of tracer activity from each kidney, whether there is prolonged cortical transit and pooling, as well as any delay in drainage from calyces, pelvis, and ureters.
  - If possible, identify the anatomic level of hold-up, i.e., the uretero-pelvic (UPJ) or uretero-vesical junction (UVJ).
  - State the time that furosemide was given and the presence or absence of a diuretic response using the NORA semiquantitative drainage assessment, with a value above 1–1.5 at 60 mins being considered abnormal.
  - Assess the late post-micturition and post-gravity-assisted images to determine further drainage from the kidneys.

Correlative Imaging

- US, CT, and MRI are not reliable in the assessment of renal function and in evaluation of drainage
- Correlation with the US is required when performing diuretic renography.
- At least one US should be performed prior to a renogram.
- US provides information such as uni- or bilateral disease, the size and position of the kidneys and pelvis, presence of dilated calyces or cortical thinning, very useful in deciding on the optimal time for a baseline renogram and follow-up studies.

Red Flags [6, 7]

- If the F + 0 protocol is planned and the child has an adequate oral fluid intake, a venipuncture with a 25-gauge needle and a three-way stopcock for saline flushing can be used when only very thin veins seem available.

- The indwelling venous cannula may be inserted to maintain sufficient hydration for an excellent diuretic effect and obviate repeated trauma from multiple percutaneous injections.
- The Intravenous fluid solution type used for pre-test hydration should concur with the hospital's regulations.
- In dysplastic kidneys with huge dilatation of the collecting system, when using the F+20 or + 30 protocol, the pelvis may not be filled with tracer activity at the end of the first 20–30 mins.
- The nuclear medicine technologist should stay next to the child, at least for the first 5 mins of the renogram, to ensure that movement is kept to a minimum. Parents'/caregivers' help whenever possible is also welcomed. Motion artifacts, common in pediatric studies, can introduce significant errors in half-time (T1/2) values, which should be therefore interpreted in conjunction with visual assessment.
- Accurate assessment of renal perfusion is difficult in small children because of the small administered activity.
- Bladder catheterization is an option in non-toilet-trained children. It should be performed on a selective basis keeping in mind the unpleasant nature of the procedure and the small risk of infection. Antibiotic prophylaxis for the procedure is advised. Bladder catheterization should be performed by qualified, trained personnel.
- Insufficient hydration impairs adequate drainage assessment.
- A full distended urinary bladder impairs drainage assessment, increases the likelihood of vesicoureteral reflux (VUR) and causes a "pseudo-obstruction."
- Drainage from hugely dilated systems or hydronephrotic kidneys with poor parenchymal function can be slow without any obstruction. The conclusion of obstruction should be avoided [8].
- When diuretic renography study suggests obstruction, pay attention to the cortical transit time (CTT). A prolonged CTT means that the obstructed kidney has an increased risk of losing function and thereby there is a need for surgery [9].
- MAG3 scintigraphy in children with normal renal function can identify major cortical abnormalities but can miss minor defects [10].
  - Renal immaturity in neonates makes it essential to use tubular agents such as MAG3.
  - In the presence of excessive movement during the first 1–3 mins of the study, if available, utilize a dynamic motion correction program.
  - Looking at DRF values, check the correct drawing of background ROIs in case of apparent discrepancy between values and images. This is especially important in young infants with physiologic renal immaturity and in cases of impaired renal function. It may be also difficult in some infants with huge hydronephrotic kidneys abutting the abdominal wall.
  - Acute UTI can cause a transient drop in DRF. In children presenting with signs or symptoms of UTI or fever, it may be useful to do a urinary dipstick on the day of the study to ensure that there is no ongoing infection at the time of the investigation.

Take Home Messages

- Diuretic dynamic renography provides essential information for therapeutic decisions regarding surgical or conservative management of urinary tract dilatations.
- MAG3 and EC are tubular agents characterized by higher extraction subsequently translating into images with improved kidney contrast. This is of paramount importance in young infants with physiologic renal immaturity and in patients with compromised renal function.

- DTPA is a glomerular radiotracer that can be an alternative radiopharmaceutical used only when tubular agents are unavailable.
- A fast 1 -s initial acquisition step is essential for evaluating transplanted kidneys but not necessary for the evaluation of urinary tract dilatation.
- A diuretic renogram can be performed at any age. In newborns, unless an urgent surgical procedure is considered, it is best to postpone the study up to the age of 30–45 days to allow for some renal maturation.
- In selected cases (e.g., single kidney with hydronephrosis and suspected obstruction), scintigraphy is often indicated before nephrostomy tube placement, even in newborns.
- Guidelines on diuresis renography in infants and children recommend two acquisition protocols based on the timing of furosemide administration.
- If there is a history of an ectopic kidney, ensure that it is included in the FOV and acquire, whenever possible, anterior view images contemporary and in addition to posterior views using a dual-head camera to improve the accuracy of the DRF.
- It is mandatory to use the same radiopharmaceutical and acquisition protocol, the same timing of furosemide administration and the same timing of the late post-void image in follow-up studies of the same patient.
- Bladder catheterization can be helpful in cases of hydro−/ureteronephrosis, high-grade (4–5) VUR, and neurogenic bladder, as these conditions may cause false-positive results for urinary obstruction.
- Good drainage at the end of the whole study has a high positive predictive value for the absence of obstruction.
- Slow drainage following furosemide challenge might imply partial obstruction, but it is not specific.
- A T1/2 value of less than 15 mins has a high positive predictive value in excluding obstruction.

Representative Case Examples

Case 8.1. Normal Renogram (Fig. 8.2)

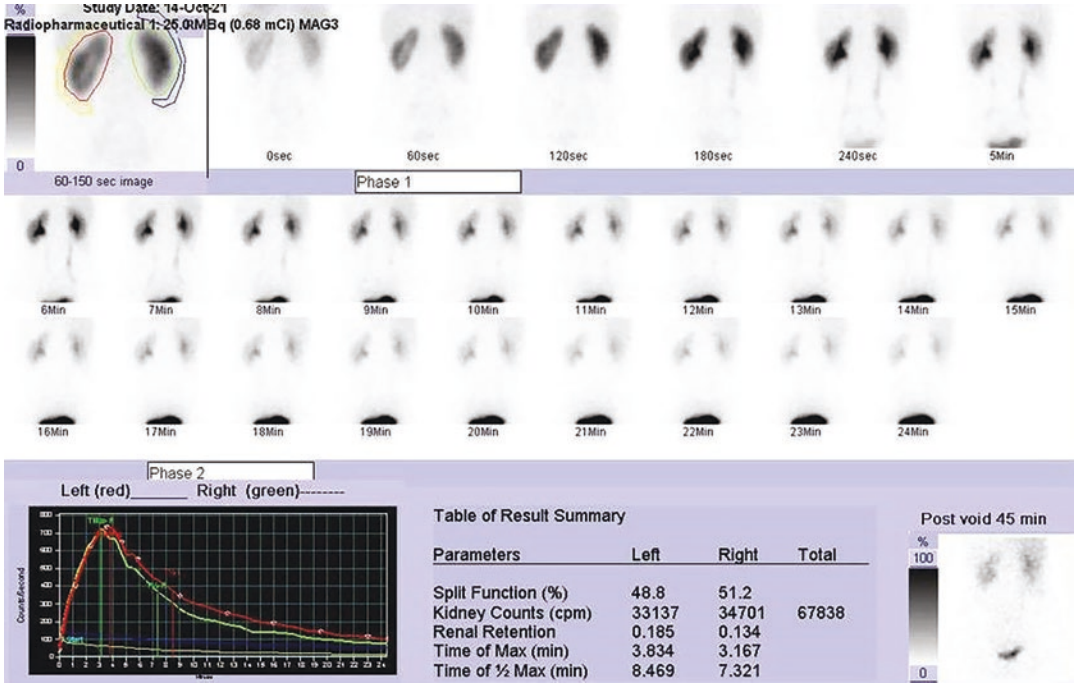


Fig. 8.2 History: A 6-year-old boy with recurrent UTIs and possible VUR performed a renogram following administration of MAG3 as a precursor for the indirect cystogram. Study report: There is good symmetrical uptake in both kidneys. No cortical defects are seen. The calyces, pelvises, and bladder are visualized 3 mins after tracer injection. There is good clearance of activity from the kidneys to the bladder, as shown on the summed 1 min images of the renogram. The DRF is normally balanced, left kidney 49%, right kidney 51%, and the perfusion and clearance curves are normal on the 1–2.5 min clearance image with drawn ROIs. Impression: This is a normal renogram

Case 8.2. Dilated Right Excretory System with no Evidence of Obstruction (Fig. 8.3)

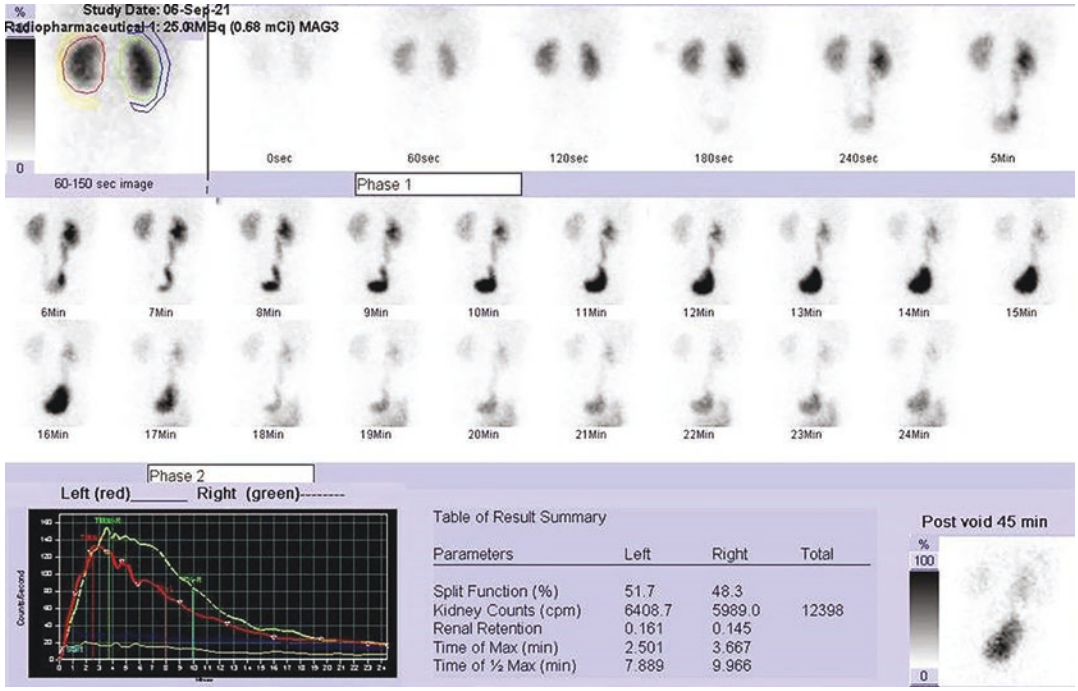


Fig. 8.3 History: A 6-month-old boy with mild-to-moderate dilatation of the right excretory system, seen on serial US examinations, performed a diuretic renal scan to exclude obstruction. The patient was orally pre-hydrated and the study was performed with the F+0 protocol, furosemide administered at a dose of 1 mg/kg. Study report: The dynamic phase over 25 mins shows mild-to-moderate dilatation of the right excretory system, with constant visualization of the ureter that appears minimally convoluted. DRF is 52% on the left and 48% on the right. During the study acquisition there is good clearance of the tracer from both kidneys. The clearance curves confirm bilateral normal clearance, with tracer that has already cleared from the left side. Impression: There is no evidence of obstruction

Case 8.3. Hydronephrotic Kidney, Follow-Up after Pyeloplasty for UPJ (Fig. 8.4)

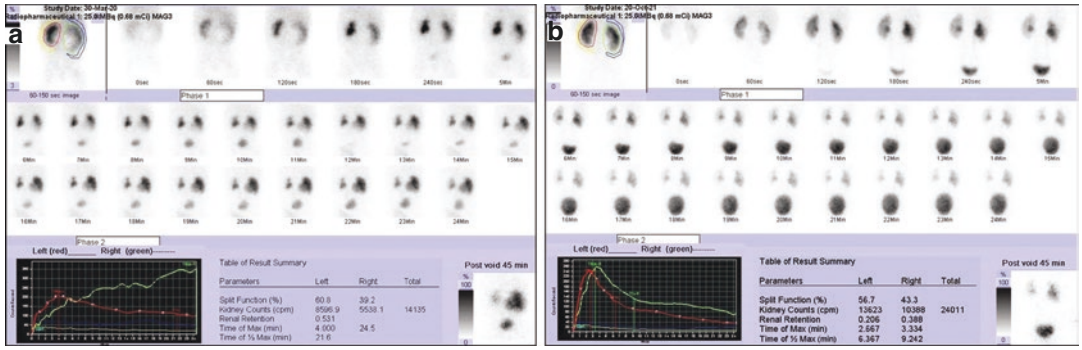


Fig. 8.4 History: A 1-month-old girl presented with severe right hydronephrosis, first detected on prenatal US, antero-posterior pelvic diameter (APD) 33 mm, further confirmed on postnatal US which showed an APD 23 mm and severe right renal parenchymal thinning. Study report: A MAG3 scan with the F+0 protocol was obtained (**a**), including a late post-void, gravity-assisted image at 45 mins. The right kidney is enlarged and hydronephrotic. Cortical uptake is reduced, especially in the lower pole, DRF 39%. There is prolonged CTT to the large, hydronephrotic right renal pelvis with no drainage. The left kidney shows normal parenchymal uptake, DRF 61%. The diuretic renogram curve is rising. The left kidney shows good although slow drainage. There is a significant residual activity in the right pelvis and a small residual amount in the left renal pelvis. The 45-min NORA value of the right kidney is elevated, 1.8. The findings are consistent with right hydronephrosis with reduced parenchymal function and markedly impaired drainage. The left kidney shows a normal function with tracer pooling in the pelvis but no evidence of a significant obstruction. The patient underwent a right pyeloplasty to relieve the UPJ obstruction. Follow-up US studies showed a gradual reduction in the size of the right pelvis. A follow-up scan using the same study protocol was obtained 1 year later (**b**). The right kidney is normal in size with only a moderate pelvic impression. Cortical uptake has improved, DRF 43%. There is normal tracer accumulation in the right pelvis with good drainage. The left kidney shows normal parenchymal uptake, DRF 57%. The diuretic renogram curve is near normal, with good drainage. There is a small, non-significant residual activity in the right pelvis and the 45-min NORA value of the right kidney is now normal, 0.4. Impression: Following the findings of obstructive UPJ in the preoperative scan (**a**) and surgery to relieve the obstruction, a follow-up diuretic renogram (**b**) shows improved function and drainage of the right kidney with no evidence of residual obstruction. Normal left kidney with improved drainage as compared to the first study

Case 8.4. Hydronephrotic Kidney, Spontaneous Improvement (Fig. 8.5)

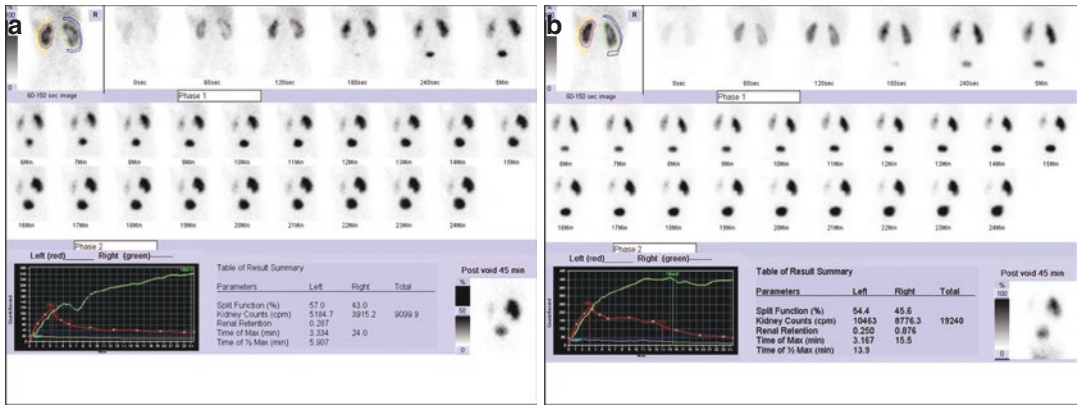


Fig. 8.5 History: A 1-month-old infant presented with right hydronephrosis, first detected on prenatal US, confirmed on postnatal examination with an APD of 20 mm, a dilated calyceal system, parenchymal thinning (4 mm) and a renal longitudinal length of 64 mm versus 49 mm of the left kidney. Study report: A MAG3 scan with the F+0 protocol was obtained, including late post-void, gravity-assisted image at 45 mins (**a**). During the first 3 mins of the study, the right kidney appears enlarged and hydronephrotic, with a good cortical uptake, DRF 43%. There is slow CTT to a large, hydronephrotic right pelvis. The left kidney shows normal parenchymal uptake, DRF 57%. The diuretic renogram curve is rising with progressive accumulation of tracer in a huge right renal pelvis with no drainage. In the "post-void image" (diaper was changed), there is a significant residual activity in the right renal pelvis and a small residual amount in the left renal pelvis. The 45-min NORA value of the right kidney is markedly elevated (>3). These findings suggest right hydronephrosis with preserved parenchymal function and markedly impaired drainage, worrisome for UPJ obstruction. The left kidney shows fast and complete drainage. Following these findings, the infant entered a strict follow-up protocol. US performed at 3 months of age showed a decrease in the size of the right renal pelvis. The two kidneys had about the same longitudinal length, 56 vs 54 mm. A follow-up diuretic renogram using the same study protocol was obtained at the age of 4 months (**b**). During the first 3 mins of the study, there is improvement in the appearance of the right kidney showing a smaller renal pelvic enlargement and good cortical uptake, with an unchanged DRF of 46%. CTT to a less dilated renal pelvis is still longer than for the left kidney which shows normal parenchymal uptake, DRF 54%. The renogram curve shows progressive tracer accumulation in the right renal pelvis with partial drainage. The left kidney shows fast and complete drainage. In the "post-void image," there is a reduced but significant residual activity in the right renal pelvis. NORA of the right kidney has decreased to 1.9 but is still abnormal. Impression: Right hydronephrotic kidney with preserved parenchymal function and markedly impaired drainage, worrisome for UPJ obstruction which improves on the follow-up study performed 3 months later. Normal functioning left kidney with no evidence for significant obstruction

Case 8.5. Duplicated Left Excretory System with Obstruction of the Upper Pole (Fig. 8.6)

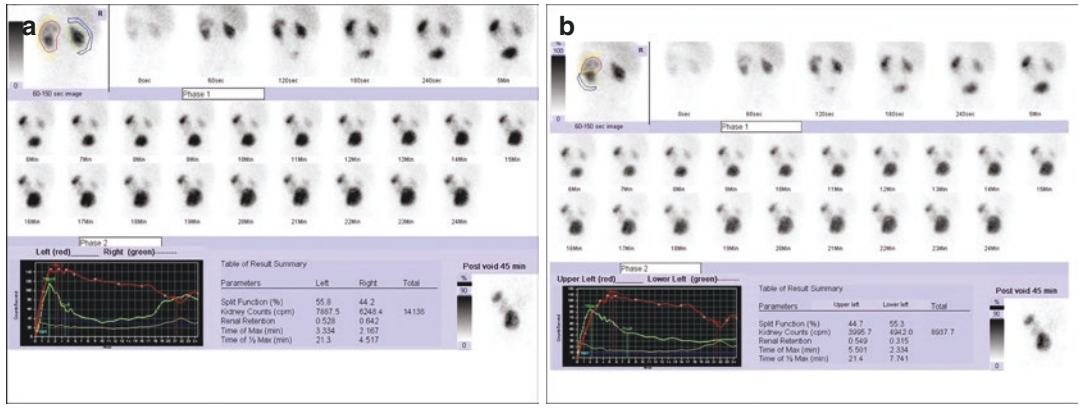


Fig. 8.6 History: A 1-month-old girl presented with US findings of complete duplication of the left excretory system and left intravesical ureterocele with dilatation of the upper pole excretory system. Diuretic renal study was requested to quantify the function of the upper pole. The patient was orally pre-hydrated. Study report: The study was performed with the F + 0 protocol, with a dose of Furosemide of 1 mg/kg. The diuretic renogram (**a**) shows dilatation of the upper pole of the left kidney. DRF was 56% on the left and 44% on the right. After about 8 mins there is a visualization of the left upper pole ureter that appears minimally convoluted. There is good clearance of the tracer from the right and the lower half of the left kidney, confirmed on the clearance curves. Note an artifact due to superimposition of the very full bladder to the background ROI. A repeat second analysis was performed (**b**) drawing separate ROIs around the two left kidney moieties. Relative DRF was 55% for the lower and 45% for the upper pole. There is good clearance of the tracer from the lower half while the upper one does not satisfactorily empty. Impression: The findings suggest obstruction of the upper pole of the left kidney due to ureterocele, with preservation of the regional function. Ureterocoele incision was then performed

8.2 Renal Cortical Scintigraphy

Clinical Indications [11–13]

- Diagnosis of acute pyelonephritis.
- Detection of renal scars after renal infection.
- Detection of renal dysplasia.
- Detection of renal ectopia and/or fusion, such as pelvic kidney, horseshoe kidney, crossed fused ectopy.
- Detection of renal infarcts.
- Confirmation of non-functioning multicystic dysplastic kidneys.
- Determination of parenchymal function:
  - DRF (one kidney relative to the other).
  - Upper vs. lower pole in cases of renal duplication.

Pre-Exam Information

- History of congenital urinary tract abnormalities.
- History of prior UTIs, clinical suspicion of acute pyelonephritis.
- Serum creatinine levels.
- History of nephrolithiasis, surgery, and trauma.
- Correlative imaging results.

Study Protocol for Renal Cortical Scintigraphy [14, 15]

Patient Preparation

- No patient preparation is required.

Radiopharmaceutical, Administered Activity, Mode of Delivery

Radiopharmaceutical:

- [^{99m}Tc]dimercaptosuccinic acid (DMSA) is the agent of choice.

Activity:

- 1.85 MBq/Kg (0.05 mCi/Kg), minimum dose 18.5 MBq (0.5 mCi).

Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

Reference to National Regulation Guidelines, if Available, Should Be Considered.

Acquisition Protocol

- Imaging at 2–4 h post tracer injection.
- Collimator: parallel hole, low-energy, high or ultra-high resolution.
- Position: supine.
- Static images for minimum 300 Kcounts each or pre-set time of 5 mins, matrix 256 × 256 or different but allowing for a pixel size below 2 mm according to a FOV that should encompass the two kidneys (Fig. 8.7).
- Views: posterior, right posterior oblique (RPO), left posterior oblique (LPO).
- In cases of renal ectopy or malformation (e.g., horseshoe kidney), and specifically for DRF calculations, an additional anterior view of the entire abdomen and pelvis is required (Fig. 8.8).
- SPECT improves lesion detectability. Acquisition parameters: 120 projections, 15 s/frame, matrix 128 × 128. Iterative reconstruction is preferred, especially in poor count studies.
- In infants younger than 1 year of age, images acquired with a pinhole collimator (when available) can be obtained for 100–150 Kcounts or a pre-set time of 10 mins, although technically more demanding.

Study Interpretation [7, 16]

- Always based on at least a complete set of planar images (posterior, left and right posterior oblique, anterior whenever acquired) in black

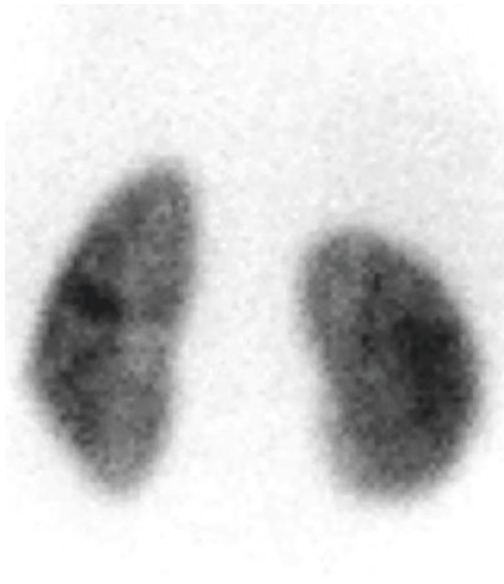


Fig. 8.7 Quality control of planar DMSA scan. Good quality images must show sharp renal outline and corticomedullary differentiation

and white, white background, with DRF clearly indicated, rounded up to the unit.
- Assess location, size, and position of kidneys.
- Identify irregularities in tracer distribution within the renal parenchyma as well as number and location of discrete cortical defects with and without associated volume loss.
- Calculate DRF, as a rule on posterior view only.

Normal variants:
- Fetal lobulations in the renal contour are normal in newborn infants.
- The lateral border of the left upper pole may appear flat due to the impression by the spleen.
- Columns of Bertin appear as areas of increased uptake. Their number and size differ from patient to patient.
- Elongated slender or pear-shaped kidneys which have different sizes of the transverse axis of the upper and lower poles.

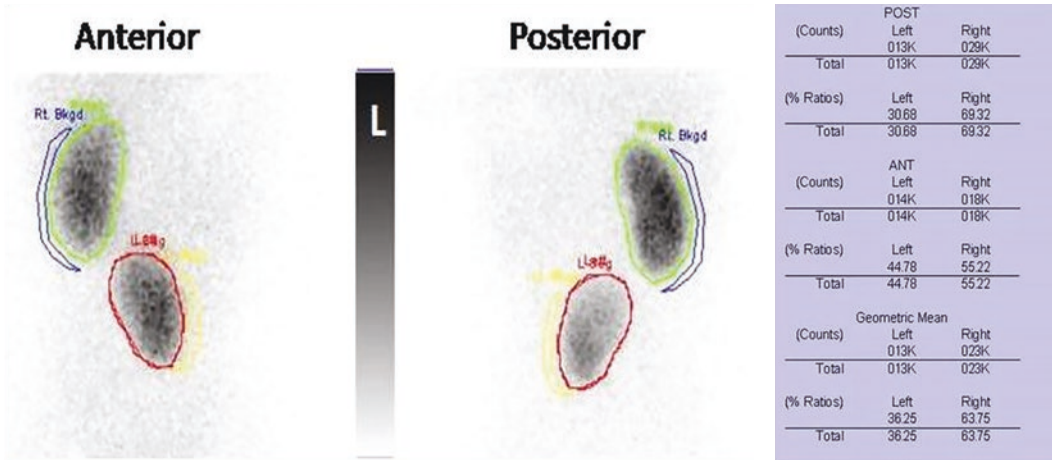


Fig. 8.8 DRF measurements in patients with renal ectopy. Calculations are based on the geometrical mean of counts measured in both anterior and posterior images

Abnormal patterns:

- One or more regions of reduced tracer uptake with a relatively preserved renal contour can suggest pyelonephritis in the appropriate clinical context.
- One or more areas of reduced or absent tracer uptake in the renal periphery interrupting the renal contour with or without associated volume loss suggest renal scar when the study is performed 6 months or more after the last UTI.
- Reduced, inhomogeneous uptake in a small kidney with a preserved outline suggests dysplasia.

Correlative Imaging [17, 18]

- Correlation with US is essential to rule out structural abnormalities (e.g., renal cysts or hydronephrosis) on the DMSA scan.
- US is not reliable in the assessment of renal acute and chronic damage.
- CT implies a higher radiation burden and MRI is more complex and less available.

Red Flags

- Air introduced into the DMSA vial may reduce renal uptake of the radiotracer and increase liver and background activities.
- Severe dilatation of the renal pelvis can result in abnormally retained activity. If significant tracer retention is noted in the renal collecting systems, additional late images up to 24 h are recommended for adequate evaluation of the cortex and in order to avoid possible inaccuracies in the assessment of split renal function.
- Reconstruction and motion artifacts, occasionally seen on SPECT, should not be confused with cortical lesions.
- Pinhole images are highly sensitive to patient motion.
- Distinction between pyelonephritis, scars, and dysplasia is not always possible based on scan findings. It should also be noted that these conditions may coexist.
- Tubular congenital abnormalities Fanconi's syndrome reduce uptake of DMSA but not of MAG3 [19].
- For diagnosis of scars, the DMSA study should be performed at least 6 months after the last documented infection to determine if the cortex has healed or was permanently damaged. Scans performed earlier than 6 months since the last UTI may be too early to identify true scarring.

Take Home Message

- DMSA binds to the proximal convoluted tubular cells. The tracer shows high parenchymal concentration and minimal excretion into the renal collecting system.
- DMSA scintigraphy is strongly integrated in evaluating children with UTI and guides management decisions. It is the best modality to determine both transient and permanent cortical damage.
- In order to diagnose acute pyelonephritis an "acute" cortical scan should be performed within 7 days of the onset of an acute febrile UTI.
- Images performed with a pinhole collimator can substitute for SPECT. They provide true optical magnification and superior spatial resolution, improving the detectability of subtle cortical lesions.
- Interpretation of DMSA studies with knowledge of US findings is strongly recommended.
- On a DMSA scan, the DRF is calculated as the ratio between the total counts inside the ROI in each kidney and the total counts in both renal ROIs after relative background subtraction.
- Duplication of the renal collecting system is not uncommon. Complications of this malformation typically include VUR to the distal collecting system with varying degrees of hydronephrosis, and possible cortical dysplasia or abnormal insertion (ectopic, ureterocele) of the upper pole ureter. The differential function of each pole can be calculated from appropriate ROIs and is useful when surgical resection is considered.
- Both MAG3 and DMSA provide equally accurate DRF [20].

Representative Case Examples

Case 8.6. Small Left Kidney with Scars (Fig. 8.9)

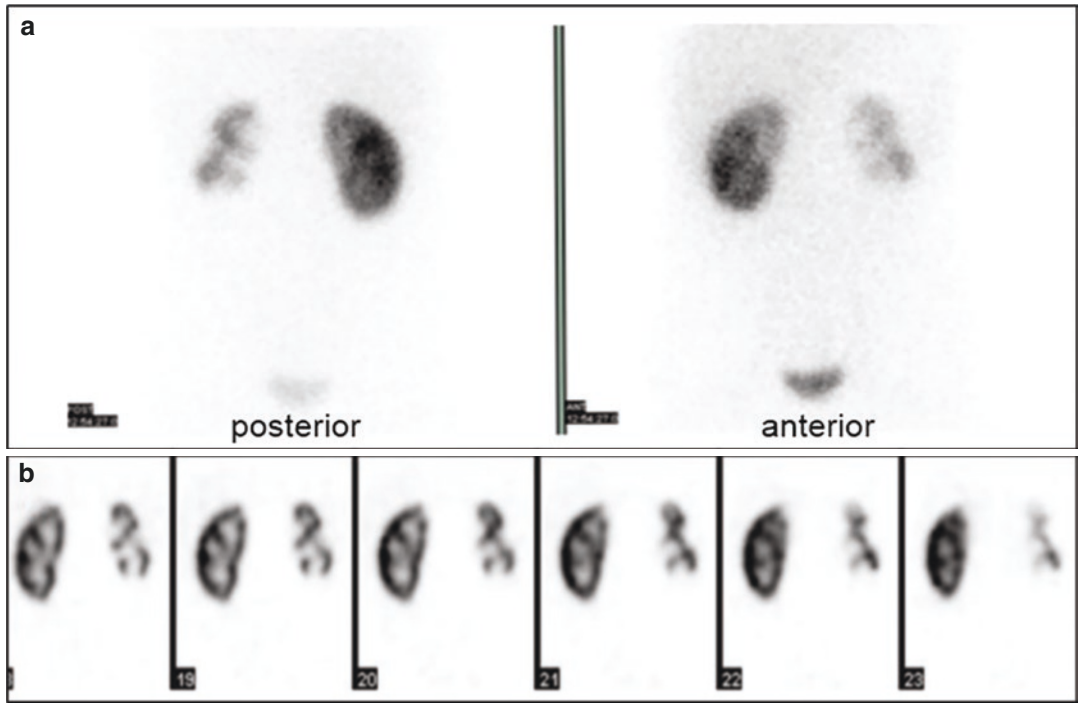


Fig. 8.9 History: A 5-year-old girl with a history of recurrent UTIs and a renal US reported as normal was referred for DMSA scintigraphy to assess for the presence of parenchymal scarring. Study report: Anterior and posterior planar images (**a**) show a small left kidney with an irregular contour. There are multiple peripheral defects in the cortical outline accompanying volume loss of the left kidney, best depicted on the coronal SPECT slices (**b**). Impression: Small left kidney with multiple scars

Case 8.7. UTI with Progression of Bilateral Renal Scars (Fig. 8.10)

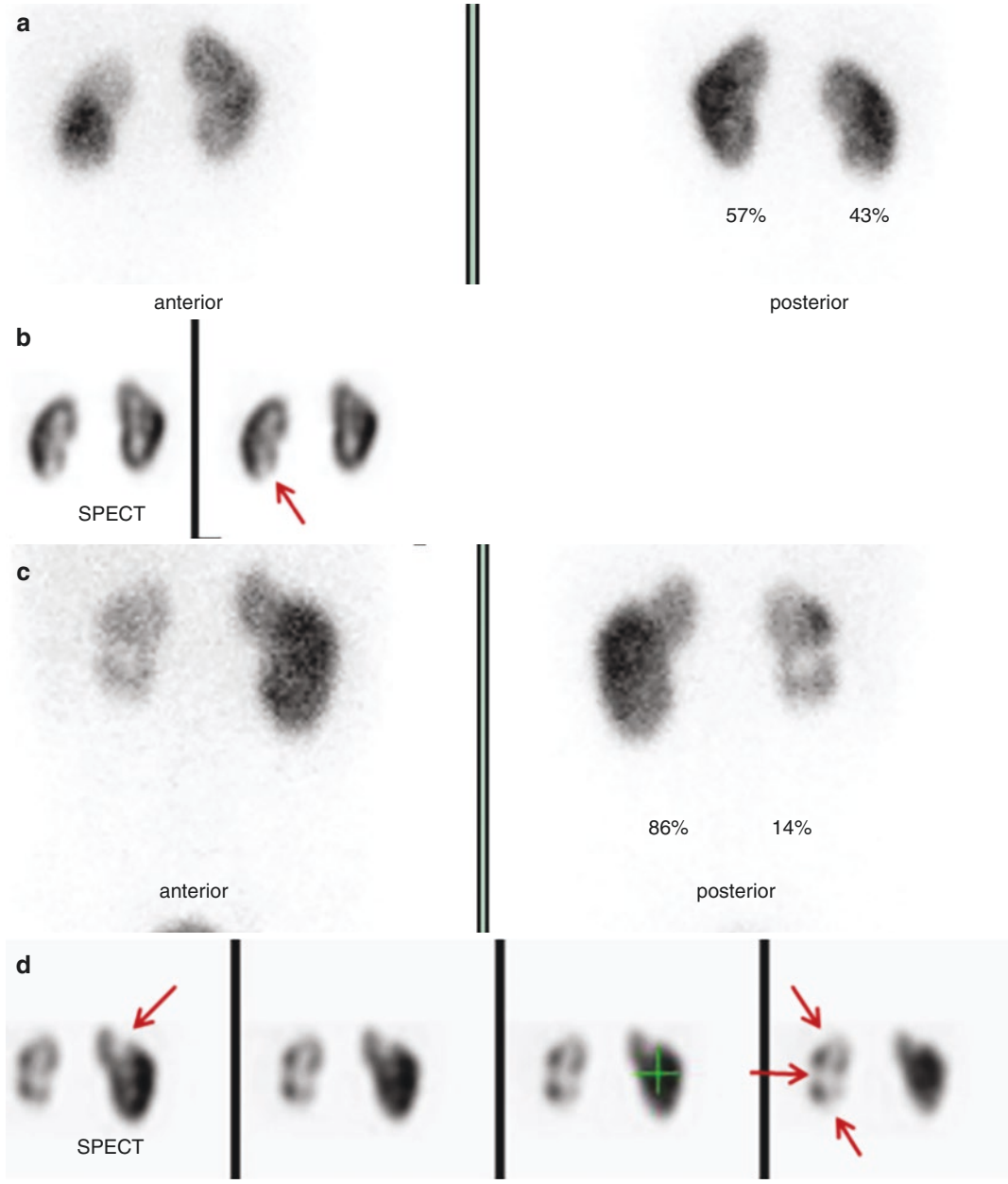
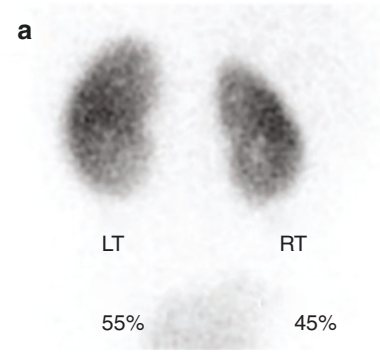


Fig. 8.10 History: A 4-year-old girl with recurrent UTIs and VUR had been lost to follow-up and returned to the clinic after 4 years with an ongoing history of infections. Study reports: the first DMSA study, anterior and posterior planar images (**a**) and coronal SPECT slices (**b**) show a small cortical defect in the lower pole of the right kidney (arrow) consistent with a small renal scar. The left kidney appears normal. The DRF of the right kidney is 43% and on the left 57%. On a follow-up DMSA study performed 4 years later planar images (**c**) and coronal SPECT slices (**d**) show decreased, inhomogeneous tracer uptake in the right kidney with multiple peripheral cortical defects (arrows). An additional cortical peripheral defect is noted in the lateral aspect of the upper pole of the left kidney (arrow). The DRF of the right kidney has dropped to 14%. Impression: Significant scarring has occurred in both kidneys in the 4-year time interval from the baseline study

Case 8.8. Acute Pyelonephritis (Fig. 8.11)



Case 8.9. Non-functioning Left Lower Renal Pole (Fig. 8.12)

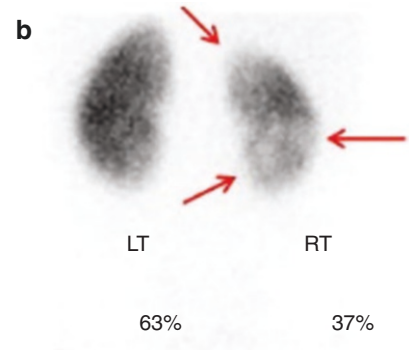


Fig. 8.11 History: A 4-year-old girl was referred for scintigraphy due to recurrent UTIs. The first DMSA scan was performed more than 6 months after the last infection. Seven months later she was hospitalized with high fever most probably due to a new UTI. An "acute" DMSA scan was performed during her hospitalization and compared to the previous study. Study reports: the first DMSA study planar posterior view (**a**) demonstrates a normal DMSA uptake pattern. The second study, the "acute" DMSA scan, planar posterior view (**b**) shows new areas of decreased uptake (arrows) in the right kidney with preserved renal contour. The right kidney DRF has decreased from 45% to 37%. Impression: The findings on the second DMSA study are consistent with acute pyelonephritis

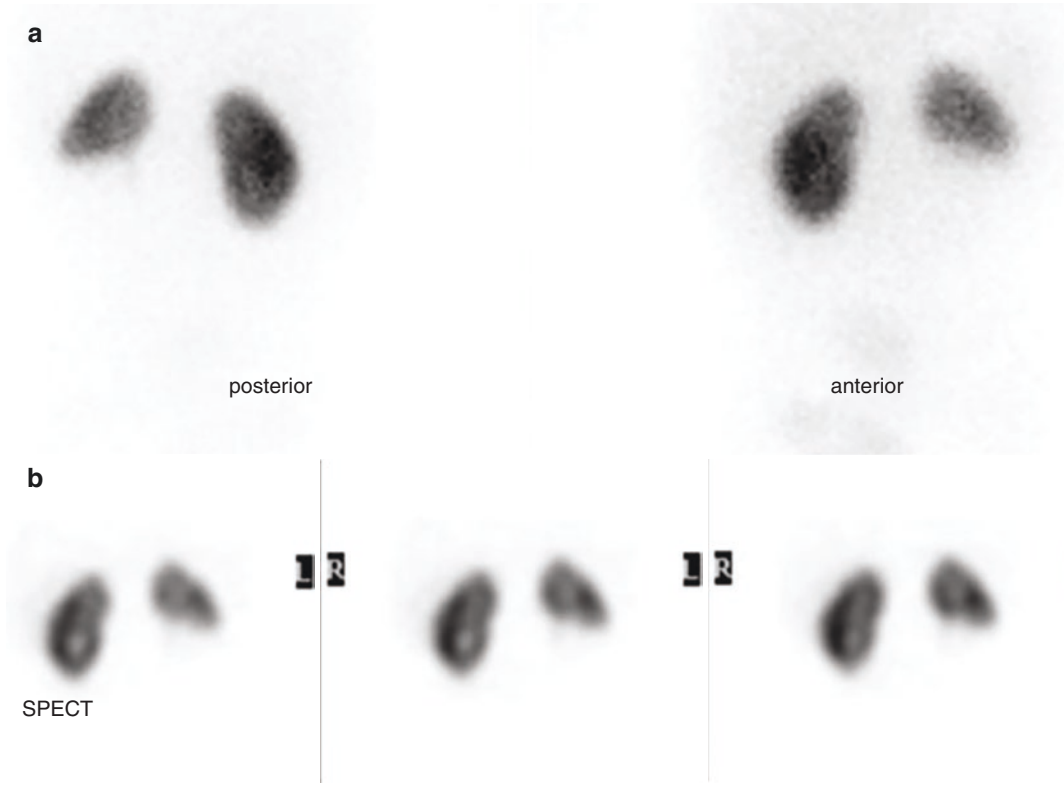


Fig. 8.12 History: A 2-year-old boy presented with left duplex collecting system. The lower collecting system was severely hydronephrotic. A DMSA scan was obtained to assess the parenchymal function of the lower pole. Study report: Anterior and posterior planar images (**a**) and coronal SPECT slices (**b**) show a sharp demarcation between the upper and lower poles of the left kidney. The upper pole has normal cortical uptake, whereas the lower pole shows no uptake and function. Impression: Non-functioning lower pole of left kidney

8.3 Glomerular Filtration Rate Radionuclide Measurement

Clinical Indications

- Chronic renal failure prior to kidney transplant.
- Post renal transplant evaluation.
- Patients receiving nephrotoxic chemotherapy/immunosuppressive therapy.
- Bilateral renal disease.
- Solitary kidneys.

General Principles for Glomerular Filtration Rate (GFR) Measurements [21]

- GFR can be quantified by measuring the clearance rate of a substance from the plasma provided that the substance:
  - Is freely filtered in the glomerulus.
  - Does not bind to plasma proteins.
  - Is not secreted or reabsorbed by the renal tubules.
- Clearance of the substrate calculation: divide the injected dose by the area under the clearance curve.
- Simplified routine clinical calculation methods in children:
  - The "slope-intercept method": requires two blood samples at 2 and 4 h after tracer injection.
  - The "distribution volume" method: requires a single blood sample 110–130 mins after tracer injection. This method is more practical in young children, avoiding repeated venipunctures. It is considered less accurate than the two-sample methods when GFR is expected to be <30 ml/min/1.73m^2.

Study Protocol for GFR Measurements [21–23]

Patient Preparation

- Avoid high-protein meals and strenuous exercise at least 12 h prior to the study.
- Adequate hydration.
- Measure height, weight, and serum creatinine.
- Explain that the test involves more than one venipuncture.
- Equipment needed:
  - A scientific scale
  - Volumetric flasks
  - A centrifuge
  - A well-counter

Radiopharmaceutical, Administered Activity, Mode of Delivery

Radiopharmaceuticals:

- [^{99m}Tc]diethylenetriaminepentaacetic acid (DTPA) is widely available.
- [^{51}Cr]ethylenediaminetetraacetic acid (EDTA) is the best agent but has limited availability.

Activity:

- [^{99m}Tc]DTPA: Adjust the dose according to the patient body surface area (BSA) obtained from height and weight:
  - For simple GFR estimate: 30 MBq (0.8 mCi, adult dose) × (patient BSA/1.73 m^2).
  - For simultaneous GFR and DTPA dynamic renal scan: 120 MBq (3.2 mCi, adult dose) × (patient BSA/1.73 m^2).
- [^{51}Cr]EDTA: 1.85 MBq (0.05 mCi).

Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

Reference to National Regulation Guidelines, if Available, Should Be Considered.

GFR Step-by-Step: The Single Blood Sample Using the "Weight" Method"

1. Check radiopharmaceutical purity, discard if <98%.
2. Draw up patient dose according to BSA and prepare a "standard" with 20 MBq.
3. Weigh full syringes (patient dose and standard), equipped with their capped needle. **Record the values.**
4. Dilute standard by expelling the syringe content into a volumetric flask containing a known, exactly measured amount of water (usually 500 ml).
5. Weigh the empty standard syringe, equipped with the same capped needle. **Record the value.**
6. Injecting the activity is the critical step! Administer the dose through a secure IV line. Flush the line carefully before injecting the activity to ensure that the line is patent and that the injection will not be an interstitial one.
7. Inject the activity into the patient *without rinsing the syringe*, taking care to inject the entire volume, flush the IV line with at least 10 ml saline.
8. **Document the time of injection.**
9. Weigh the empty patient's syringe, equipped with the same capped needle and **Record the value.**
10. Note the site of injection—do not draw subsequent blood from this area (preferably use the opposite arm for the blood sample).
11. Draw a blood sample between 110 and 130 mins after tracer injection for children using vials with an anticoagulant (like the ones used for blood cell count). Try to get at least 5 ml of blood, allowing enough plasma for duplicates.
12. **Accurately record the time that the blood samples were taken**.

GFR Single Blood Sample Processing

- Centrifuge the blood samples at 3000 rotations/min for 5 mins to separate the plasma and blood cells.
- Count the following duplicate samples in the well counter for enough time to get at least 100 Kcounts for each sample and 500 Kcounts for each standard.
- Counting times can be different and must always be registered.
  - 1 ml of your standard solution × 2.
  - 1 ml of the plasma sample × 2.
- Always use the same volume in all the samples. The duplicates allow for an essential quality control step. If the total counts (not counts/min) in the two duplicates differ significantly, it is an alert of technical difficulties, i.e., different volumes drawn with the pipette.
- A recount of all samples is usually the first step in troubleshooting.

GFR Calculation

- Apply background corrections to all the measurements.
- Use the mean values of the two samples in the calculations.
- Standard counts are multiplied by the volume (ml) used for dilution.
- Determine injected activity. This calculation is necessary because the injected dose that was counted with an external dose calibrator needs to be calibrated to the plasma sample that was counted with a well counter.
- Use the following formula: injected activity weight divided by net standard weight*standard counts**.**
- Calculate the volume of distribution (VOD, ml) as:

$$\frac{\text{Counts injected}\left(\text{counts}/\text{min}\right)}{\text{Counts of the plasma sample}\left(\text{counts}/\text{min}\right).}$$

- Calculate the GFR using Ham & Piepsz's formula GFR (ml/min) = 2.602 *VOD(120) - 0.273 [24].
- Whenever the blood sample is not obtained at exactly 120 mins after the injection, the counts of the sample must be corrected: P(120) = P(t)* e [0.008*(t-120)], where: t = time of sampling in mins after tracer administration.

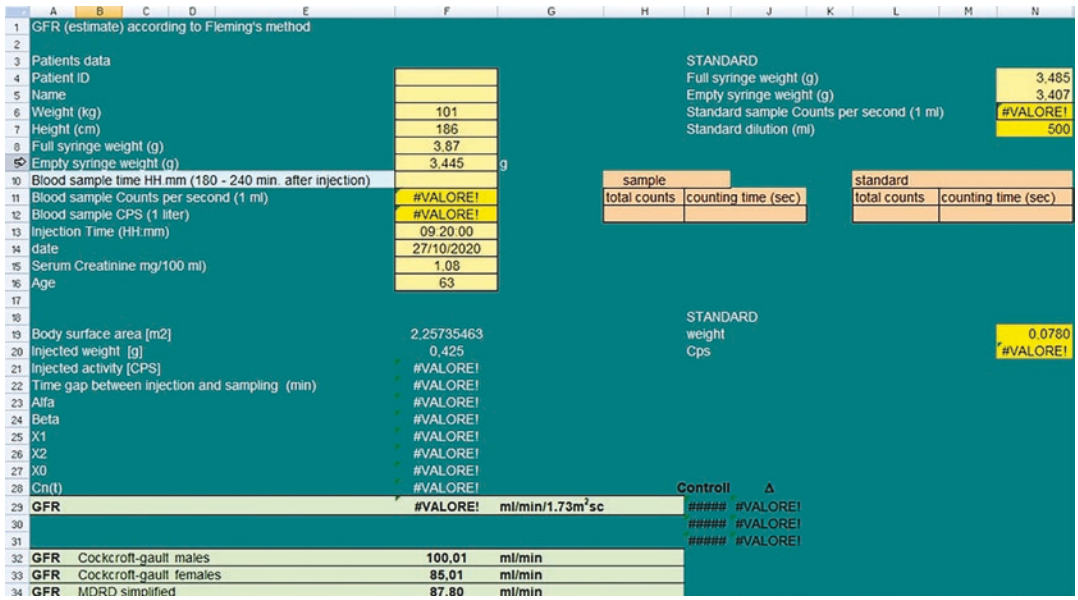


Fig. 8.13 Excel sheet including all measured parameters and calculations made with the creatinine-based method

- Normalize to 1.73 m^2 BSA.
- Despite the apparent complexity, data input is simple once if the math is put into an Excel sheet, where calculations made with the creatinine-based method can be also inserted and compared (Fig. 8.13).

GFR Quality Control

- Step 1: Check that the samples counted in the counter do not differ significantly. Calculate the standard error. The difference between the two samples should not exceed 3%.
- Step 2: Check the volume of distribution. It should be around 20–30% of body weight. The study should be repeated if it is less than 15% or more than 40%.

Normal Values [25]:

Normal GFR values are 104 ± 20 ml/min/1.73 m^2 body surface area (BSA), in the age range 2–15 years.

Below 2 years of age:

- 1–4 months 62 + 14 ml/min/1.73 m^2 BSA.
- 4–8 months 72 + 14 ml/min/1.73 m^2 BSA.
- 8–12 months 83 + 17 ml/min/1.73 m^2 BSA.
- 12–18 months 92 + 18 ml/min/1.73 m^2 BSA.
- 18–24 months 95 + 18 ml/min/1.73 m^2 BSA.

Red Flags

- Reproducibility of the GFR measurement should be:
  - 4.1% in patients with a GFR > 30 ml/min.
  - 11.5% in patients with a GFR < 30 ml/min^2.
- The precision of the calculation can be hampered in severely dehydrated or edematous patients because the radiopharmaceutical diffuses into the extracellular space.
- Recent IV fluids, e.g., fluid loading before chemotherapy, may also affect the study.
- Single sample methods are less precise when GFR is below 30 ml/min/1.73 m^2BSA. On the other hand, their best use is in evaluating longitudinal loss of renal function before an overt chronic kidney failure is evident.

Take Home Message

- A detailed protocol of the two methods is available in the EANM guidelines for glomer-

ular filtration rate determination in children [26].

- Clinical GFR measurements are based mainly on serum creatinine levels, an endogenous catabolite derived from muscle protein. However, this test becomes abnormal only when about 50% of the renal function is lost. False positives occur in people with large muscle masses and false negatives in patients with muscle wasting.
- Biochemical GFR calculations based on serum and/or urinary creatinine levels are less accurate [27].
- The most accurate radionuclide GFR measurement method is based on the plasma disappearance curve after a single bolus injection of a glomerular tracer. Gamma camera methods are less reliable [22, 23].
- EDTA is the best radiotracer due to the tight binding of the two components.
- It is possible to administer EDTA together with MAG3 for dynamic renal scan; in this case count the samples after complete decay of the 99 mTc. DTPA can be used (dose adjusted) for GFR measurements followed by a dynamic renal scan.

8.4 Direct Radionuclide Cystography (DRC)

Clinical Indications [28, 29]

- Detection of VUR in children after UTI.
- Follow-up of children with known VUR.
- Assessment of the results of endoscopic or surgical treatment.
- Screening of siblings of children/parents with proven VUR.

Pre-Exam Information

- Knowledge of clinical history, biochemistry, and urinalysis results, previous imaging results.
- Determine whether the patient may need sedation.
- Whether uroculture has been performed during the week before the procedure and if it is negative.

Study Protocol for Direct Radionuclide Cystography [28, 30]

Patient Preparation

Preparation prior to bladder catheterization

- Explain to the child, parents, or carers about the procedure. Continued communication, reassurance, and explanation of each step is essential for a successful study.
- A quiet, dimly lit room, watching TV, or reading a story, a calming effect can be produced, making sedation rarely necessary.
- The child may be instructed to void immediately prior to catheterization, if the residual volume is measured by catheterization rather than by computer analysis.
- Ensure the child has adequate antibiotic coverage for the procedure.
- Calculate theoretical bladder volume to avoid overdistension, mainly in children with a neurologic bladder [31].
  - Infants <1 year: Capacity (ml) = (2.5 × age [months]) + 38.
  - Older children >1 year: Capacity (ml) = (2 + age [years]) × 30.

Catheterization Technique

- Performed by qualified personnel.
- Catheter: usually use a feeding catheter without a balloon that will comfortably pass the meatus (6 French-gauge).
- A urine specimen can be taken for culture.

Radiopharmaceutical, Administered Activity, Mode of Delivery

Radiopharmaceutical:

- [^{99m}Tc]DTPA.

Activity:

- 20 MBq (0.5 mCi) followed by 100–500 ml saline according to bladder estimate volume.

Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

Reference to national regulation guidelines, if available, should be considered.

Delivery:

- Through the catheter at the beginning of the filling by a 3-way stopcock.
- The bottle of warm saline should be placed no higher than 80 cm above the head of the patient.
- Let the saline run at about 100 drops/min.

Acquisition Protocol

- Cover the detector with plastic and diaper to avoid contamination during micturition.
- Position: the camera is positioned posteriorly to the patient lying supine.
- Collimator: general purpose or high-sensitivity low-energy parallel hole are preferable if available.
- Filling phase: dynamic images at a rate of 5 s/frame for a total of 600 s, matrix 128 × 128.
- Voiding phase (using the same parameters as for filling phase): another 600 s. If the child is cooperative, acquire at least ten frames before the beginning of voiding and ten frames after the end.
- Non-toilet-trained children usually void without a problem with the catheter in place. In toilet-trained ones it is better to remove it for achieving more child comfort.
- Residual volume in the bladder can be calculated by a 30-s anterior pre- and post-void image using these images.
- All acquisition sequences can be repeated until the filling, or the voiding is completed.

Study Processing

- Set the image window so that a "cloud" of scatter activity is seen around the bladder during the filling phase.
- Visual assessment: if present VUR is readily seen, always evaluate the study by lowering and increasing the windowing.
- Quantitative techniques: measure the activity/ml and can evaluate the degree of VUR, bladder volumes, and voiding flow rates.
- Quantitation of post-void residual volume requires recording the volume of voided urine.

Study Interpretation

- Radionuclide classification of VUR is based on the location of the radiotracer activity:
  - Mild reflux: in the ureter.
  - Moderate reflux: in the non-dilated collecting system and ureter.
  - Severe reflux: in dilated collecting system and ureter.
- Record the volume of saline infused.
- An estimate of the residual volume can be made if the child voided just before the beginning of the study and the voided volume is recorded.

Correlative Imaging

- Fluoroscopic voiding cystourethrography (VCUG) has been the standard for detection and classification of VUR utilizing a 5-point scale. It is the best method to visualize the urethra in males and especially for detection of posterior urethral valves. It does require direct bladder catheterization and utilizes fluoroscopy to view bladder filling and presence of reflux. The bladder can be filled more than once but because of use of fluoroscopy there is

potential for a significantly increased radiation exposure to the child [32, 33].
- More recently the use of US contrast-enhanced voiding cysto-sonourethrography has been proposed as a replacement for previous techniques. It employs US without radiation exposure but still requires direct bladder catheterization. The posterior urethra can be adequately visualized when multiple cycles of bladder filling can occur. Like many US techniques, it is highly operator-dependent, and the learning curve and scanning time are longer in comparison to both X-ray and radionuclide methods [34].

Red Flags

- It is wise to have 2 or 3 radiotracer doses ready at the start of the procedure.
- Check all the tube connections to avoid spilling.
- Beware of contamination of diapers and dresses in non-toilet-trained children, especially if micturition happens at full bladder filling.
- High-resolution collimators can be used if there is no choice; modern cameras are sensitive enough to warrant a full diagnostic study.
- Quantitative techniques are not necessary for a fully diagnostic study and require a careful methodology.
- Calculation of bladder volume can be affected by bladder geometrical changes during filling/voiding.
- If a syringe, although small, is used for pushing the radionuclide into the catheter, resistance should not be forced because, although very rarely, the catheter can enter a very dilated, the so-called "golf-hole," ureteral meatus.
- Sometimes, older non-toilet-trained children may feel such subjective pain during the first attempt to void with the catheter in situ that they will subsequently refuse to void for many hours. In this case, it is up to the caring physician to decide when to stop the scan (normally, do not wait for more than 1 h).

Take Home Message

- DRC is the most common nuclear medicine study to evaluate VUR. It has a low radiation dose and high sensitivity as compared to both voiding cysto-ureterogram and the indirect scintigraphic technique [35].
- VUR classification on radionuclide DRC differs from the radiographic classification.
- Do not perform DRC in children, mainly males, in whom US does not exclude anatomical bladder abnormalities.
- DRC is the preferred radionuclide procedure for assessing VUR in children who are not toilet-trained or those on whom clean intermittent catheterization (CIC) is performed.
- DRC allows for repeated cycles of bladder filling and voiding. This improves the detection of reflux in children with intermittent VUR [33].

Representative Case Examples

Case 8.10. Bilateral VUR (Fig. 8.14)

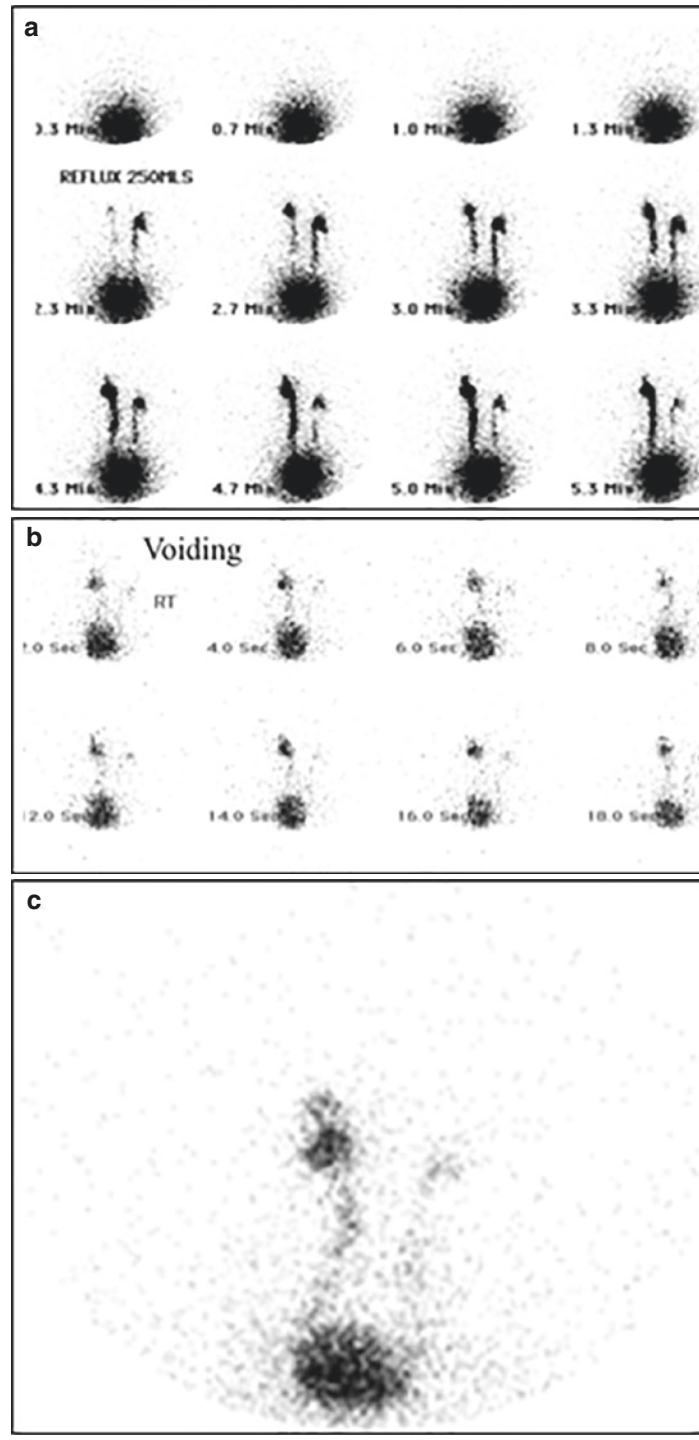


Fig. 8.14 History: A 4-year-old girl with recurrent UTI. Study report: During the filling phase (**a**, volume 250 ml) VUR is detected, more evident on the left side, persisting during the voiding phase (**b**), also seen on the post-void image (**c**). Impression: Bilateral moderate VUR

Case 8.11. High-grade unilateral VUR (Fig. 8.15)

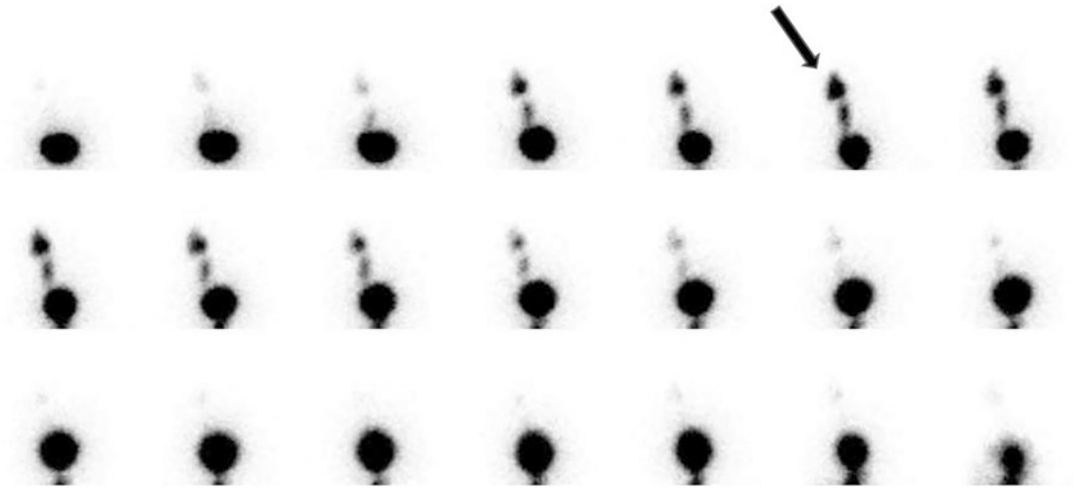


Fig. 8.15 History: 1-year-old girl had a DRC performed one month after a febrile UTI. US had been reported as normal. Study report: After clean catheterization, the radiopharmaceutical was injected through the bladder catheter, followed by warm saline. A series of 5 s sequential frames was acquired, starting at the time of tracer administration. Selected frames show during the late filling phase, a left-side VUR which increases (arrow) during the voiding phase. The reflux activity returns to the bladder after the end of the voiding, although incomplete. A second voiding phase without a new increase of the residual intra-pelviureteric activity is visible in the last three images. Impression: Unilateral active and passive severe VUR

Case 8.12 Intermittent unilateral VUR (Fig. 8.16)

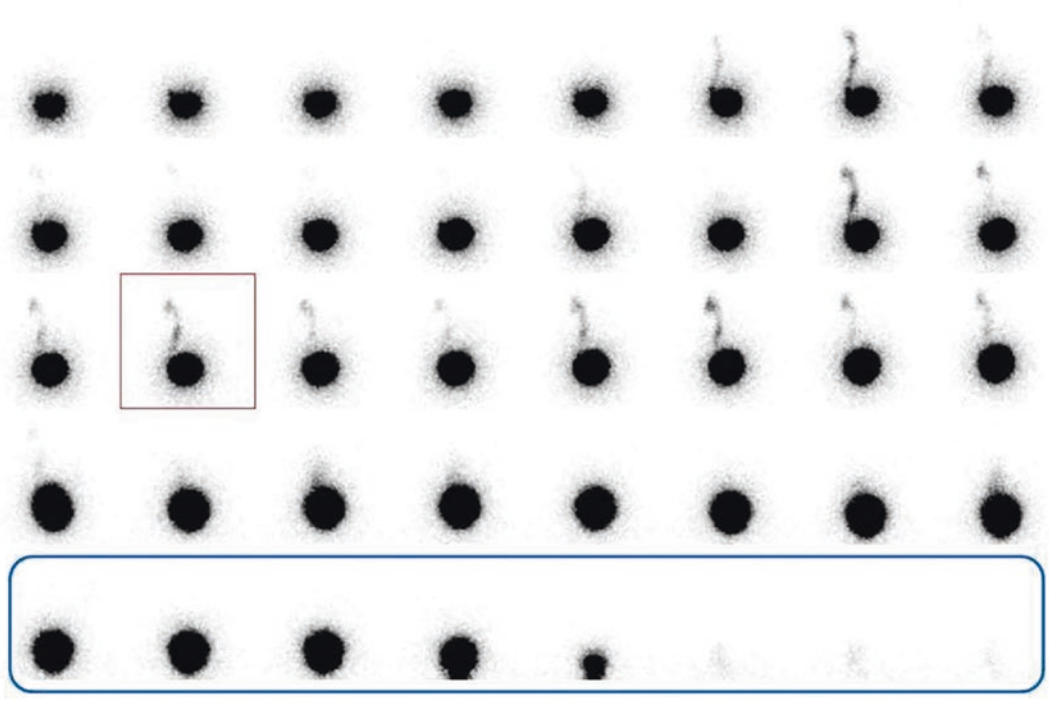


Fig. 8.16 History: Four-year-old girl. The first episode of febrile UTI 3 months prior to current study, had an early relapse after the end of the 2-weeks course of antibiotic therapy. Study description: After clean catheterization, the radiopharmaceutical was injected through the bladder catheter, followed by warm saline. A series of 5-s sequential frames were acquired, starting together with the administration. Grouped 10-sec images are shown. In the early filling phase, a left-side VUR is detected, randomly increasing and decreasing during the bladder filling. No active reflux is visible during the voiding phase (blue box). Impression: Unilateral intermittent, passive, moderate VUR

8.5 Indirect Radionuclide Cystogram (IRC)

Clinical Indications (*in Toilet-Trained Children!*) [36–38]

- Recurrent UTIs and suspected VUR.
- Known VUR, for follow-up of disease status.

Study Protocol for Indirect Radionuclide Cystography [29, 36]

Patient Preparation

- The child should be cooperative and toilet trained.
- The child should have a relatively normal renal function.

Radiopharmaceutical, Administered Activity, Mode of Delivery

Radiopharmaceutical:

- [^{99m}Tc]MAG3.

Activity:

- 3.7–5.55 MBq/kg (0.10–0.15 mCi/kg).
  Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.
  Reference to National Regulation Guidelines, if Available, Should Be Considered.

Acquisition Protocol

- The study is preceded by a standard renogram.
- Collimator: the same as for the renogram.
- Detector in an upright position.
- FOV—should include the kidneys and bladder prior to starting acquisition.
- Build a makeshift toilet in front of the camera (Fig. 8.17).
  - Girls: Put a bedpan on the seat of a backless chair. A parent/caregiver can help stabilize the patient on the bedpan.
  - Boys: The patient stands and holds the urine bottle or his parent/caregiver does it for him.

To improve privacy, only one or two technologists, preferably of the same sex as the patient, are in the room with the parents and patient.

Acquisition Parameters

- Dynamic study, 1–2 s/frame until the child has finished voiding, matrix 128 × 128, using the same zoom as for the renogram.
- NB: Acquire at least 30 s of images before the start of voiding and after.
- To allow enough time, it is useful to set up the camera for 300 or even 600 s and stop the study once the urinary bladder has emptied.
- Measure the volume of the urine passed, if the RV has to be calculated.

Study Processing

Methods for accurate assessment of VUR, eliminating errors that may lead to false positives:

- Draw curves over the expected position of the kidney(s). True VUR is accompanied by a significant increase in counts in the kidney in question.
- To calculate the residual bladder activity volume (when requested) ROIs have to be drawn over the bladder on micturition images before and at the end of the void. Measure the volume of urine passed.

Example:

- Before micturition, there are 600 counts in the bladder.
- At the end of micturition 240 counts remain in the bladder.
- The child passed 50 ml of urine.
- Therefore, there were 360 counts in 50 ml and thus: 1 ml contains = 7.2 counts.
- The residual volume of bladder urine activity = 240 (counts in bladder)/7.2 (counts/ml) = 33 ml.

Study Interpretation

- The report of the indirect cystogram is preceded by the report of the renogram.
- Ideally, there should be little activity in the kidneys at the start of an IRC.
- Look at the renogram images because sometimes a passive reflux can be seen toward the end of the study when the bladder is filled and the kidneys empty. Assess whether:
  - No reflux is seen on the IRC.
  - Reflux of a large/small volume is seen in the left or right or both kidneys.
  - The reflux starts before or at the time of micturition.
  - The refluxed activity drains promptly from the kidney to the bladder or whether it persists in the affected kidney.
  - Bladder emptying is complete or incomplete. If measured, note the amount of urine passed by the child and the amount that remained in the bladder at the end of micturition.

Correlative Imaging [1]

- Same as for DRC (see Sect. 8.4).
- In doubtful cases, especially in children with renal damage, it is suggested to perform a VCUG or DRC.

Red Flags [1, 38]

- The technologist usually starts the acquisition once the patient is comfortably seated and positioned. In case of poorly cooperative chil-

Fig. 8.17 Makeshift gender-adapted toilet in front of the camera. For girls (left) there is a bedpan on the seat of a backless chair. For boys, the patient stands and holds the urine bottle (right)

dren, it may be necessary to start during patient positioning.
- To avoid missing the void the technologist instructs the child to void only after the acquisition has started and after he/she tells him to do so.
- The child should stay as still as possible during the void.
- The study is stopped once the child has finished passing urine.
- Diuresis with furosemide may decrease the sensitivity of IRC study in well-hydrated children.
- The lower target-to-background ratio with DTPA limits its use for IRC.
- In children with severe hydronephrosis or hydroureter clearance of activity from these systems may be slow and the high renal and collecting system activity can mask VUR.
- The test may be difficult to interpret if the patient has a pelvic kidney as the bladder may overlie the kidney.
- If there is still a considerable amount of bladder activity, because of poor voiding or urgency without a complete upper urinary tract clearing, a second or even third cystogram can be performed later.

Take Home Messages

- IRC is the only way to evaluate VUR without using a bladder catheter. It uniquely allows non-invasively evaluate the upper and lower urinary tract in a single session and is associated with low radiation exposure to the patient and staff. The sensitivity of IRC is lower as compared to both VCUG and DRC.
- Study processing is not mandatory, a qualitative assessment with a correct windowing is enough in the greatest majority of cases.
- If there is still a considerable amount of activity in the kidneys and the child does not need to void immediately, wait for the activity to clear from the kidneys. This improves the study outcome.
- If the child wants to void, do an indirect cystogram and repeat when the bladder refills, sometimes 2–3 cystograms can be performed following one renogram in children with incomplete voiding or discrete retention of urine into the upper excretory system.

Representative Case Examples

Case 8.13. Normal Indirect Radionuclide Cystography (Fig. 8.18)

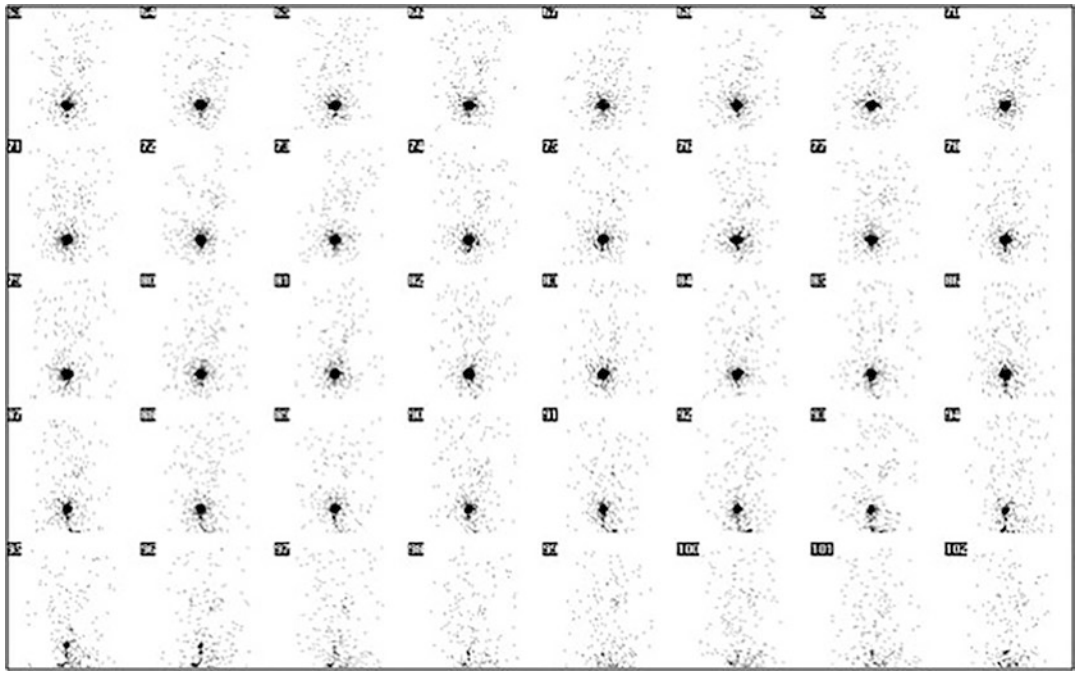


Fig. 8.18 History: A 5-year-old boy with recurrent UTIs and a family history of VUR. Study report: The posterior IRC images acquired for 1 s/frame show no evidence of reflux and complete bladder emptying. Impression: Normal study

Case 8.14. Positive Indirect Radionuclide Cystography (Fig. 8.19)

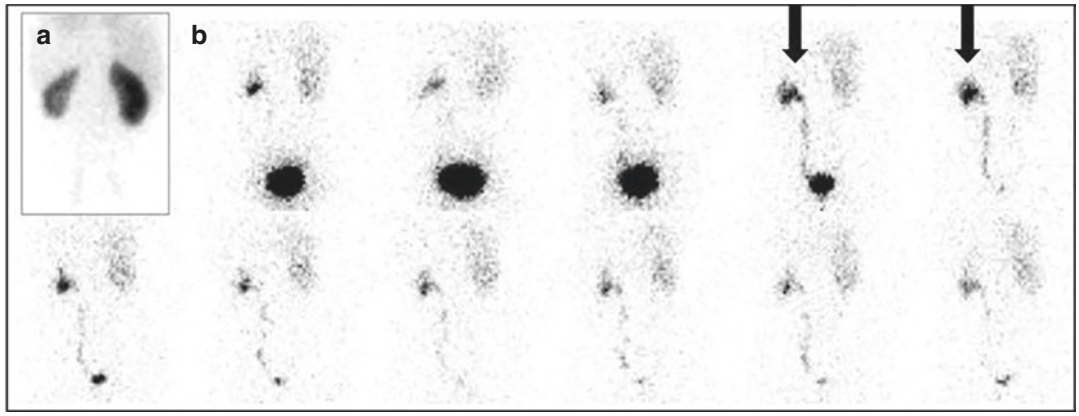


Fig. 8.19 History: An 11-year-old with bilateral VUR grade 3–4 diagnosed at 1 year of age. On US his left kidney was smaller than the right one. He was followed conservatively and remained asymptomatic for 10 years. Following a doubtful febrile UTI a renogram followed by an indirect cystogram was performed Study report: Parenchymal phase posterior images of the renogram (**a**) showed a small left kidney with a DRF of 32%, and a normal right kidney with a DRF of 68%. On IRC (**b**) reflux into the left kidney is seen when the child starts to void (arrows). Bladder emptying is complete. Impression: Small left kidney with moderate reflux during micturition

Case 8.15. Non-functioning Left Kidney with Reflux (Fig. 8.20)

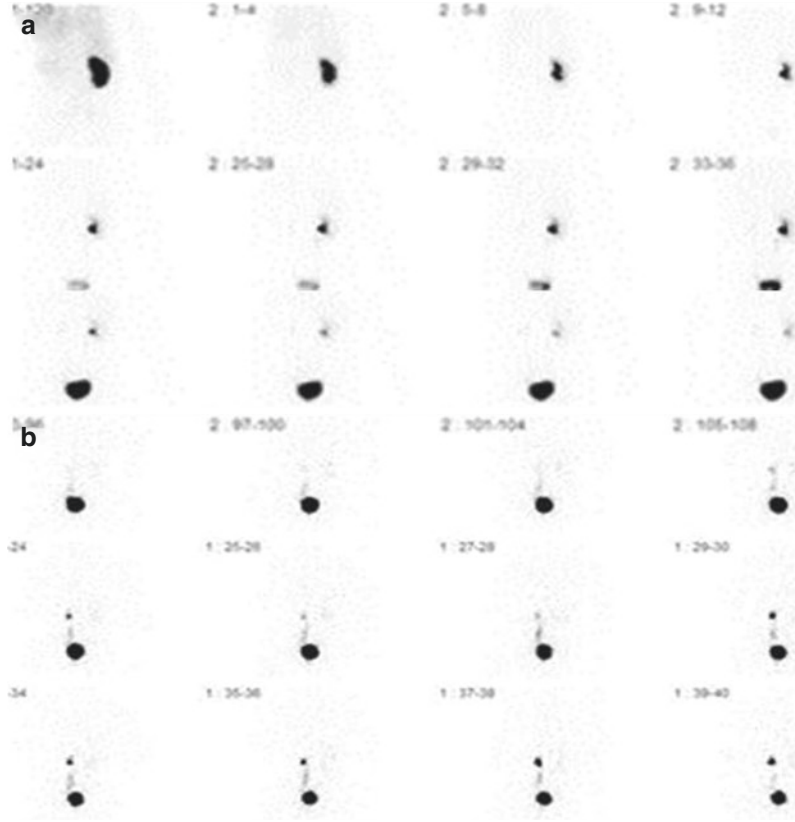


Fig. 8.20 History: A 7-year-old girl with recurrent UTIs. On US her left kidney is small and hydronephrotic. A renogram followed by an indirect cystogram was performed. Study report: On posterior images of the renogram (**a**) acquired for 2 s/frame, perfusion and uptake to the right kidney is normal. There is prompt drainage of activity from the kidney to the bladder. There is no functioning tissue in the expected position of the left kidney. A small amount of activity is seen entering the left kidney after the bladder starts to fill. On IRC (**b**), repeated episodes of reflux into the left kidney are seen before the child starts to void and during voiding. This activity persists in the left kidney until the end of the study. Impression: Non-functioning left kidney with reflux during bladder filling and micturition. Bladder emptying is incomplete. Normal functioning right kidney

Case 8.16. Two-Voids IRC (Fig. 8.21)

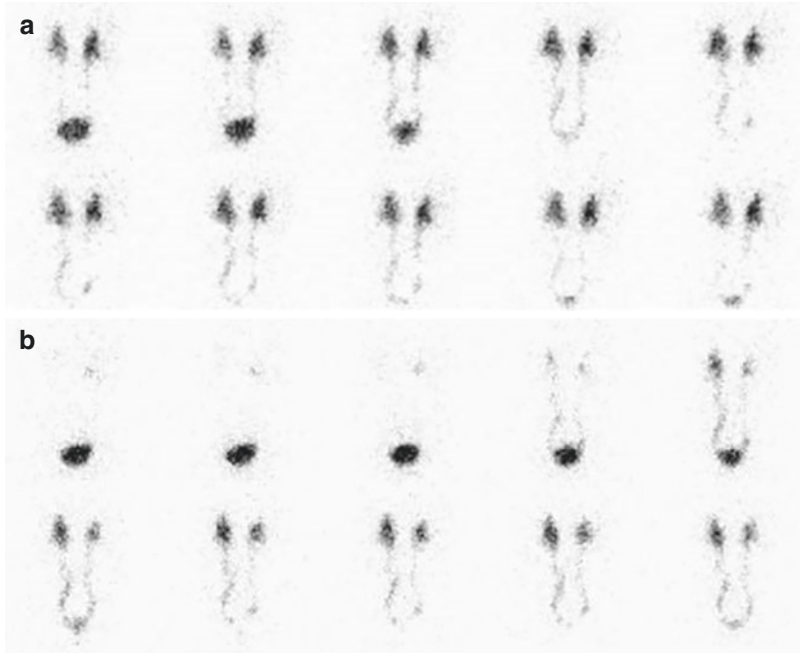


Fig. 8.21 History: A 5-year-old boy with previous resection of posterior urethral valves and residual, bilateral, high-grade VUR. A renogram followed by an IRC was performed for evaluating DRF, drainage, and persistence of VUR. Study report: At the first void (**a**) bladder emptying is complete but there is residual activity in the upper tract and the presence of VUR cannot be correctly assessed. At a second void after bladder refilling by the residual activity (**b**), bilateral VUR is clearly visible. Impression: Persistent bilateral VUR

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