Lesson 6

Nephro-urologic scintigraphy and multi-modality imaging

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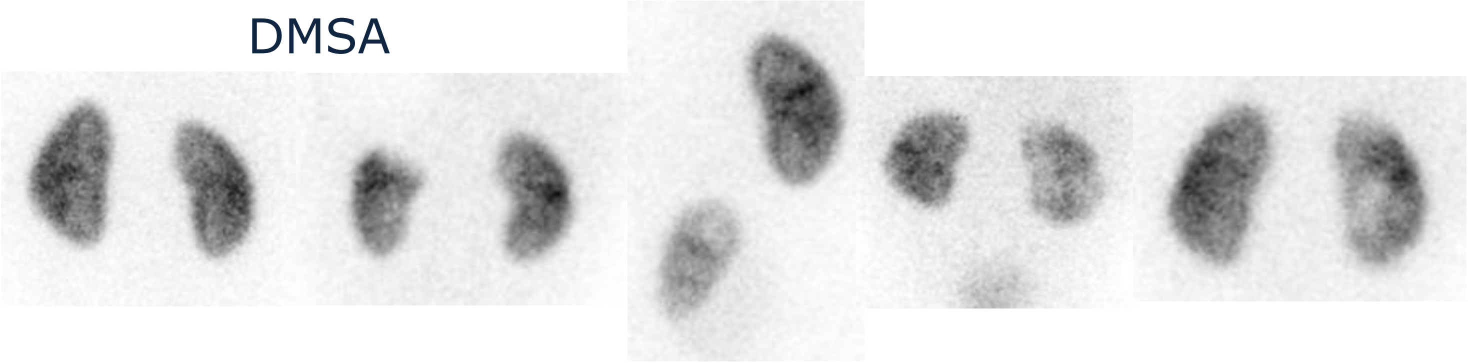
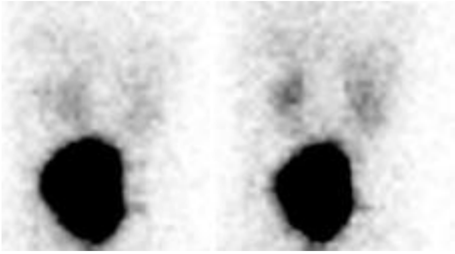
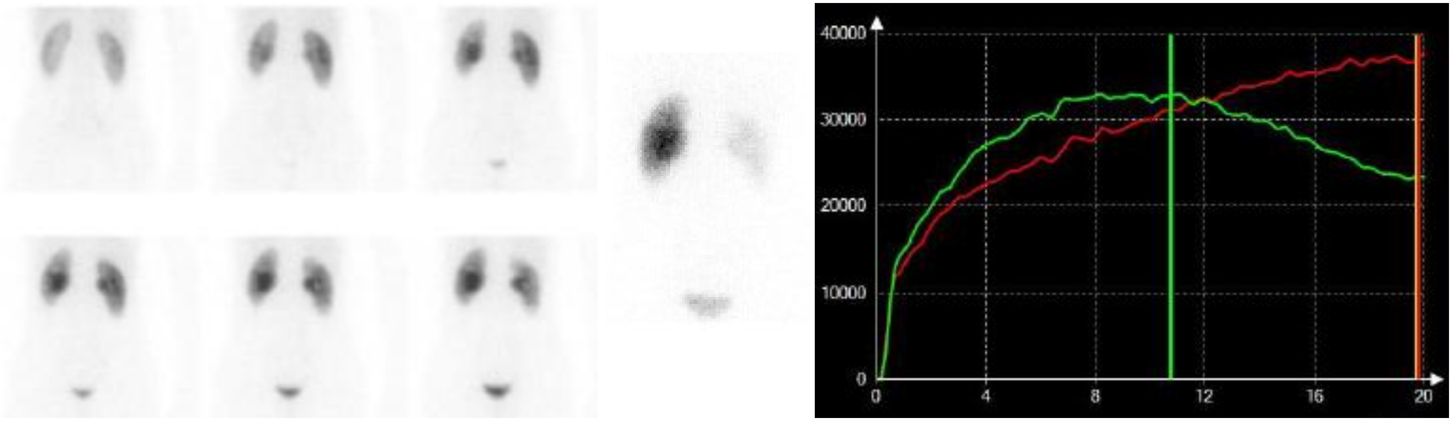
NM imaging in Paediatric Nephrourology

DMSA

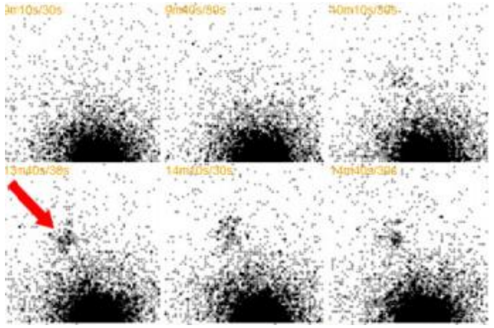




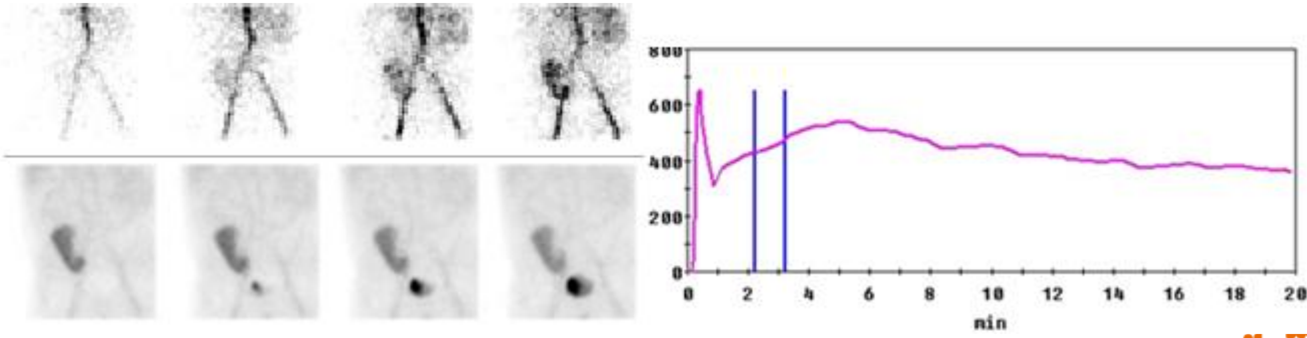
Indirect cysto



MAG$_3$ Renography



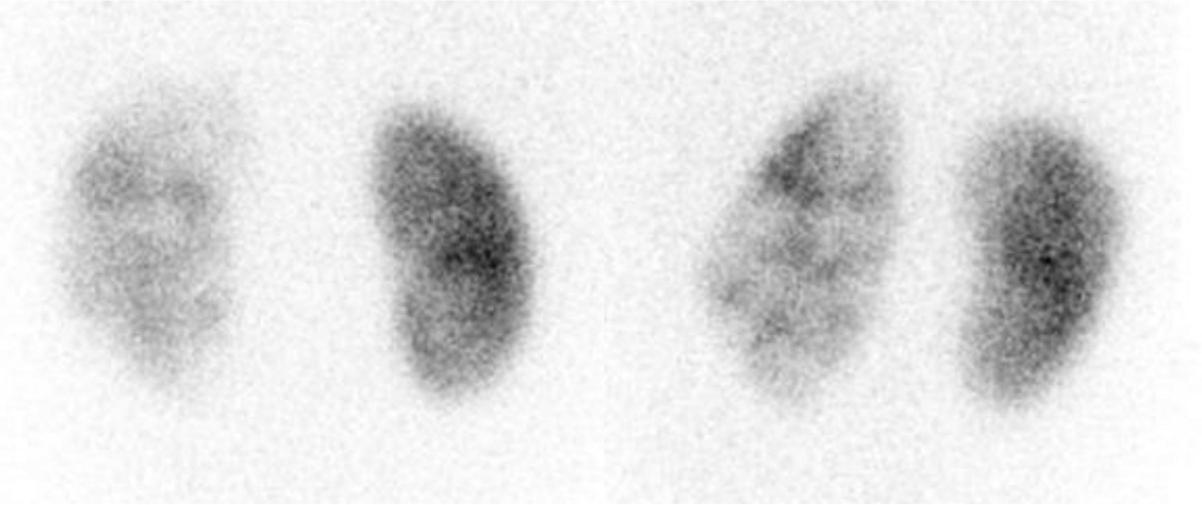
Direct cysto



Renal Transplant Renography

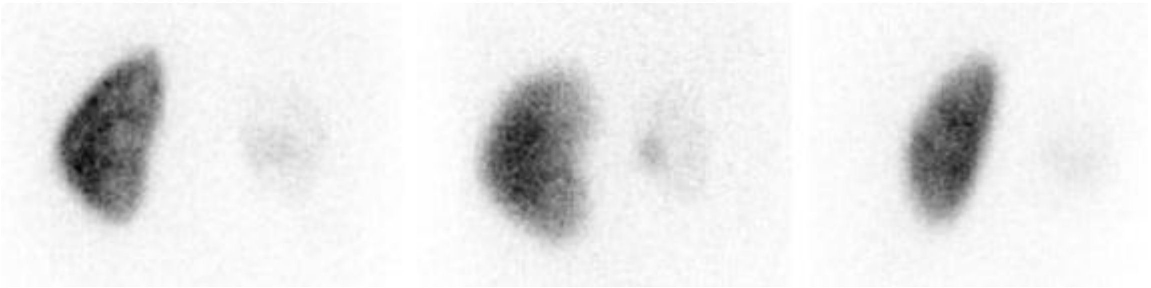
Long term consequences of acute pyelonephritis in children

- Cortical scar
- Diffuse lesion with small kidney
- Proteinuria
- Hypertension
- Pregnancy-related complications: UTI, HTN,…
- CKD…



Pyeloureteral junction obstruction

- Loose of function
- w/wo infection
- Follow-up



OVERVIEW

- DMSA RENAL CORTICAL SCINTIGRAPHY IN PAEDIATRIC FEBRILE UTIs
- LASIX RENOGRAPHY IN URINARY OBSTRUCTION
- DIRECT AND INDIRECT RADIONUCLIDE CYSTOGRAPHY
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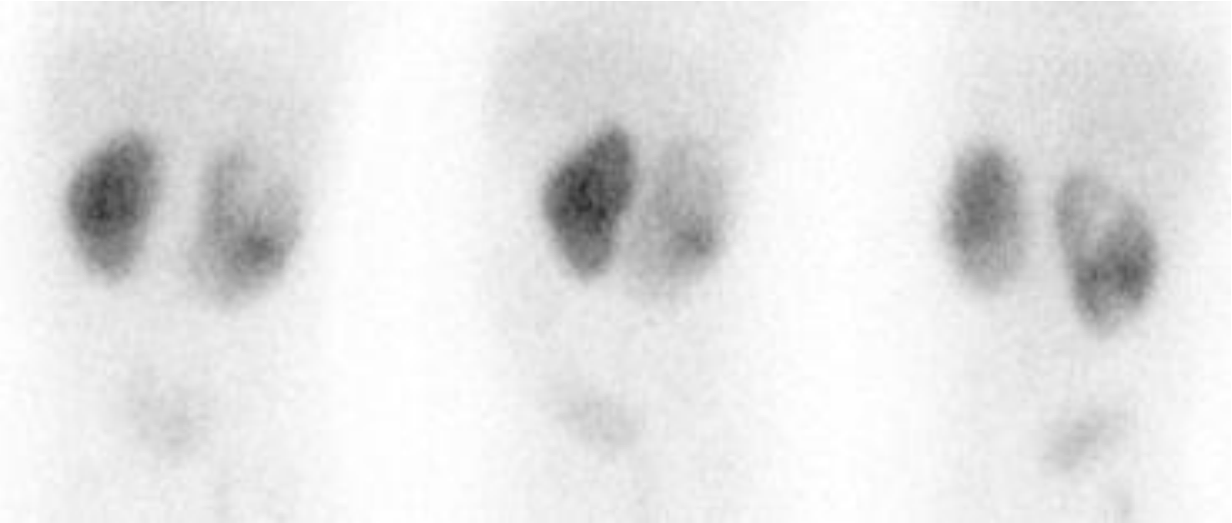
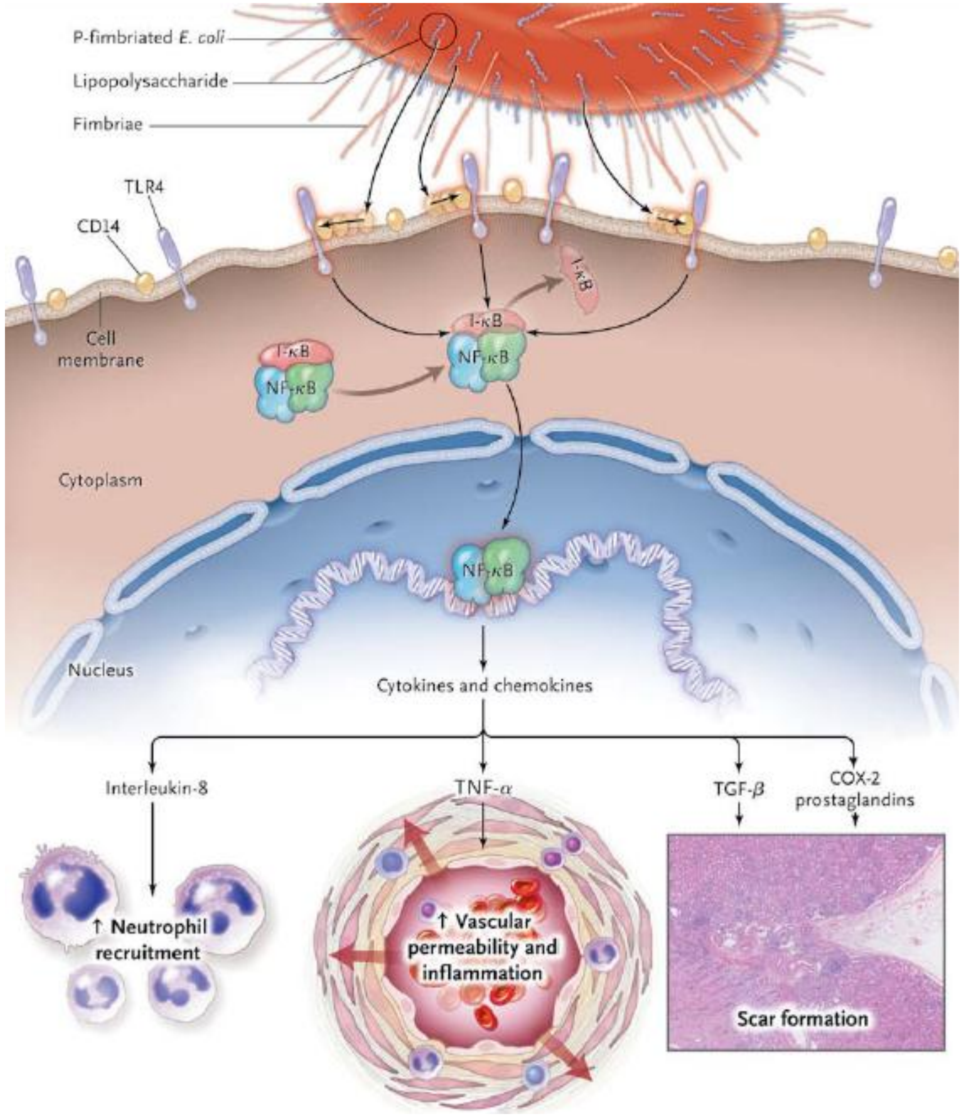
Acute pyelonephritis

Cold / hypoactive areas
- Inflammation
- Thrombus
- Infection





Acute pyelonephritis

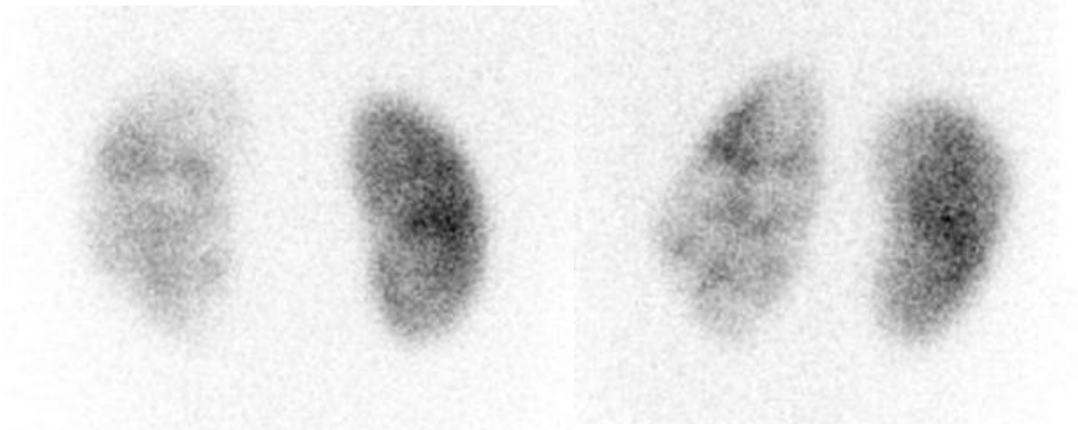
Febrile URINARY TRACT INFECTION → **ACUTE PYELONEPHRITIS** → ≈60% photon defect → ≈10-40% permanent scar

Renal cortical scintigraphy in case of UTI is useful to diagnose ACUTE PYELONEPHRITIS, assessing about severity parameters.

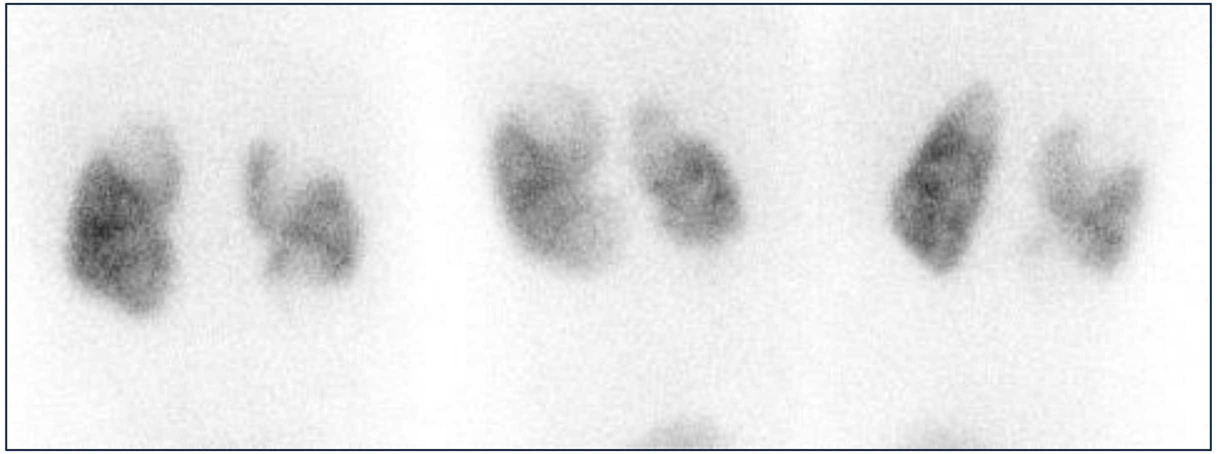
This important clinical information has to be valued in the context of recent guideline recommendations.

ACUTE PYELONEPHRITIS – LONG TERM CONSEQUENCES

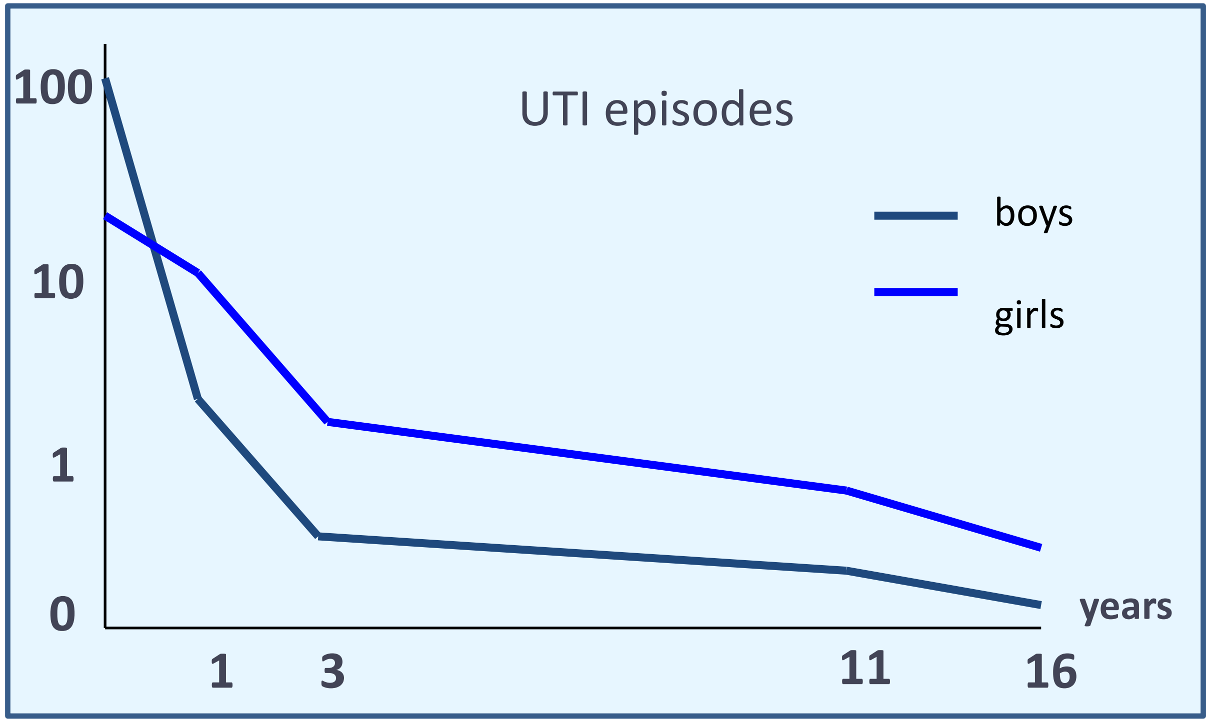
- Cortical scar
- Diffuse lesion with small kidney
- Proteinuria
- Hypertension
- Pregnancy-related complications: UTI, HT…
- CKD and renal failure



ACUTE PYELONEPHRITIS – FIRST fUTI



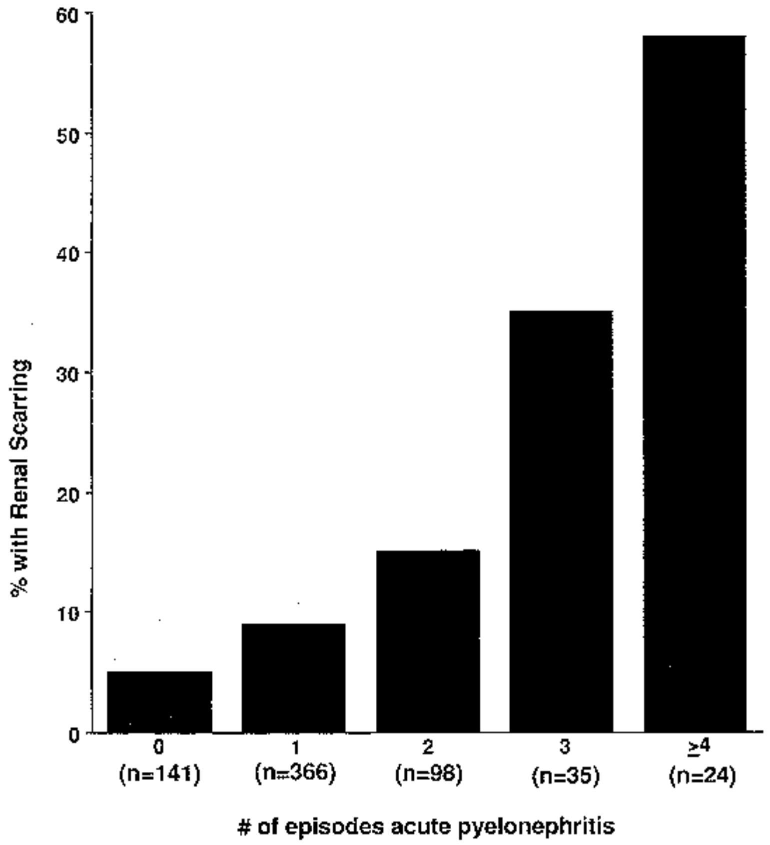
- F-UTI are 2-3 times more frequent in boys < 6-month
- **Febrile UTI have the highest incidence during the 1st year of life**



Winberg J, Bergström T, Jacobsson B.
Morbidity, age and sex distribution, recurrences and renal scarring in symptomatic urinary tract infection in childhood.
Kidney Int Suppl. 1975 Aug;4:S101-6.

ACUTE PYELONEPHRITIS – RENAL SCARS and NUMBER OF APN EPISODES

The relationship between renal scarring and number of episodes of acute pyelonephritis was described in the 1980s



Jodal U.
The natural history of bacteriuria in childhood.
Infect Dis Clin North Am 1:713, 1987

ACUTE PYELONEPHRITIS – RENAL SCARS and VUR SEVERITY

The relationship between renal scarring and VUR severity was also described in the 1980s

Reflux grade	% scars
1	5
2	6
3	17
4	25
5	50

Skoog SJ, Belman AB, Majd M.
A nonsurgical approach to the management of primary vesicoureteral reflux.
J Urol. 1987 Oct;138(4 Pt 2):941-6.

Guideline recommendation for acute ^{99}Tc-DMSA in childhood febrile UTI

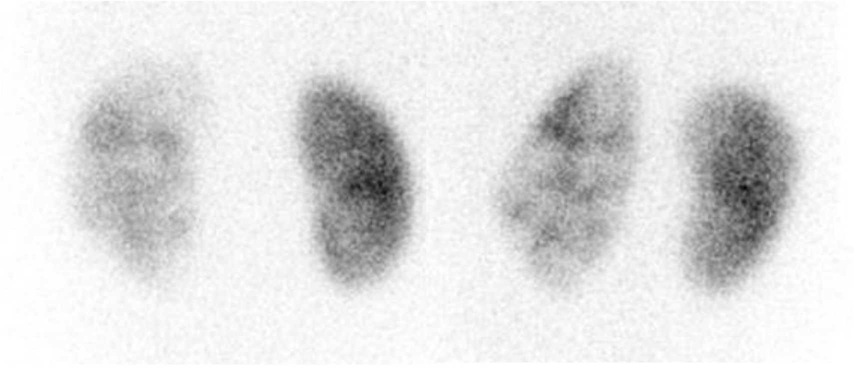
DMSA Recommended
TDA ("top down" approach)
DMSA Not recommended
NICE (National Institute of clinical excellence)
ISPN (Italian society of Pediatric Nephrology)
RCH (Royal Children's Hospital of Melbourne)
AAP (American Academy of Pediatrics)

TDA: ^{99}Tc DMSA and urinary tract infection

^{99m}Tc DMSA scan is more sensitive than ultrasound (uptake defects: APN and scars)

^{99m}Tc DMSA is used to detect risk of severe VU reflux and reduce other imaging procedures (cystography) in low-risk children

Acute pyelonephritis



Renal scars

Ability of acute ^{99}Tc-DMSA for predicting dilating (III-V) VU reflux

473 children
< 2 years or younger

first febrile UTI

289 boys
184 girls
mean age: 5 months

^{99}Tc-DMSA Sensitivity (dilating reflux)	^{99}Tc-DMSA NPP (negative predictive value)	^{99}Tc-DMSA Positive likelihood ratio	^{99}Tc-DMSA Negative likelihood ratio
95.8%	97.9%	1.90	0.08

Abnormal acute DMSA :	282 (59.6%)
VU reflux	153 (32.3%)
Dilating VU reflux	95 (20.1%)

Sheu JN, Wu KH, Chen SM, Tsai JD, Chao YH, Lue KH.
Acute 99mTc DMSA scan predicts dilating vesicoureteral reflux in young children with a first febrile urinary tract infection: a population-based cohort study.
Clin Nucl Med. 2013 Mar;38(3):163-8.

“Top-down” diagnostic approach

- **Febrile UTI**
  - **DMSA**
    (MRI?, CT?)
    - **cortical defect (pyelo)**
      - VCUG
    - normal
      - no work-up
        - VCUG ?
          recurrent UTI
    - central photopenia (hydro)
      - ultrasound

ACUTE PYELONEPHRITIS – GUIDELINES

Table 2 The imaging recommended for children following a UTI, according to the NICE CG54 guidelines, presented by age categories and clinical features. Atypical features are listed below

Age categories (months)	Clinical features	Ultrasound	DMSA	MCUG
<6	First, typical	+		
	Atypical*	+	+	+
	Recurrent	+	+	+
6–36	First, typical			
	Atypical*	+	+	
	Recurrent	+	+	
>36	First, typical			
	Atypical*	+		
	Recurrent	+	+	

*Atypical features consist of: seriously ill, poor urine flow, abdominal or bladder mass, raised creatinine, septicaemia, failure to respond to treatment with suitable antibiotic within 48 h, non-*Escherichia* coli infection.
DMSA, dimercaptosuccinic acid; NICE, National Institute of Health and Care Excellence; UTI, urinary tract infection.

DMSA only in cases of
- recurrence or
- atypical UTI

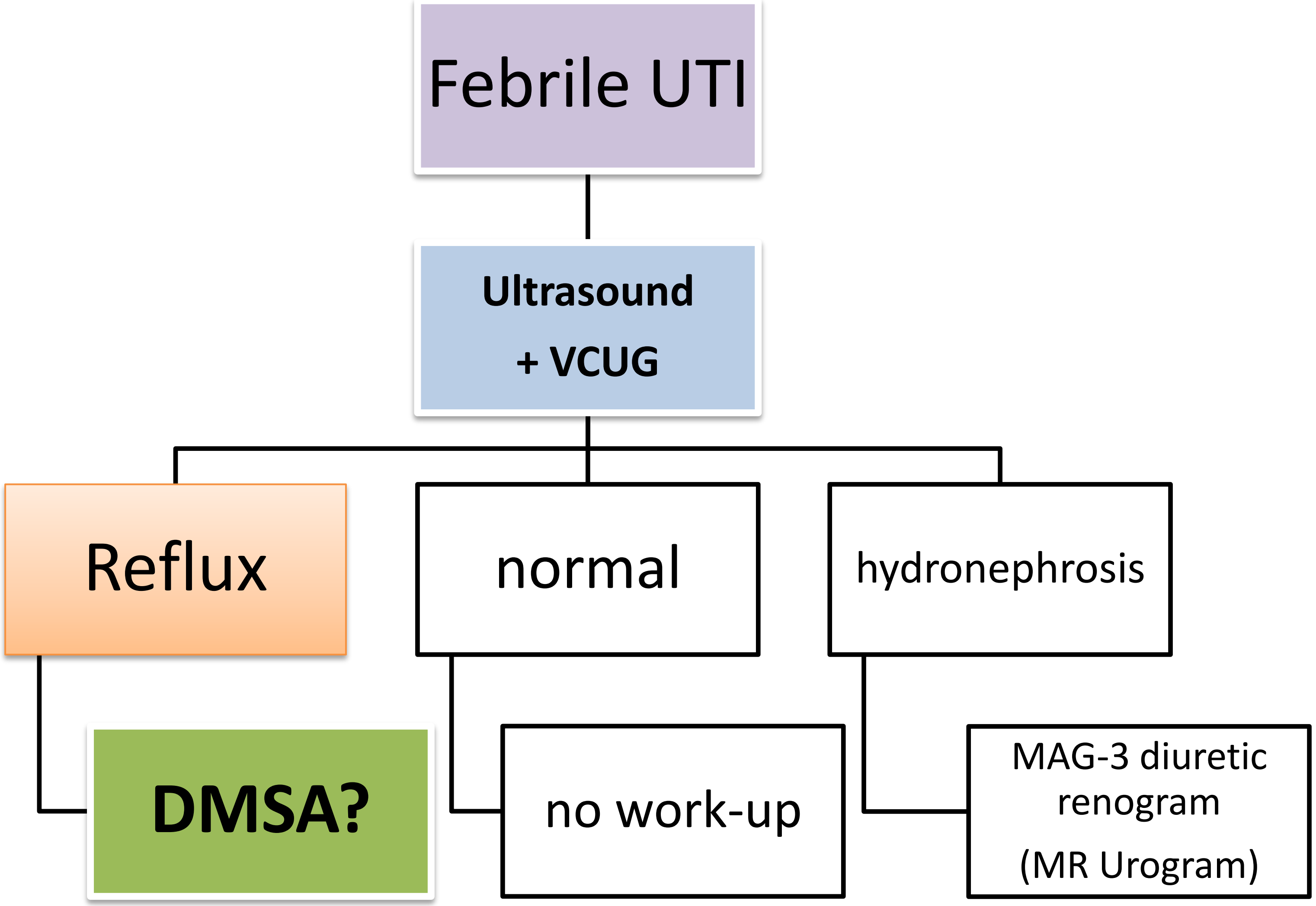
Box 3 | Main characteristics of patients with atypical or recurrent urinary tract infection

Atypical (any of the following)
- Septicaemia or patient who looks seriously ill (see NICE guideline[2])
- Poor urine flow
- Abdominal or bladder mass
- Raised creatinine concentration
- Failure to respond to treatment with suitable antibiotics within 48 hours
- Infection with non-Escherichia coli organisms

Recurrent (any of the following)
- Two or more episodes of urinary tract infection with acute pyelonephritis or upper urinary tract infection
- One episode of urinary tract infection with acute pyelonephritis or upper urinary tract infection plus one or more episode of urinary tract infection with cystitis or lower urinary tract infection
- Three or more episodes of urinary tract infection with cystitis or lower urinary tract infection

Mori R, Lakhanpaul M, Verrier-Jones K. Diagnosis and management of urinary tract infection in children: summary of NICE guidance. BMJ. 2007 Aug 25;335(7616):395-7.

"Bottom-up" diagnostic approach

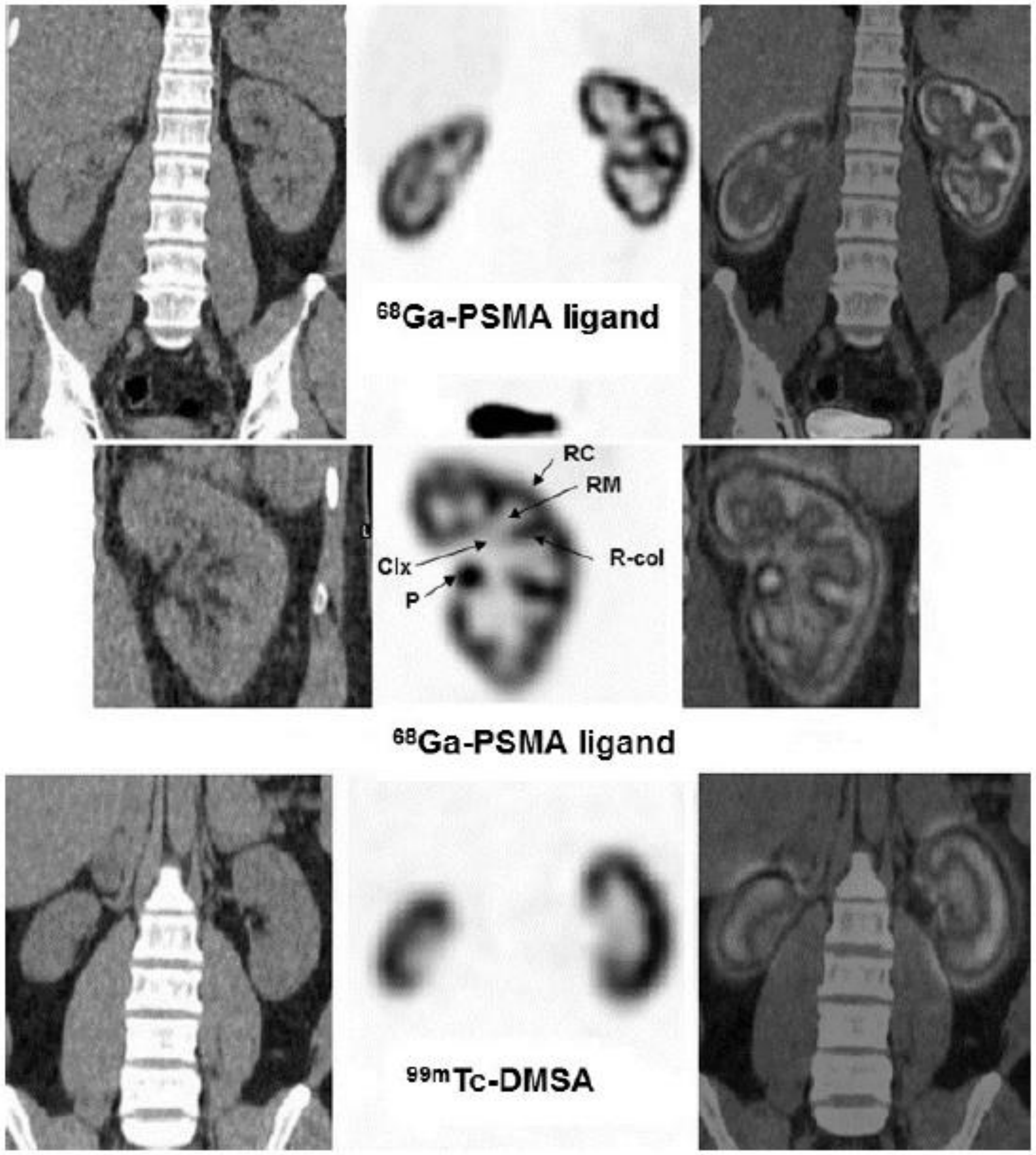


ACUTE PYELONEPHRITIS – SUMMARY

- There is not a single diagnostic algorithm that fits every child with a first febrile urinary tract infection

- There is a growing consensus that most infants and children with UTI do not need invasive imaging, at least initially, BUT THIS APPROACH MISSES RENAL SCARS

- An aggressive protocol has a high sensitivity for detecting VUR and scarring but implies high financial and radiation costs with questionable benefit



New tracer?

^{68}Ga-PSMA

Sarikaya I, Alqallaf A, Sarikaya A.
Renal Cortical 68Ga-PSMA PET and 99mTc-DMSA Images.
J Nucl Med Technol. 2020 Sep 4:jnmt. 120.248922.
doi: 10.2967/jnmt.120.248922. Epub ahead of print. PMID: 32887764.

Sarikaya I, Sarikaya A.
Current Status of Radionuclide Renal Cortical Imaging in Pyelonephritis.
J Nucl Med Technol. 2019 Dec;47(4):309-312.
doi: 10.2967/jnmt.119.227942. Epub 2019 Jun 10. PMID: 31182659.

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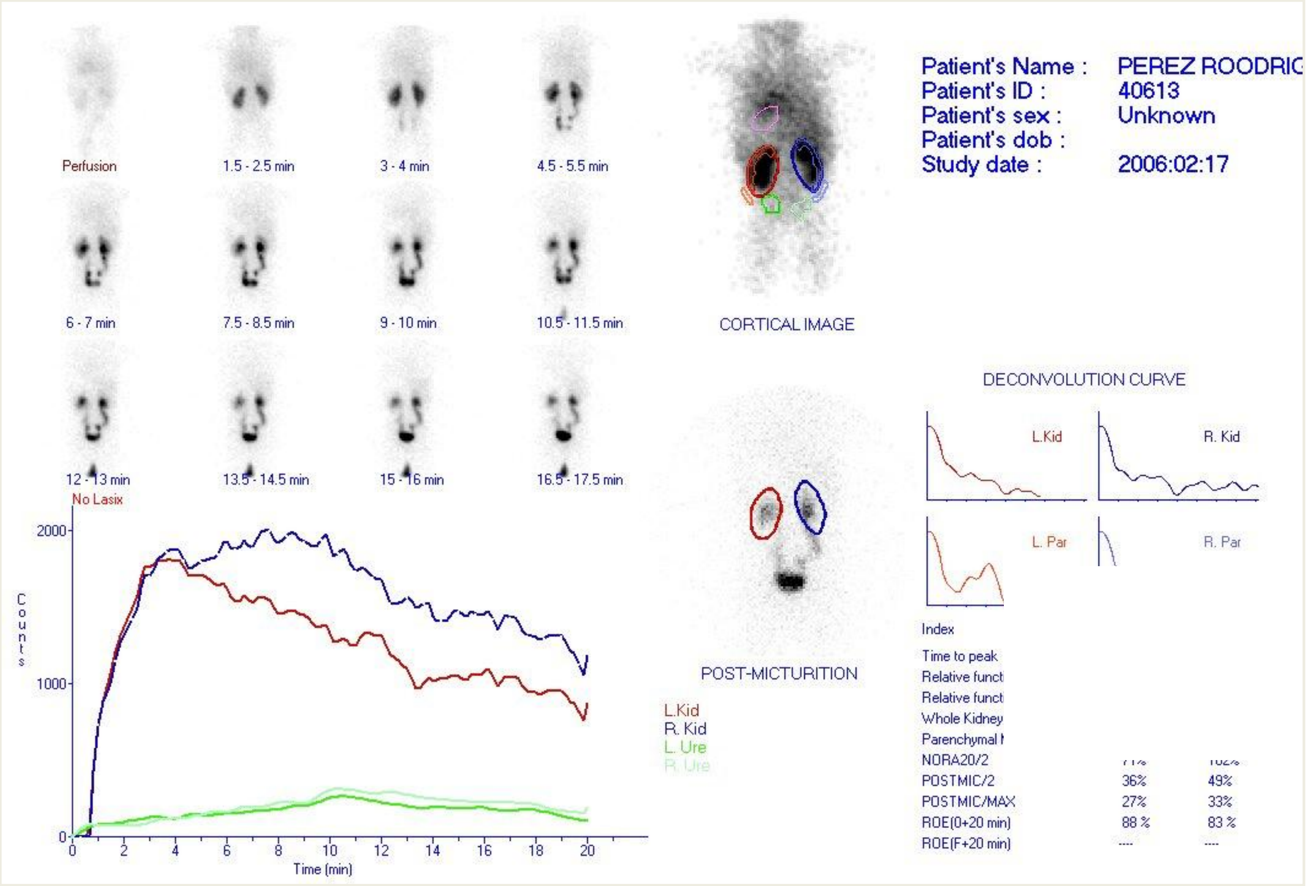


- **DIFFERENTIAL RENAL FUNCTION**
  - method
  - factors affecting DRF

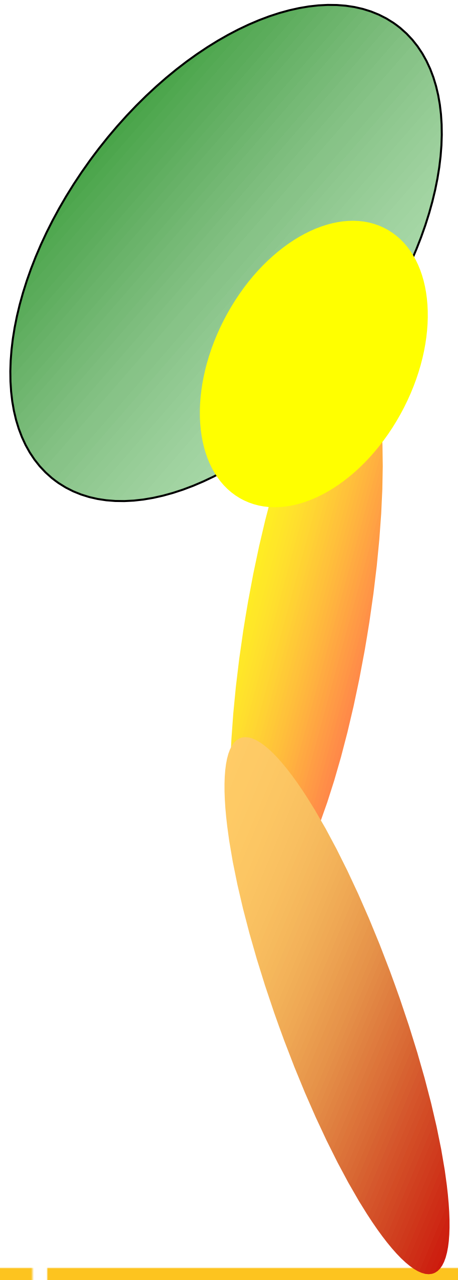
- **DRAINAGE**:
  - evaluation
  - factors affecting drainage

- **QUANTIFICATION**:
  - DRF
  - DRAINAGE PARAMETERS:
    - NORA
    - GRAVITY ASSISTED DRAINAGE
    - PROLONGED CORTICAL TRANSIT TIME

- **INTERPRETATION :**
  - severe HN
  - increase in the degree of HN
  - low DRF
  - decrease in DRF
  - còrtex: thickness, focal lesions

ANY DETERIORATION = KIDNEY AT RISK

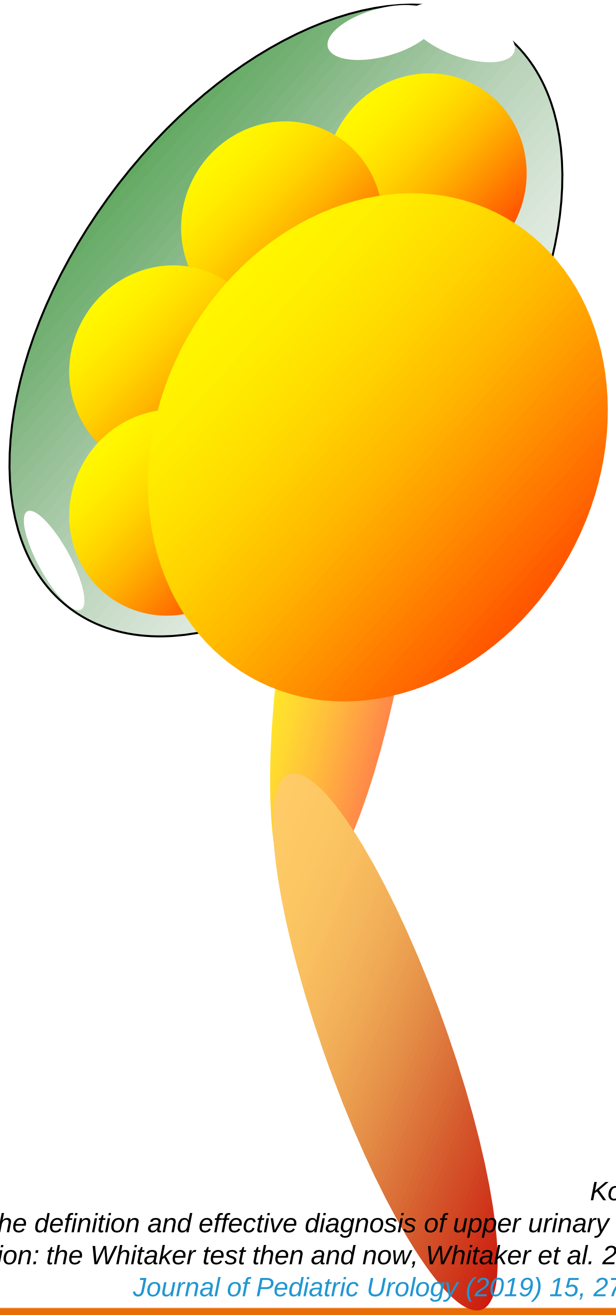
Majd M, Bar-Sever Z, Santos AI, De Palma D. The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children. J Nucl Med. 2018 Oct;59(10):1636-1640.



OBSTRUCTION

CHRONIC PARTIAL OBSTRUCTION
CPO

as seen in most clinically relevant instances, unlike total obstruction, is caused by an intermittent rather than a continuous pathologic process.



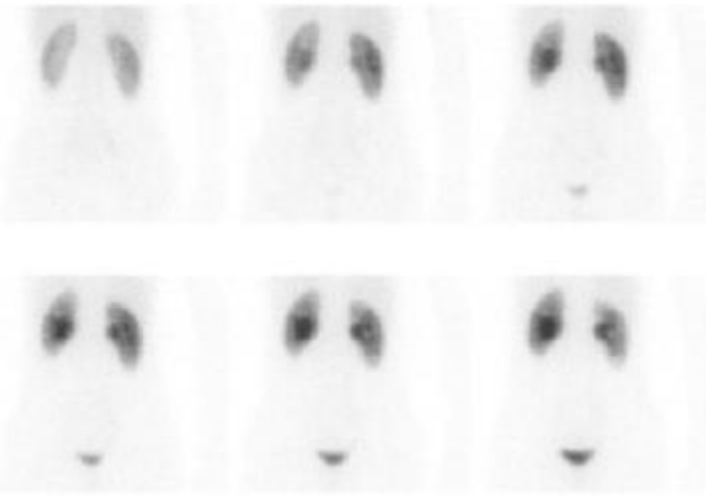
Koff S.
The search for the definition and effective diagnosis of upper urinary tract obstruction: the Whitaker test then and now, Whitaker et al. 2018.
Journal of Pediatric Urology (2019) 15, 27-28.

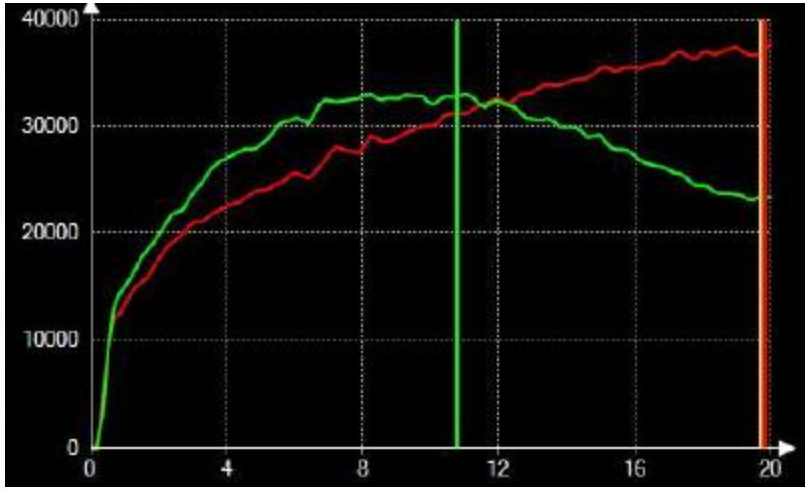
WHAT DOES THE PAEDIATRICIAN WANT ?

+++
Surgery: **yes** / **not**

Lasix Renography detects easily if a CHRONIC PARTIAL OBSTRUCTION

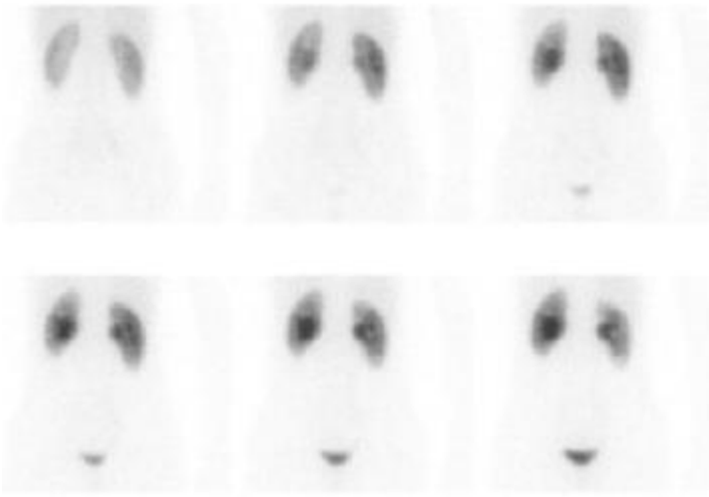
INTERPRETATION OF LASIX RENOGRAPHY

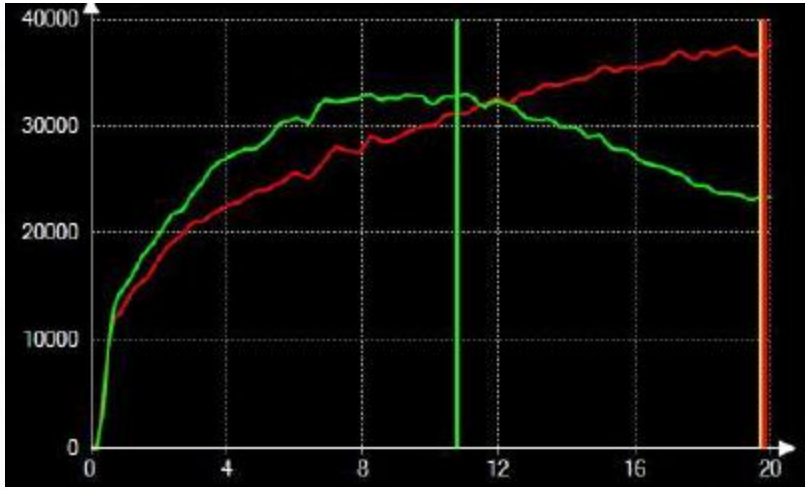




TECHNIQUE	- Preparation - Radiopharmaceuticals - Image acquisition
DATA PROCESSING	- Images - Curve - Quantitative parameters
INTERPRETATION	Chronic partial obstruction

INTERPRETATION OF LASIX RENOGRAPHY





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DATA PROCESSING	- Images - Curve - Quantitative parameters
INTERPRETATION	Chronic partial obstruction

SPECIAL CONTRIBUTION

The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children

Massoud Majd[1], Zvi Bar-Sever[2], Ana Isabel Santos[3], and Diego De Palma[4]

[1]SNMMI Pediatric Imaging Council, Children's National Medical Center, Washington, DC; [2]EANM Paediatric Committee, Department of Nuclear Medicine, Schneider Children's Medical Center, Petach Tikva, Israel; [3]EANM Paediatric Committee, Nuclear Medicine Service, Hospital Garcia de Orta, Almada, Portugal; and [4]EANM Paediatric Committee, Nuclear Medicine Unit, "Circolo" Hospital, Varese, Italy

Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
J Nucl Med. 2018 Oct;59(10):1636-1640.

TECHNIQUE

VI. PROCEDURES/SPECIFICATIONS OF THE EXAMINATION

A. Patient preparations and precautions

1. **Parent information**

   The parents should be given detailed information about the examination at the time of scheduling. Preparation before arrival in the department is usually not necessary if the procedure protocol includes routine administration of intravenous hydration. Otherwise, oral hydration before arrival and while in the department should be encouraged. Fasting is unnecessary and should be avoided. In rare cases, when the study will be done under sedation, the guidelines of the institution must be followed and the patient must be hydrated during examination by intravenous administration of fluid (see below).
2. **Before the examination**

   The supervising nuclear medicine physician should review all available clinical, laboratory, and imaging data. In particular, knowledge of relevant urologic procedures and surgeries such as presence of nephrostomy tube, ureteral stent, and urinary diversion is essential in the technical planning of the test and interpretation of the results. The nephrostomy tube should be clamped before examination.
3. **Patient education**

   The procedure should be explained to the parents and children old enough to understand. The parents should be encouraged to stay with the child throughout the examination.
4. **Anesthetic cream**

   Application of an anesthetic cream or spray on the potential venous access site(s) is advised.
5. **Intravenous access**

   With the F-0 technique, the tracer and furosemide can be injected through a butterfly needle of appropriate size. With the F+(20 or 30 min) technique, however, it is necessary to establish a secure intravenous access using an intracath to be used for initial injection of the tracer and subsequent injection of furosemide in a timely fashion (see D-5), as well as infusion of intravenous fluid per protocol.
6. **Hydration**

   Adequate hydration before or during examination is essential to achieve optimal postfurosemide diuresis and prevent dehydration. This is particularly important in infants and young children. Intravenous hydration with 5% dextrose in 0.33 normal saline or any other solution per the institution's policy is essential in patients who cannot or will not comply with oral intake of fluids. The suggested volume of intravenous fluid is 15–20 mL/kg (about two thirds of it should be given before furosemide injection). However, many children can achieve adequate hydration by age-appropriate oral intake of fluids (milk, water, juice) when clear instructions are presented to them (or to their caregivers) and when compliance with these instructions can be monitored.
7. **Eliminating/minimizing potential effects of a full bladder**

   A full bladder may result in significant increase in intravesical pressure and cause delayed drainage from the renal pelvis. In toilet-trained children, a full bladder may also cause premature interruption of the study due to the need of the patient to void. Therefore, it is important to eliminate or minimize overdistention of the bladder during the examination. This could be achieved by insertion of an indwelling bladder catheter allowed to drain freely into a closed collection bag. An additional advantage of continuous drainage of the radioactive urine from the bladder is significant reduction in gonadal radiation dose. However, catheterization, for the child, is an invasive and unpleasant procedure. Therefore, its routine use is controversial. But it is advised in infants and children with HUN, PUV, known VUR, or neuropathic bladder.

In the absence of an indwelling bladder catheter, all toilet-trained patients should be asked to empty their bladder before acquisition of the dynamic images. All boys who are able and willing to void while supine, using a urinal without moving, should be asked to void a few times during the dynamic acquisition of data. All gravity-assisted drainage images should also be obtained after the patient voids (see D-6).

Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
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RADIOPHARMACEUTICALS

B. Radiopharmaceuticals

The preferred radiopharmaceuticals for diuresis renography are ^{99m}T-labeled tubular agents, because they are much more efficiently extracted by the kidney than the glomerular agents. This is particularly important in neonates and in children with severely dilated collecting systems or impaired renal function.

1. **^{99m}Tc-MAG3 (tubular secretion)**

   ^{99m}Tc-mercaptoacetyltriglycine (MAG3) is highly protein-bound and is removed from the plasma primarily by the proximal renal tubules (*4*). The extraction fraction of ^{99m}Tc-MAG3 is 40%–50%, more than twice that of ^{99m}Tc-diethylenetriaminepentaacetic acid (DTPA) (see below). A small fraction of the administered activity of ^{99m} Tc-MAG3 is excreted via the hepatobiliary system. Therefore, visualization of the tracer in the gallbladder or small bowel on the delayed images is a normal physiologic finding and should not be mistaken for retention in the right renal pelvis or urine leak.

2. **^{99m}Tc-EC (tubular secretion)**

   ^{99m}Tc-L,L- and -D,D-ethylenedicysteine (EC) are enantiomers. Both are excellent renal radiopharmaceuticals with clearances slightly higher than ^{99m}Tc-MAG3 (*5*). Although ^{99m}Tc-D,D-EC is cleared more rapidly than ^{99m}Tc-L,L-EC, ^{99m}Tc-L,L-EC was first described, and it is available as a kit formulation in several countries but not in the United States.

3. **^{99m}Tc-DTPA (glomerular filtration)**

   ^{99m}Tc-DTPA is purely filtered by the glomeruli (*6*). Although its extraction fraction is approximately 20%, it can be used for diuresis renography if tubular agents are unavailable.

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IMAGE ACQUISITION

D. Image acquisition

1. **Patient position**

   The images are acquired with the patient supine on the imaging table.

2. **Camera position**

   The camera is usually under the table for acquisition of dynamic and static posterior images of normally positioned kidneys. If the affected kidney is a horseshoe variant or in an ectopic location, the posterior images alone would not be adequate for accurate calculation of the differential renal function (DRF). In this situation, if it is feasible, the initial images should be acquired with a dual-detector camera for geometric mean calculation of the DRF, but posterior images are adequate for evaluation of the postdiuresis drainage. The images for evaluation of HN in transplanted kidneys must be acquired anteriorly.

3. **Administered activity**

   All administered activities in children should be scaled down according to the tables provided by either the EANM or the SNMMI (*7*).

4. **Dose of furosemide**

   The standard dose of furosemide is 1 mg/kg with a suggested maximum dose of 40 mg.

5. **Image acquisition protocols**

   Several protocols have been used for diuresis renography based on the administration of furosemide before, simultaneous with, or at varying intervals after administration of the radiopharmaceutical (*8,9*). The most commonly used protocols are F-0 and F+(20 or 30 min).

   In the F-0 protocol, furosemide is administered simultaneously with the radiopharmaceutical, and dynamic posterior images (10–15 s per image) are obtained for 20 min (*10*).

   In the F+20 or F+30 protocols, the radiopharmaceutical is injected intravenously, and dynamic posterior images (10–15-s per image) are acquired for 20 or 30 min, followed by intravenous administration of furosemide and acquisition of a second set of dynamic images (10–15 s per image) for 20 or 30 min. However, furosemide should ideally be injected after the entire dilated collecting system is filled with radioactive urine and there is adequate residual tracer activity for a meaningful evaluation of postdiuresis drainage parameters. Therefore, in the following situations it may be necessary to modify the timing of furosemide administration:

   a. The dynamic images should be reviewed immediately after acquisition. In severely dilated systems particularly with dilated ureter, the entire system may not be filled with radioactive urine at the end of 20 or 30 min of dynamic imaging. These patients should be kept upright or prone for a few minutes to achieve better filling of the entire dilated system and more homogeneous distribution of the radiotracer before administration of furosemide.

   b. If monitoring of the initial dynamic images during acquisition shows fast drainage of the tracer from the dilated collecting system that may result in inadequate residual activity at the end of 20 or 30 min of acquisition, furosemide should be administered earlier to evaluate drainage under high diuresis.

6. **Gravity-assisted and postvoid drainage**

   Regardless of the protocol used, the quality of drainage must be assessed both visually and semiquantitatively at the end of the postfurosemide dynamic imaging because drainage could be affected by the supine position of the patient and, in the absence of indwelling bladder catheter, by varying degrees of bladder filling. Therefore, if drainage at the end of dynamic imaging is insufficient (high residual activity), it must be reassessed after the patient is kept upright for a standardized period of time and, in the absence of indwelling bladder catheter, after he/she empties his/her bladder (*11*). The following imaging techniques are commonly used for evaluation of gravity-assisted/postvoid drainage:

   a. Static 1-min posterior images are obtained before and after the patient is kept upright for a standardized period of time (e.g., 10 or 15 min).

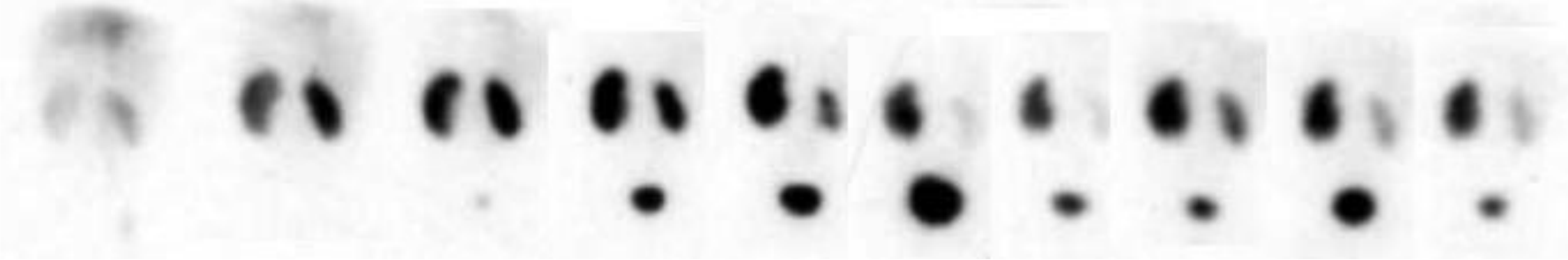
   b. Static 1-min image is obtained at a standardized time period (60 min or longer) after the radiopharmaceutical injection.

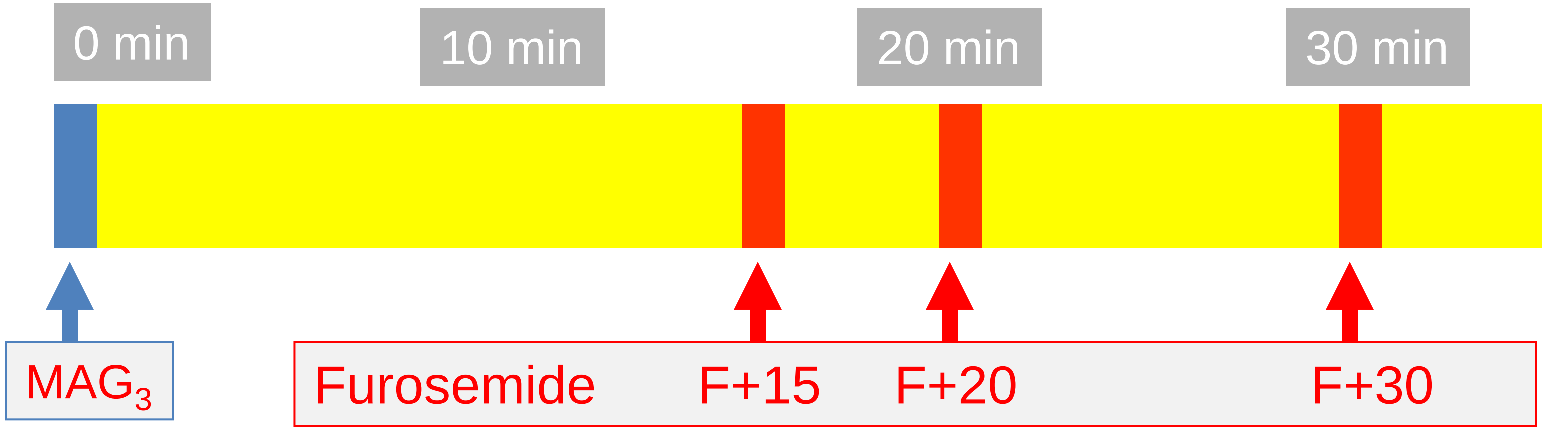
Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
J Nucl Med. 2018 Oct;59(10):1636-1640.

→ • F-15 F0 FUROSEMIDE: 1 mg/kg máximum 40 mg

Furosemide IV administration BEFORE the tracer injection

ONLY 1 PUNCTURE



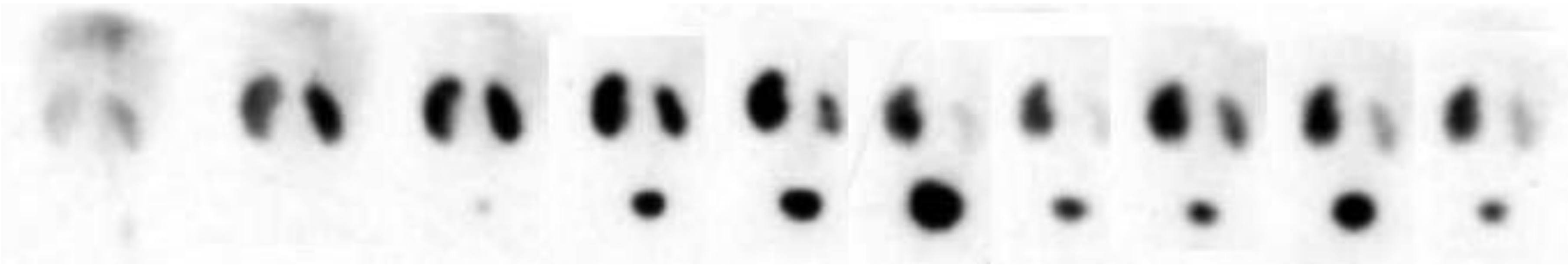


ADVANTAGES:

1. INTERACTIVE RENOGRAPHY
2. MAXIMUM FUNCTIONAL INFORMATION

• F+15 F+20 F+30 FUROSEMIDE: 1 mg/kg máximum 40 mg

Furosemide IV administration when the maximum activity is in the dilated structure just above the stenosis



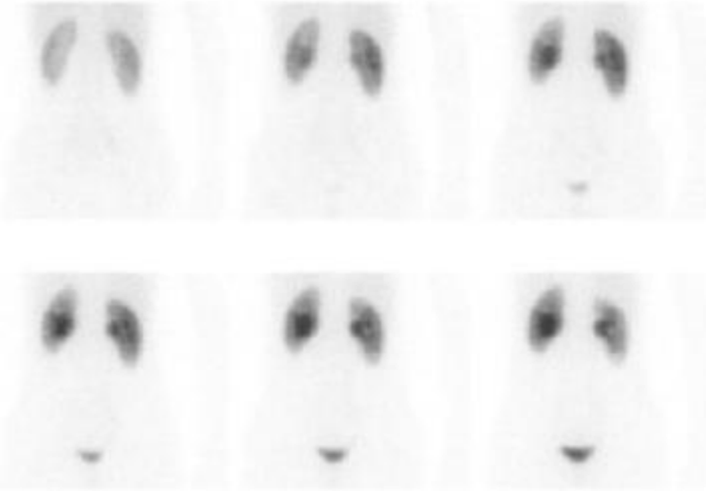
MAG_3

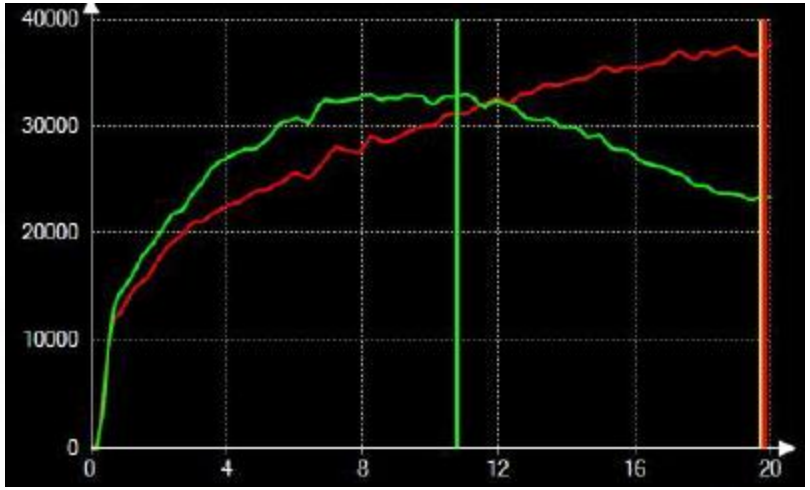
Furosemide
F0

ADVANTAGES:

1. JUST 1 PUNCTURE
2. NO NEED TO MAINTAIN THE IV TRACT
3. LESS TIME OF EXPLORATION (AND GAMMACAMERA)

INTERPRETATION OF LASIX RENOGRAPHY





TECHNIQUE

- Preparation
- Radiopharmaceuticals
- Image acquisition

DATA PROCESSING

- Images
- Curve
- Quantitative parameters

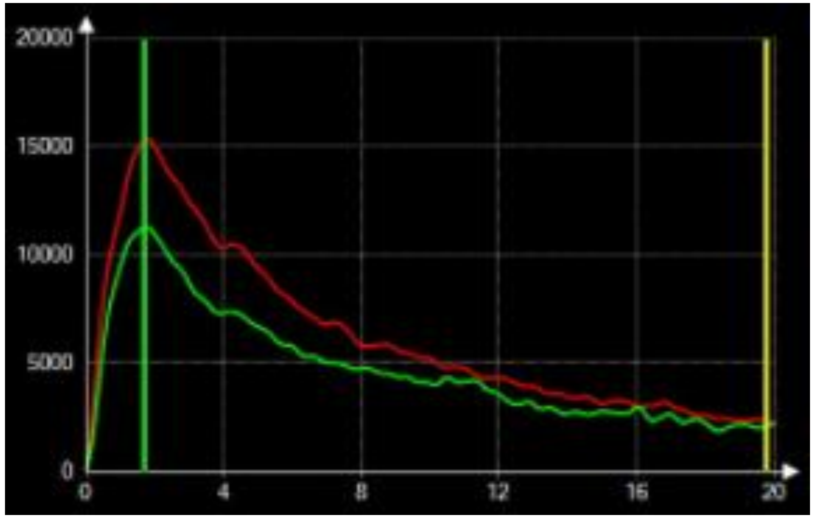
INTERPRETATION

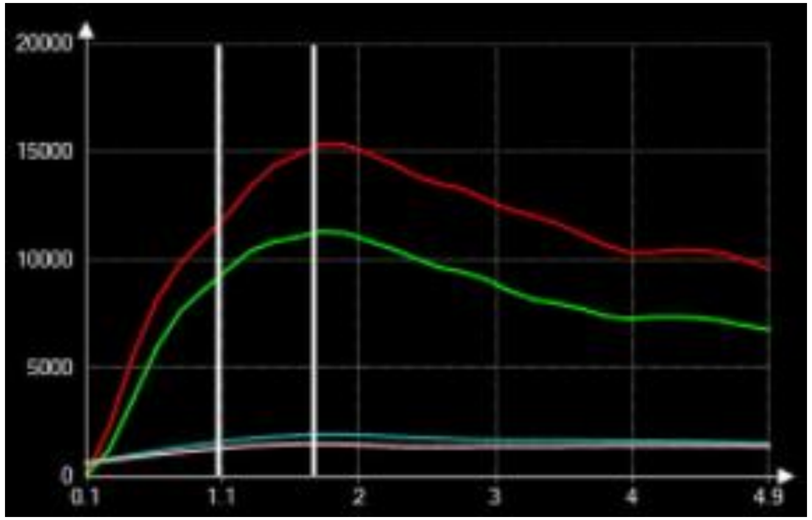
Chronic partial obstruction

DATA PROCESSING

1. **Calculation of DRF**

Calculation of the DRF should be based on the summed image with the maximum accumulation of the radiopharmaceutical in the parenchyma and no radiopharmaceutical in the pelvicalyceal system, usually the second minute (60–120 s) images. The renal region of interest (ROI) should include only the entire functioning renal tissue. The preferred ROI for background subtraction is, around and slightly separated from the renal ROI, excluding the hilum of the kidney. This C-shaped ROI appropriately includes the contributing counts from the liver and spleen blood-pool activity. Background-subtracted counts in each kidney are used for calculation of the DRF by using the integral method (area under the curve) or the Rutland-Patlak plot (*12–15*).





Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
J Nucl Med. 2018 Oct;59(10):1636-1640.

DATA PROCESSING

2. **Calculation of drainage parameters**
   a. Generation of time–activity curves. Postfurosemide dynamic images are used for evaluation of the pattern and speed of clearance of the radiotracer from the dilated pelvicalyceal system and ureter. Attention must be paid to the following crucial points in the processing of the postdiuresis data and generation of the time–activity curves:
   - Motion correction. The dynamic images must be displayed in a cinematic form to detect and correct for patient movement during the acquisition time.
   - The ROI for generation of the postdiuresis time–activity curve must include the entire dilated system. In the case of HN, it should include the entire dilated pelvicalyceal system. But if the ureter is also dilated, it must be included in the ROI (single ROI). However, in a small percentage of cases of HUN, the level of obstruction, if any, may not be clear. For example, if the pelvicalyceal system is disproportionately more dilated than the ureter, it is important to exclude UPJ obstruction by adding a separate ROI for the pelvicalyceal system (double ROIs) or even a third ROI for dilated ureter (triple ROIs).
   - The images with maximal dilatation of the collecting system must be chosen for drawing the ROI for generation of the postdiuresis time–activity curve. After injection of furosemide, the dilated renal pelvis may gradually become more dilated and if the early postfurosemide images are chosen for drawing the ROI, the entire dilated pelvis will not be included in the ROI on all images and the resultant time–activity curve would not be true representative of postdiuresis clearance of the tracer from the dilated pelvis.

Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
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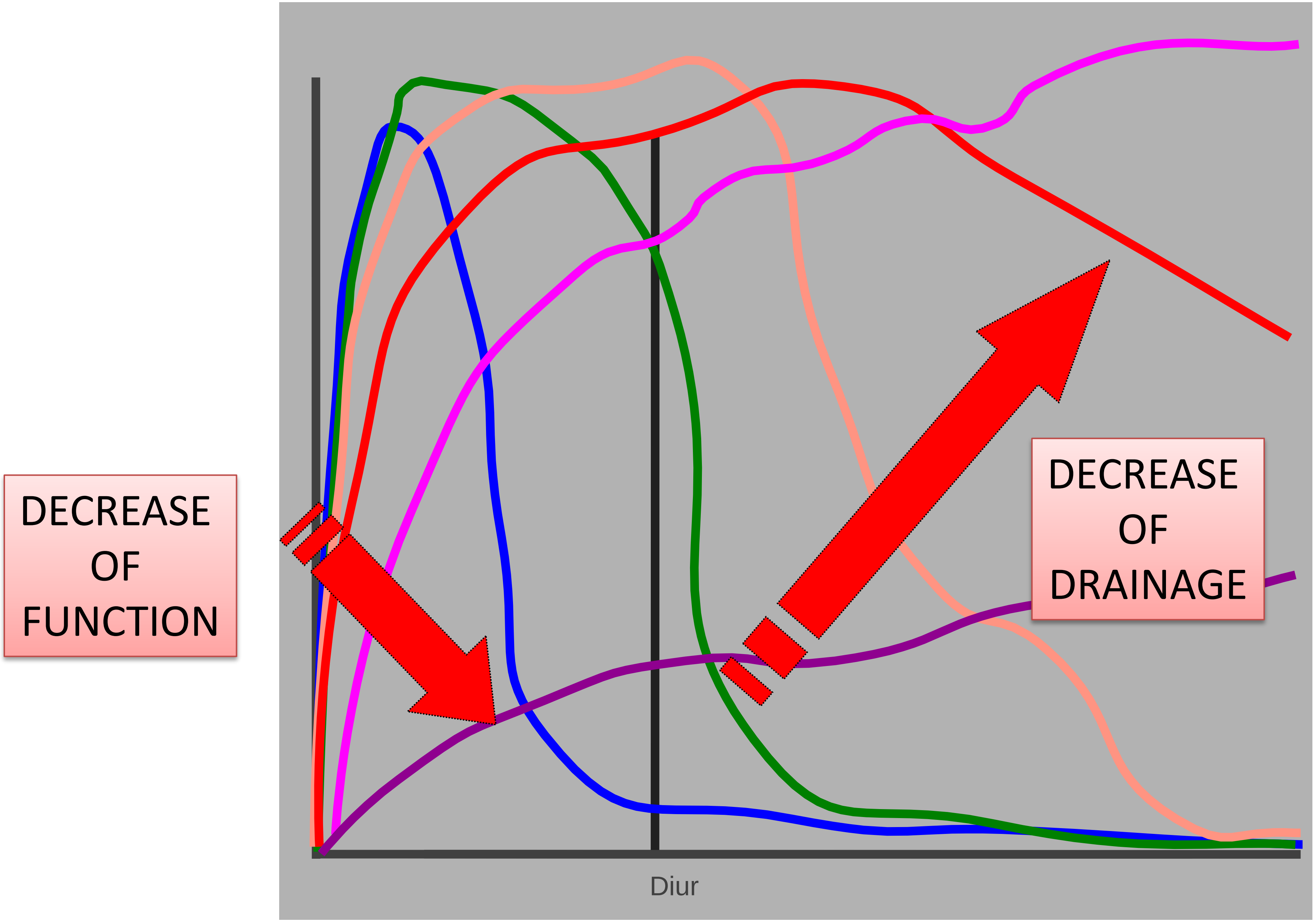
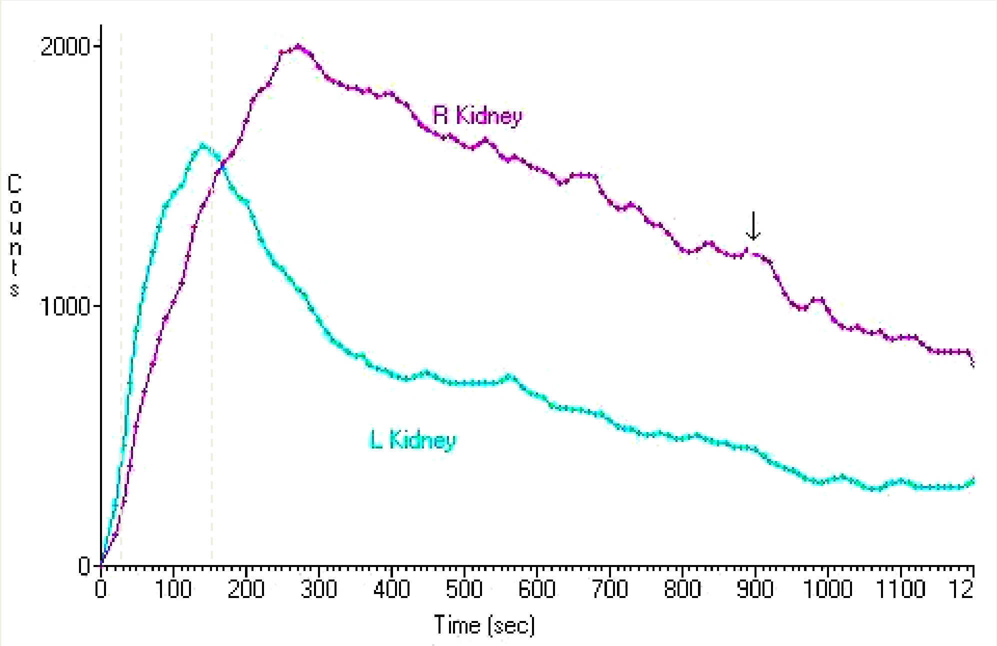

DECREASE
OF
FUNCTION
DECREASE
OF
DRAINAGE
Diur

RENOGRAPHY
3 phases



Phase 1:
- First seconds
- ↑↑↑ activity
- Injection speed

= renal perfusion

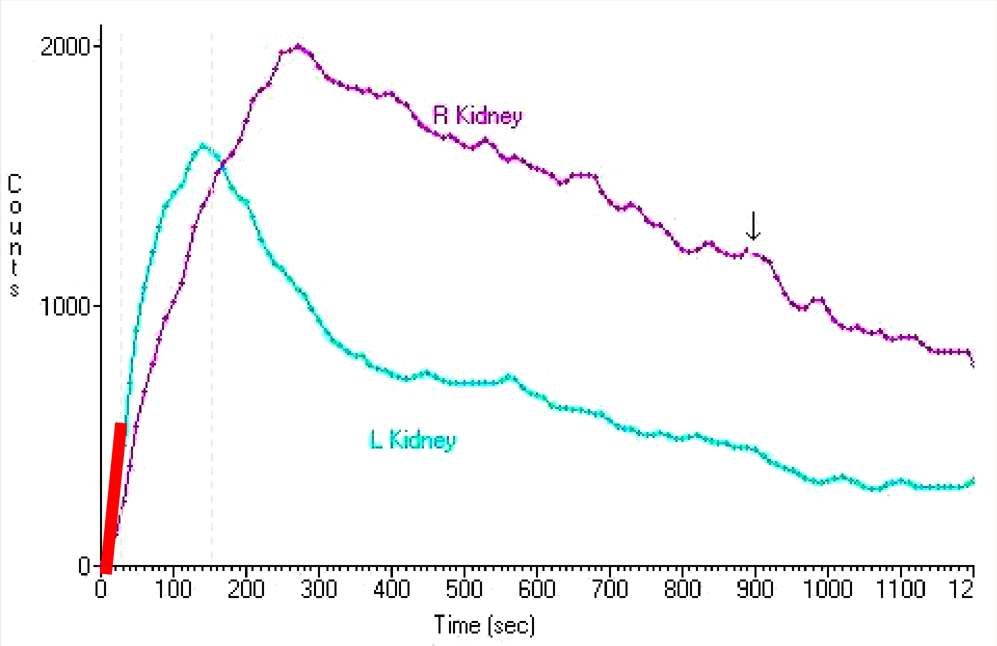
Phase 2:
- 2–3 min post inyection
- Tracer accumulates in kidney
- No drainage

= renal uptake

Phase 3:
- 2–5 min: start of drainage

= renal drainage

RENOGRAPHY
3 phases



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RENOGRAPHY
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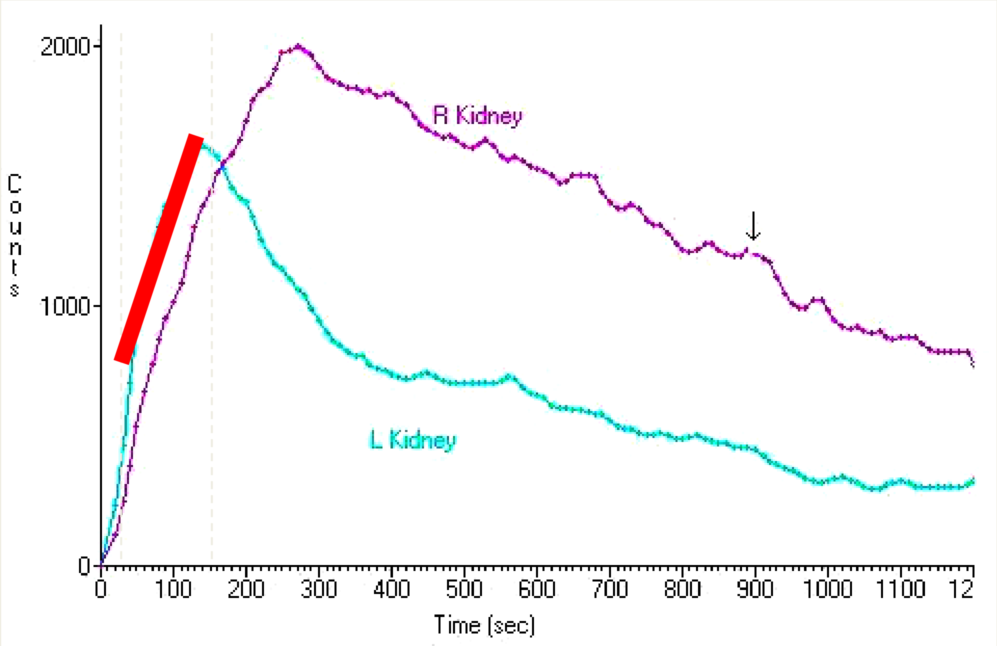

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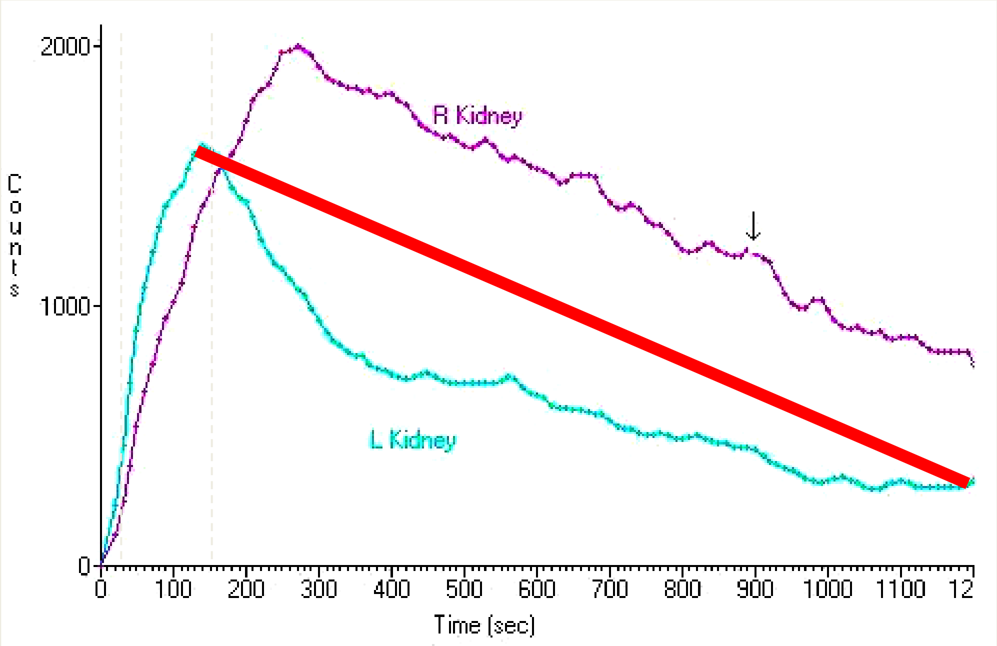
RENOGRAPHY
3 phases



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= renal perfusion

Phase 2:
- 2–3 min post inyection
- Tracer accumulates in kidney
- No drainage

= renal uptake

Phase 3:
- 2–5 min: start of drainage

= renal drainage

DATA PROCESSING

c. Evaluation of gravity-assisted/postvoid drainage. With the technique using static pre- and postupright images obtained shortly after completion of dynamic imaging (see D-6a), the gravity-assisted drainage is simply calculated by using the total counts in the ROIs drawn around the entire dilated system on both images and using the following formula (background activity and decay factor are negligible):

- Gravity-assisted drainage = (counts in the preupright image ROI) minus (counts in the postupright image ROI) divided by (counts in the preupright image ROI).
- With the technique using a single delayed image (see D-6b), the gravity-assisted/postvoid drainage is assessed either visually or by NORA.

Majd M, Bar-Sever Z, Santos AI, De Palma D.
The SNMMI and EANM Procedural Guidelines for Diuresis Renography in Infants and Children.
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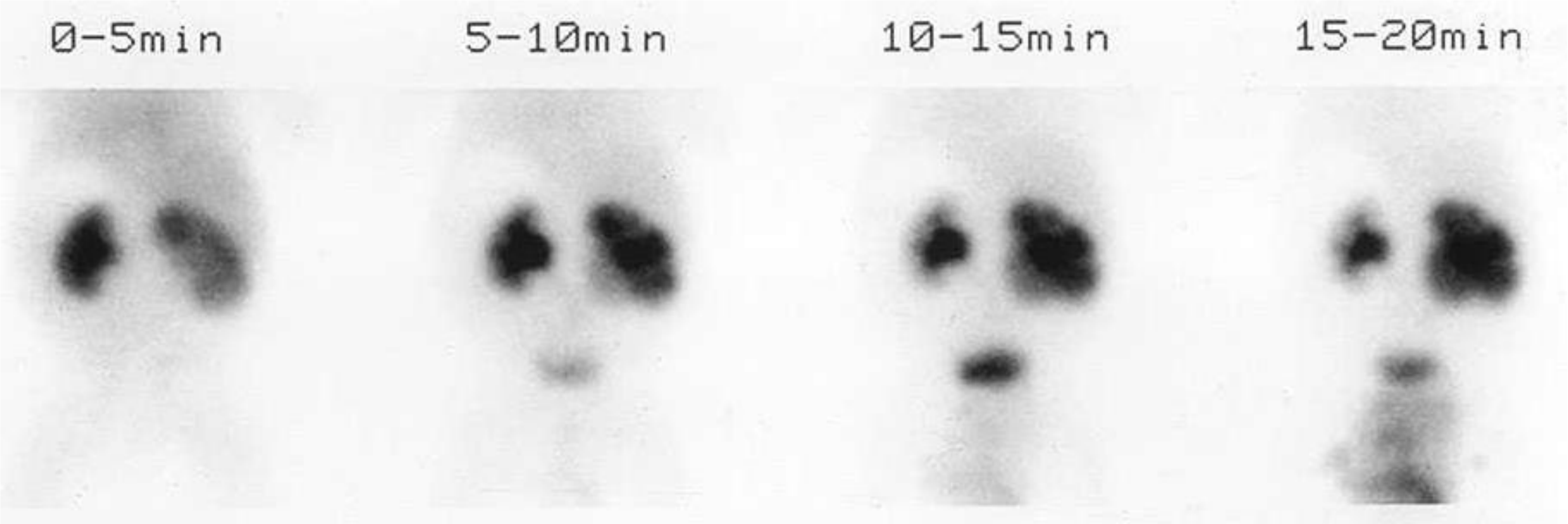


LASIX RENOGRAPHY

FUROSOMIDE 1mg/kg F0

GRAVITY ASSISTED DRAINAGE IMAGE

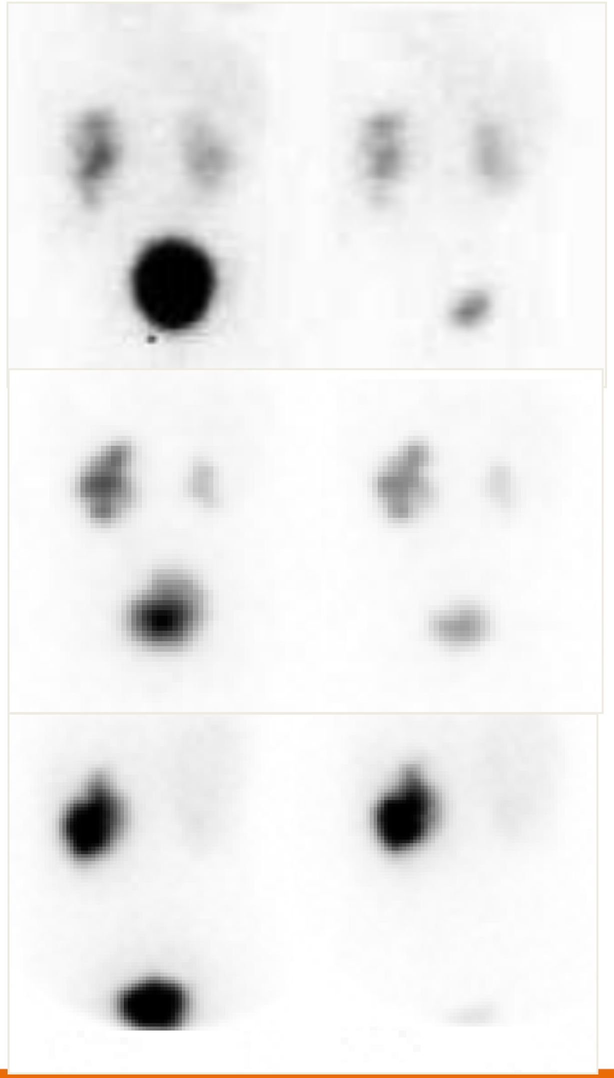
GRAVITY ASSISTED POST-VOID DRAINAGE

visual assessment

NO renal retention

MINOR renal retention

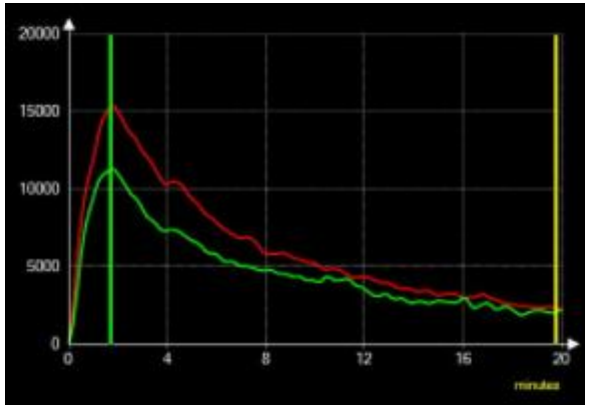
MAJOR renal retention



GRAVITY ASSISTED POST-VOID DRAINAGE

NORA
Normalized Residual Activity

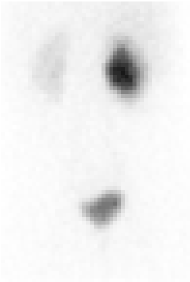
NORA 20/2 min = activity 20 min / activity 2 min
NORA postmicc/2 = activity postmicc / activity 2 min



Activity 2 min

Activity 20 min

NORA 20/2 50%

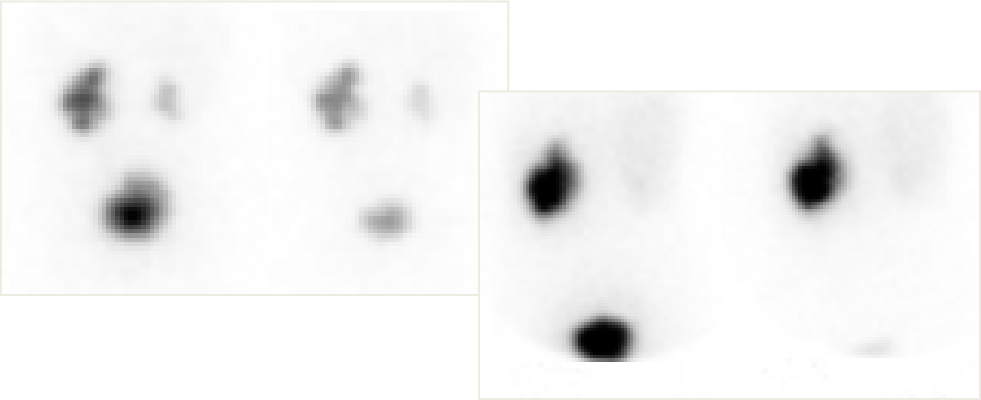


Activity postmicc

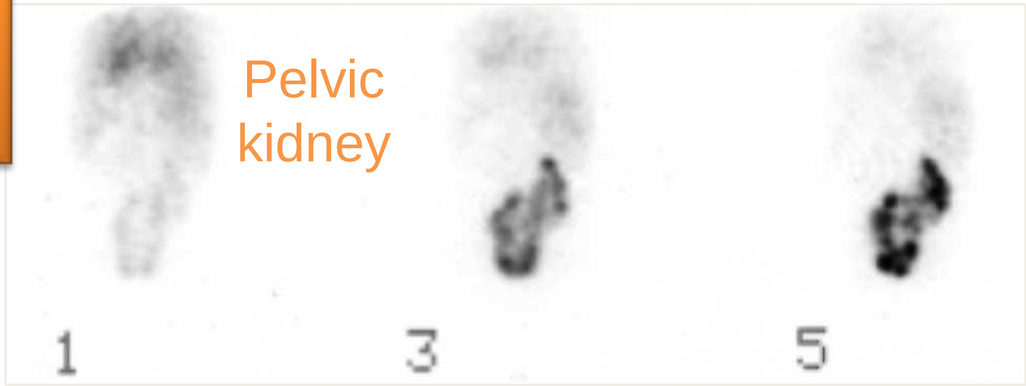
NORA PM/2 44%

BLADDER CATHETER

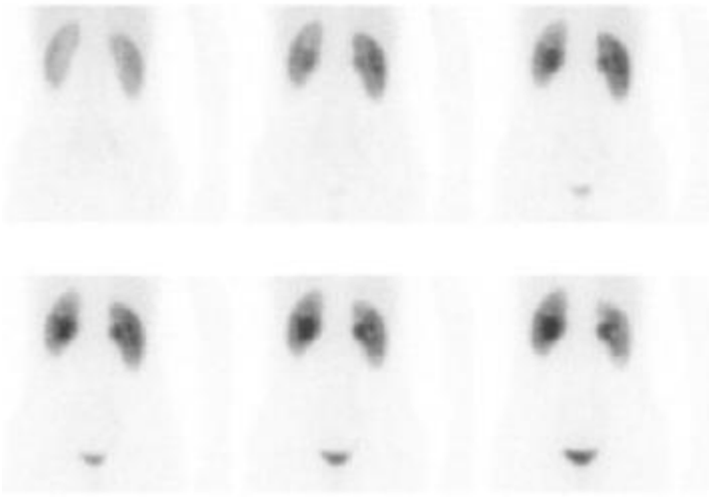
NOT necessary usualy:
- Gravity assisted image
- after patient voids

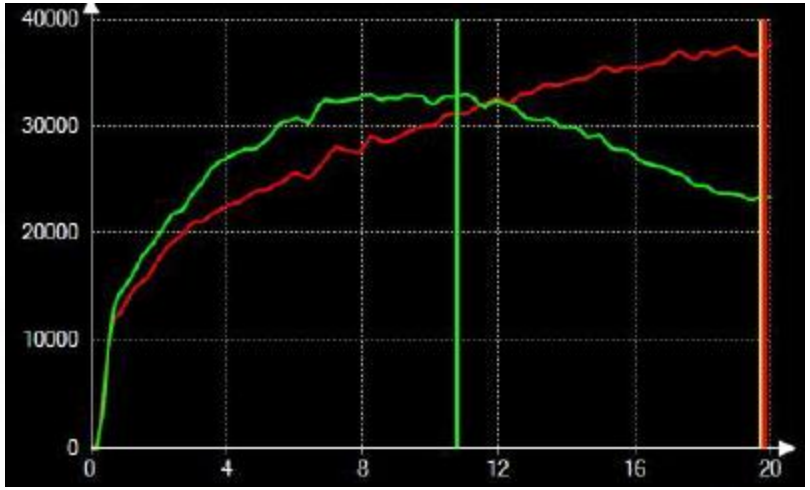


Can be used in case of:
- huge VUR or megaureter
- ectopic pelvic kidney
- neuropathic bladder



INTERPRETATION OF LASIX RENOGRAPHY





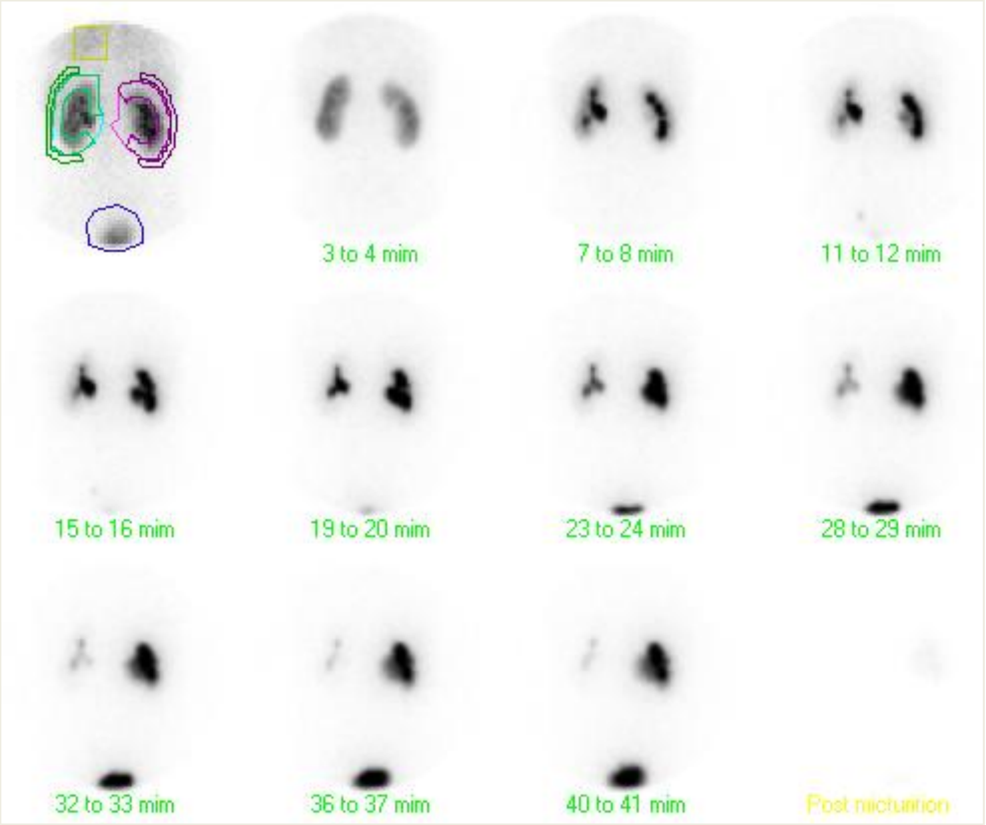
TECHNIQUE	- Preparation - Radiopharmaceuticals - Image acquisition
DATA PROCESSING	- Images - Curve - Quantitative parameters
INTERPRETATION	Chronic partial obstruction

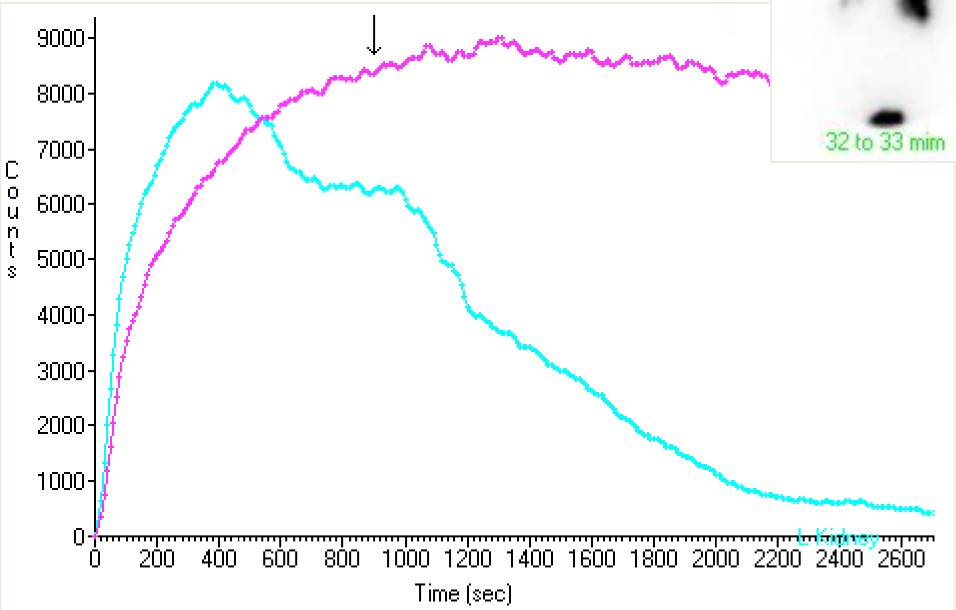
INTERPRETATION

- review all the images
- the shape of the drainage curve: drainage pattern
- the quality of cortical clearance of the tracer
- Semiquantitative indices
    - DRF
    - postfurosemide drainage T1/2
    - percentage drainage at the end of dynamic imaging
    - gravity-assisted drainage
    - NORA

INTERPRETATION

- Scintigraphic findings and semiquantitative drainage parameters are interrelated
- None of them should be interpreted in isolation





COMPARISON
-IMAGES
-CURVES

INTERPRETATION

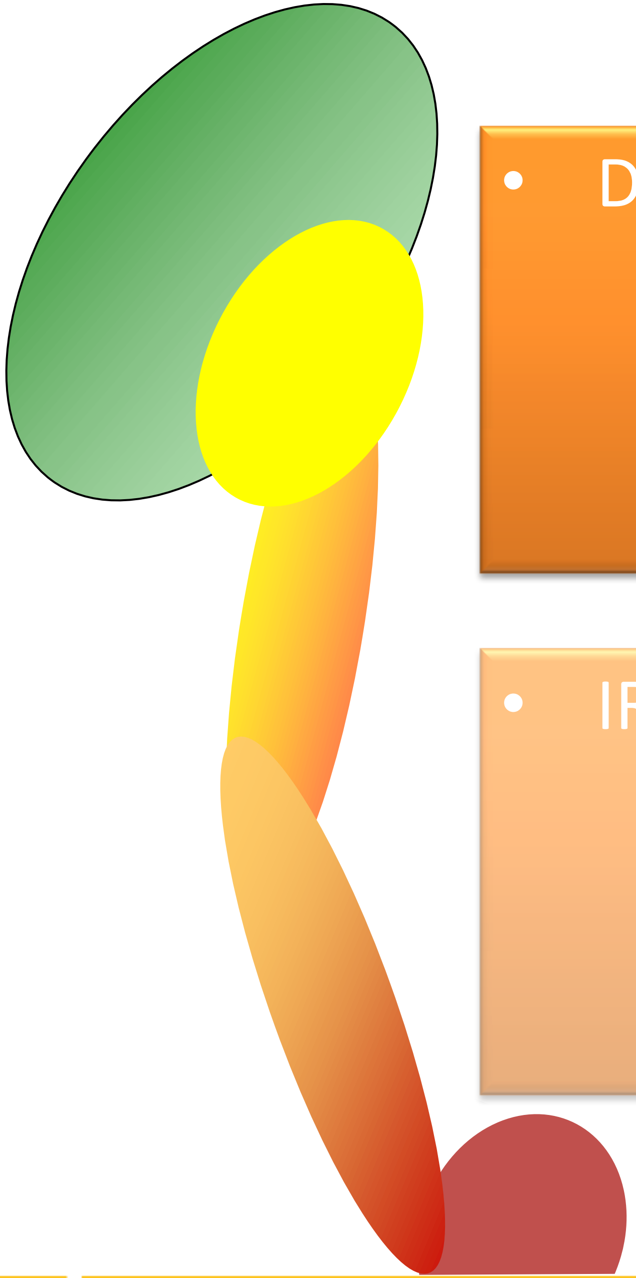
- On any single study, diagnosis of high likelihood for critical partial obstruction and eventual loss of function can be made only if there is:
  - a flat or rising drainage curve with
  - little or no clearance in the upright position,
  - particularly if there is unilateral delayed cortical clearance of the tracer throughout the study or
  - initial good clearance but with reaccumulation of the tracer in the renal cortex after furosemide administration
- In most cases:
  - the initial study will serve as a baseline
  - Follow-up:
    - detection of a significant drop in DRF or
    - worsening of postdiuresis drainage

OVERVIEW

- DMSA RENAL CORTICAL SCINTIGRAPHY IN PAEDIATRIC FEBRILE UTIs
- LASIX RENOGRAPHY IN URINARY OBSTRUCTION
- DIRECT AND INDIRECT RADIONUCLIDE CYSTOGRAPHY
- RENAL TRANSPLANT RENOGRAPHY
- RADIONUCLIDE STUDIES IN RENAL VASCULAR HYPERTENSION

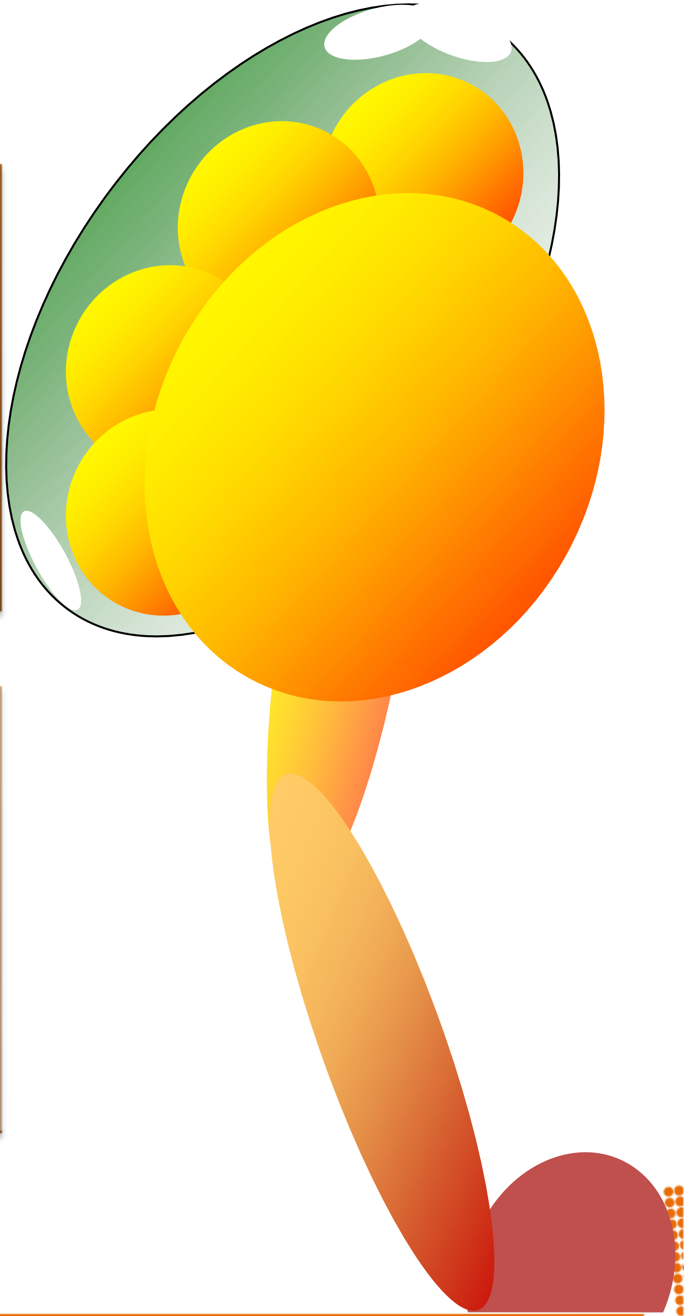
- DRC
  DIRECT
  RADIONUCLIDE
  CYSTOGRAPHY

- IRC
  INDIRECT
  RADIONUCLIDE
  CYSTOGRAPHY

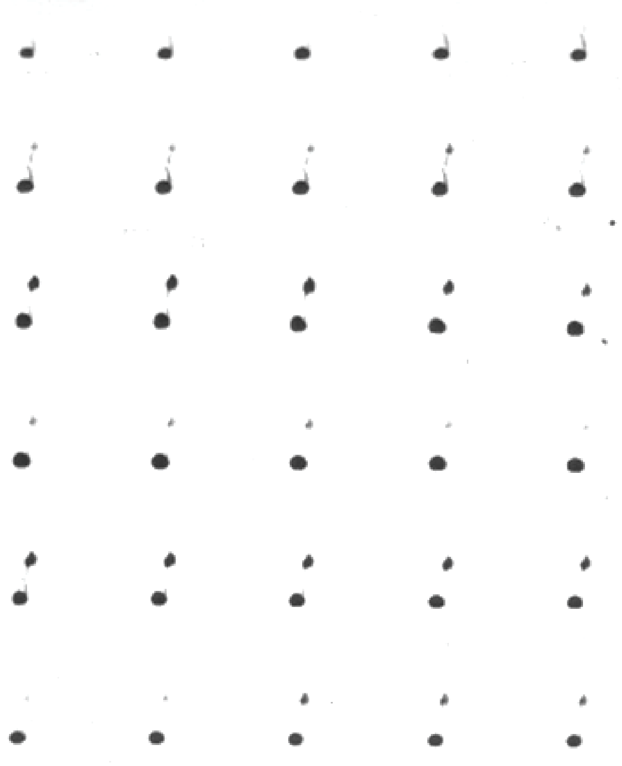


- DRC
  - DIRECT
  - RADIONUCLIDE
  - CYSTOGRAPHY

- IRC
  - INDIRECT
  - RADIONUCLIDE
  - CYSTOGRAPHY

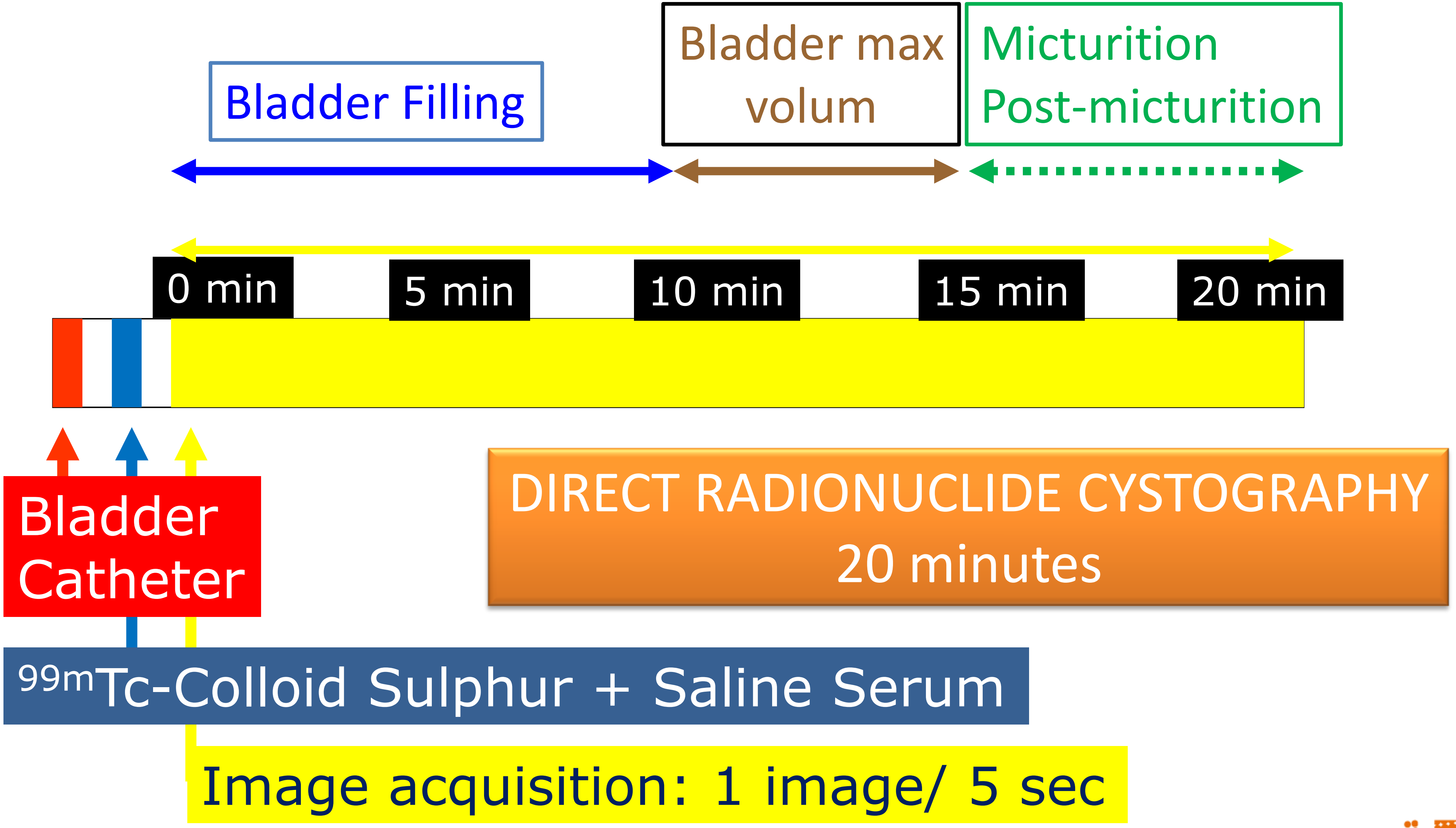


DIRECT RADIONUCLIDE CYSTOGRAPHY

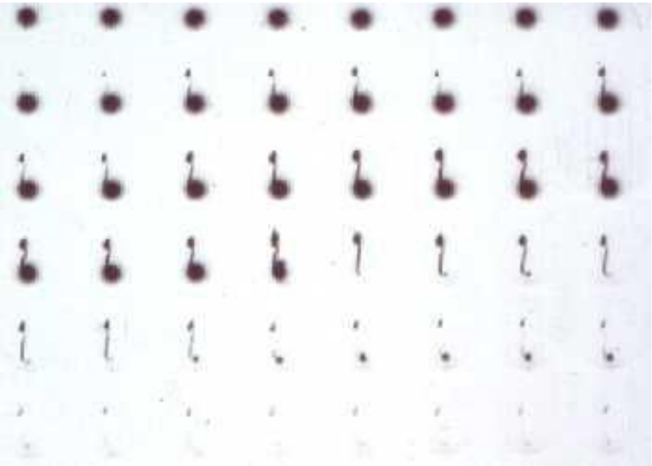


Same technique than radiological VCUG

- Bladder catheter
- AB treatment 48 hours
- Bladder filled with SS
- Depth of Bladder filling: 60 cm
- Study one or two micturitions
- Bladder administration:
  - 1 mCi ^{99m}Tc-Colloid Sulphur


Bladder Filling
Bladder max volum
Micturition
Post-micturition
0 min
5 min
10 min
15 min
20 min
Bladder Catheter
DIRECT RADIONUCLIDE CYSTOGRAPHY
20 minutes
99mTc-Colloid Sulphur + Saline Serum
Image acquisition: 1 image/ 5 sec

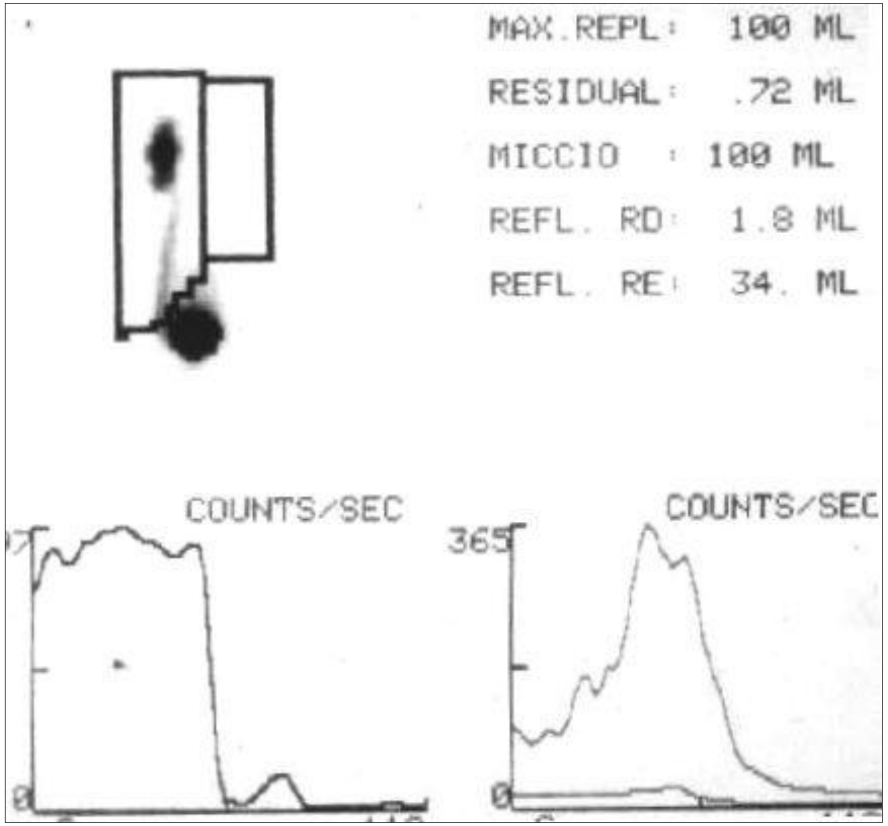
DIRECT RADIONUCLIDE CYSTOGRAPHY



- MINIMAL DOSIMETRY
- HIGH SENSITIVITY

but

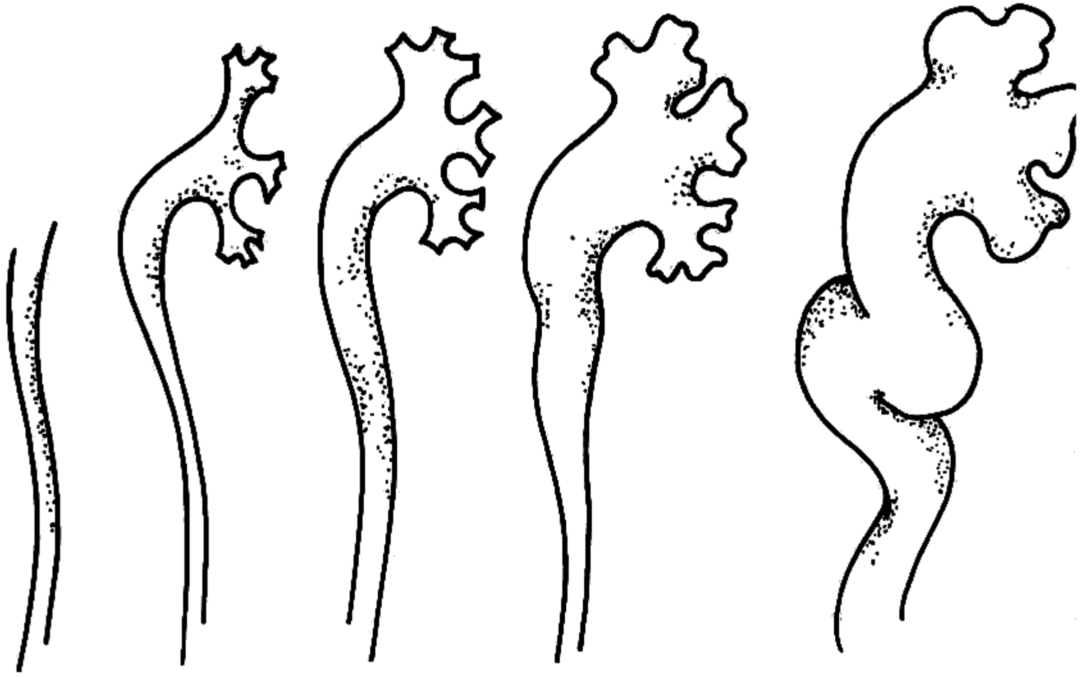
- BLADDER CATHETER



- Total time with reflux
- Volum of reflux
- Number of refluxes

- Cyclic reflux: neuropathic bladder
- Micturition or premicturition reflux

MICTIONAL CYSTOURETHROGRAPHY



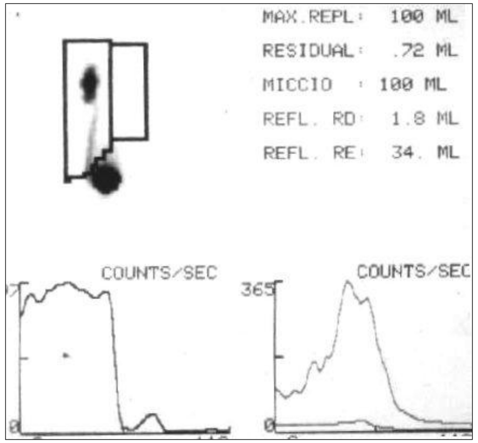
I II III IV V

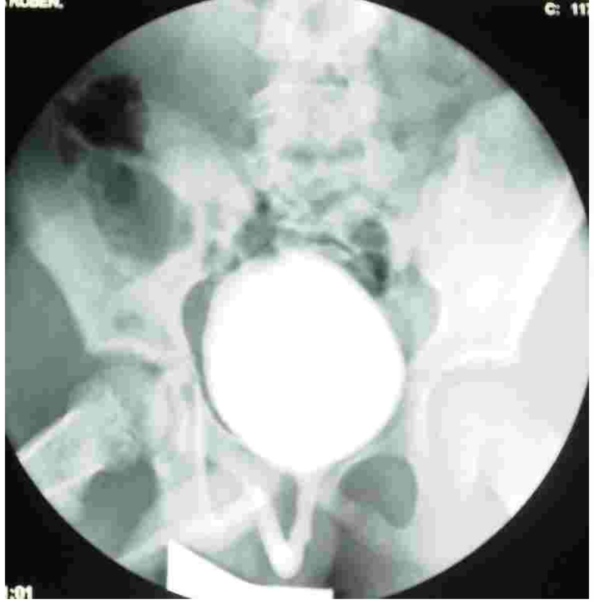
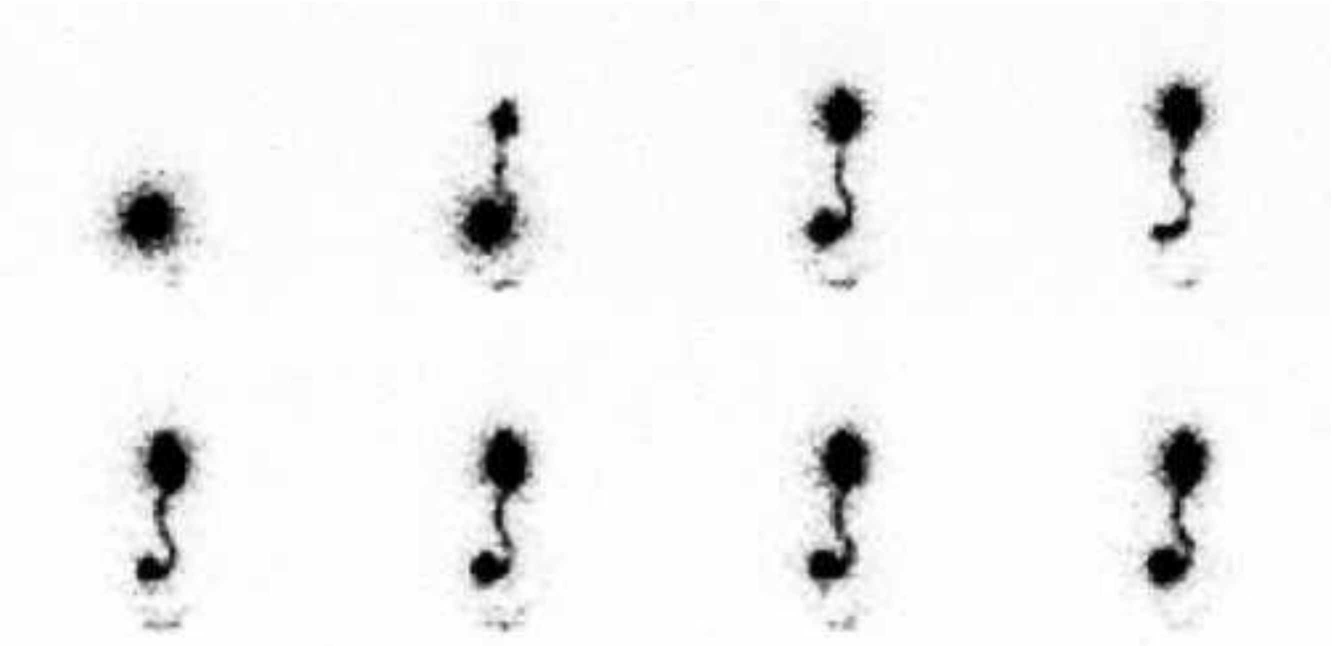
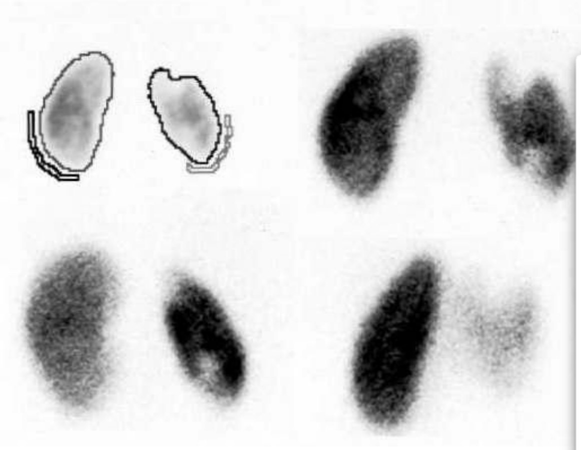
- Grades of reflux
  - Ureteric …. Renal
  - Dilation …. Non-dilation
  - Intrarenal reflux

DIRECT RADIONUCLIDE CYSTOGRAPHY

- Total time with reflux
- Volum of reflux
- Number of refluxes

- Cyclic reflux: neuropathic bladder
- Micturition or premicturition reflux



DIRECT RADIONUCLIDE CYSTOGRAPHY

17 % discordances with VCUG

sensitivity DRC > VCUG

- DRC
  - DIRECT RADIONUCLIDE CYSTOGRAPHY

- IRC
  - INDIRECT RADIONUCLIDE CYSTOGRAPHY

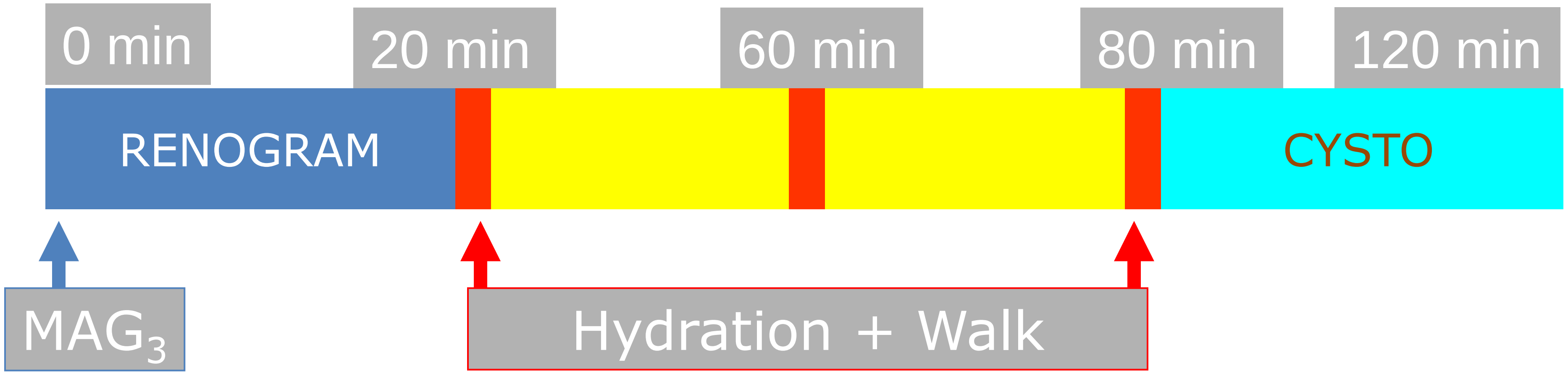
INDIRECT RADIONUCLIDE CYSTOGRAPHY

1- previous oral hydration + furosemide
2- renogram 20 min

3- cystography

$MAG_3 \rightarrow DRF$

$CYSTO \rightarrow VUR$



CHILDREN > 4-5 Y
WITH BLADDER CONTROL

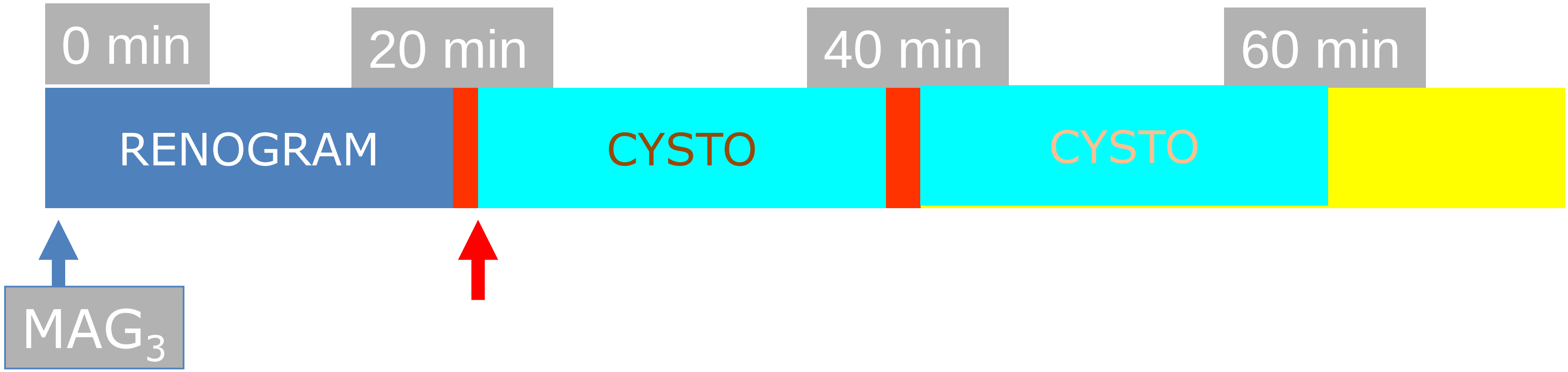
INDIRECT RADIONUCLIDE CYSTOGRAPHY

1- previous oral hydration + furosemide
2- renogram 20 min

3- cystography

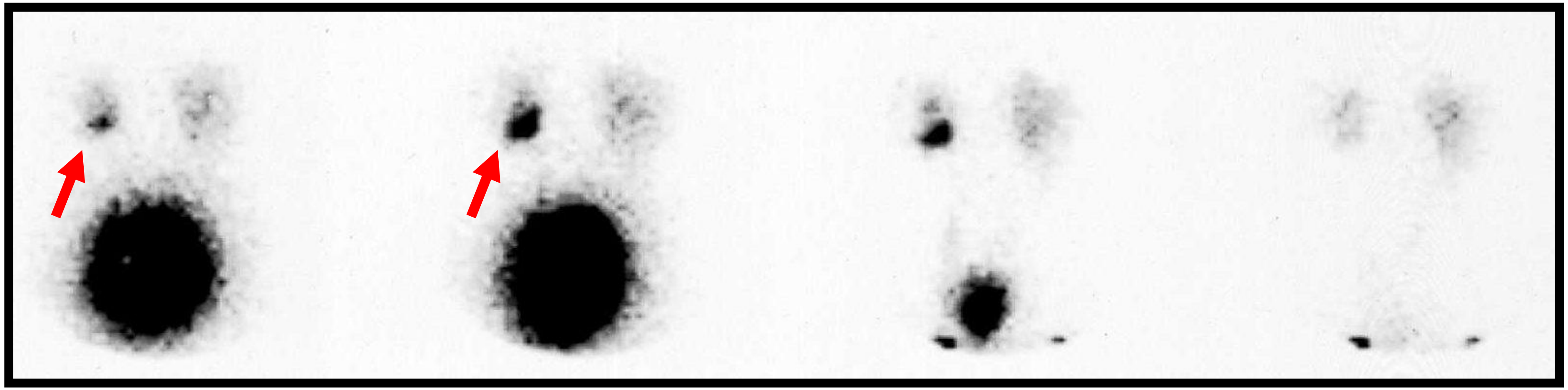
$MAG_3 \rightarrow$ DRF

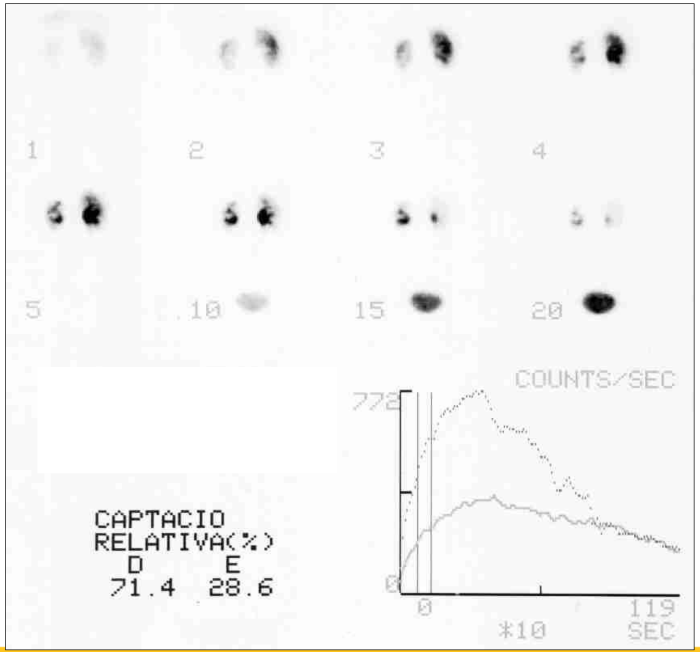
CYSTO $\rightarrow$ VUR



BABIES

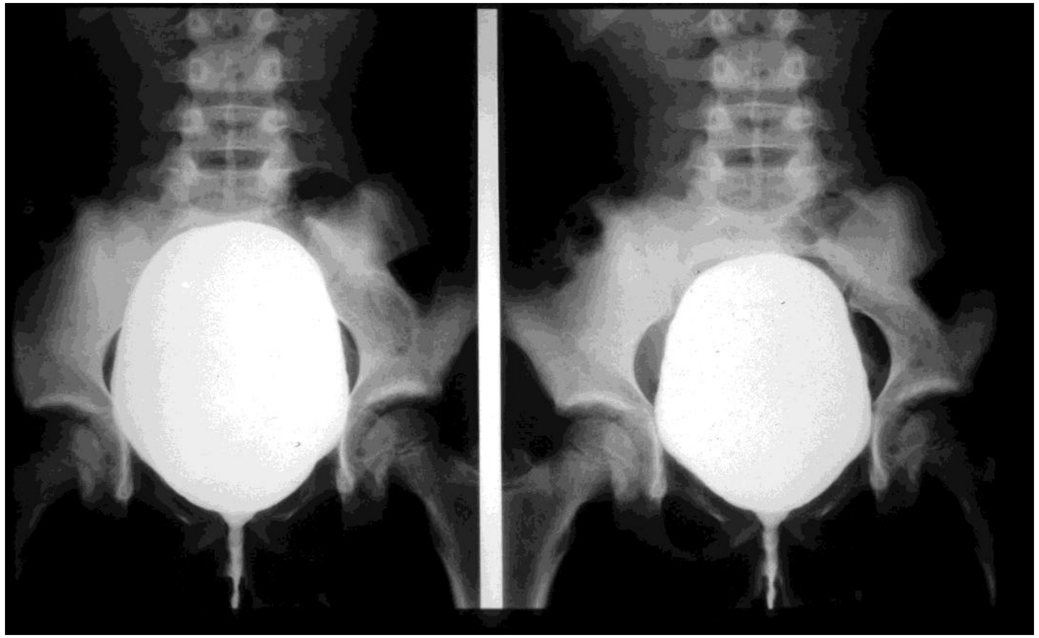
INDIRECT RADIONUCLIDE CYSTOGRAPHY





- Only detects RENAL REFLUX
  - VUR III-IV-V
- NO BLADDER CATHETER
- % DIFF RENAL FUNCTION
- LOW DOSIMETRY

COMPARISON VCUG – DRC - IRC



Sensitivity for VUR detection

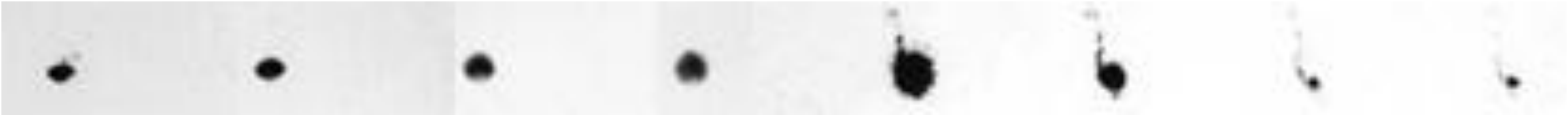
- DRC > VCUG> IRC

Sensitivity for VUR grade III, IV or V detection

- DRC ± VCUG ± IRC

Sensitivity for VUR grade I or II

- only VCUG



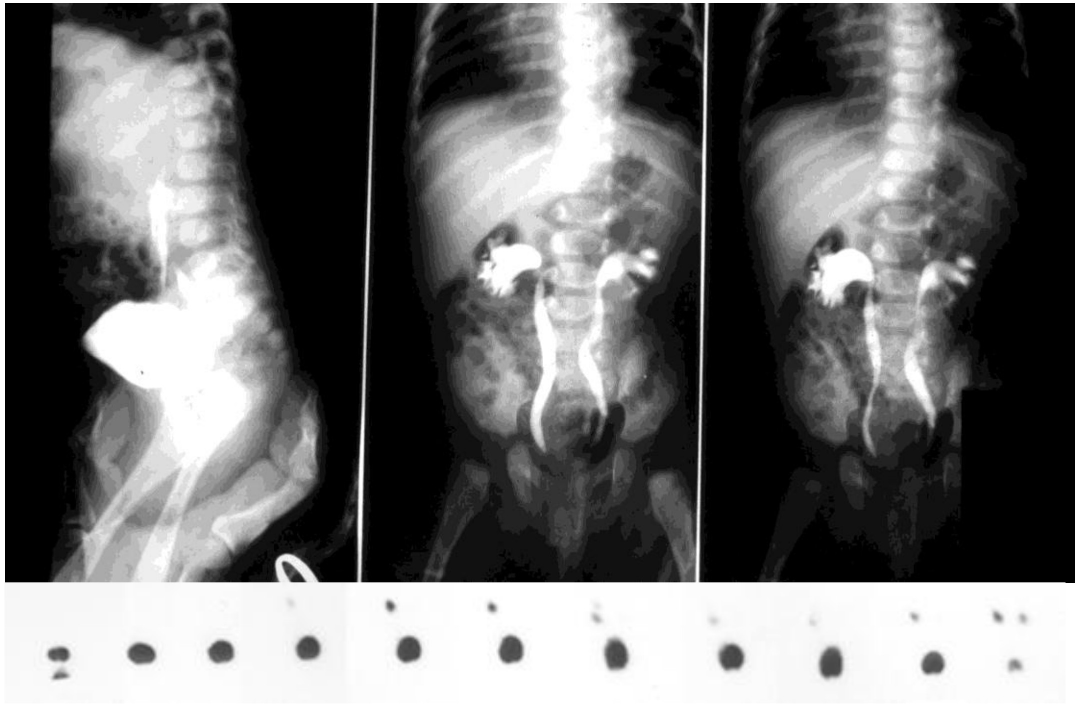
VCUG vs DRC

No Agreement:
VCUG: no VUR
DRC: LK VUR

COMPARISON VCUG – DRC - IRC

VCUG
- Reference technique
- Morphology (valves, bladder)
- Higher dosimetry >>>>> IRC > DRC (x200)

DRC and IRC
- Severity criteria?
  - Time (persistence) VUR
  - Number VUR / time
- IRC:
  - no catheter
  - detects significant VUR >III



VCUG vs DRC

Agreement:

VUR bilateral, III

Added information DRC:

RK: only micturition VUR

LK: persistent (>20min) VUR

VUR: Detection Rates

	VCUG		DRC
Dikshit(1993)	87%	=	96%
Merrick(1995)	47%	<	78%
Polito(2000)	55%	<	94%
McLaren(2001)	43%	<	91%
Unver(2006)	85%	=	69%
Average	**63%**	**<**	**86%**

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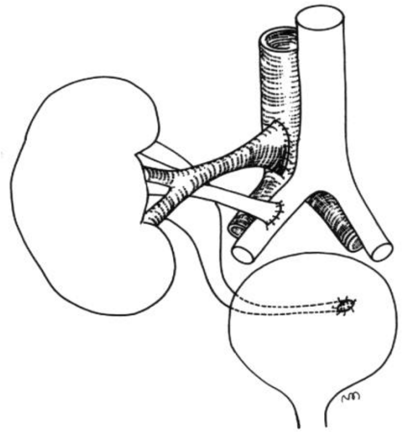
RENAL TRANSPLANT

In renal transplant, renography with 99mTc-DTPA or MAG3 can depict urgent renal transplant complications, like:

- Rejection
- Toxicity
- Urinary leakage

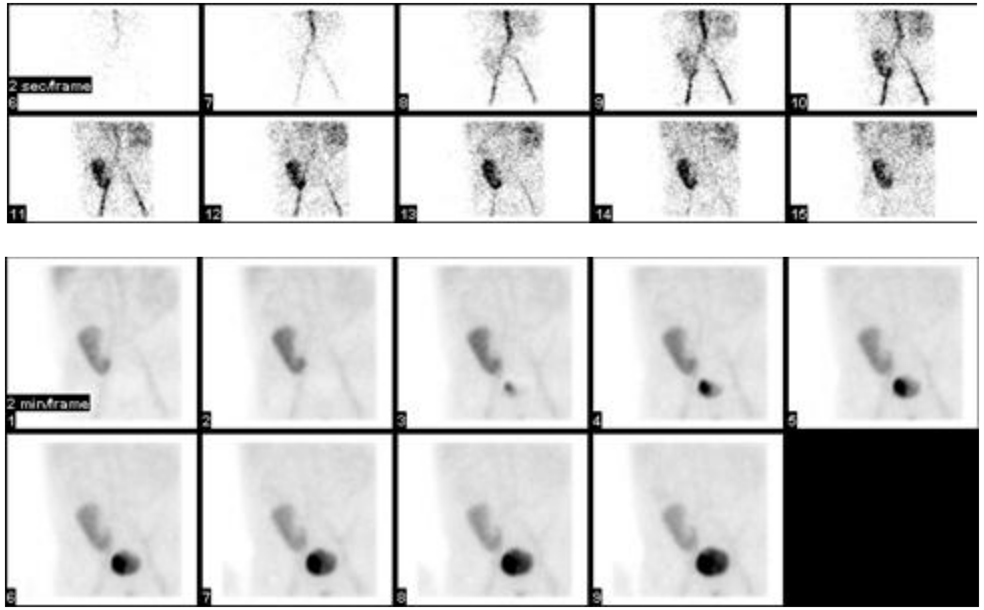


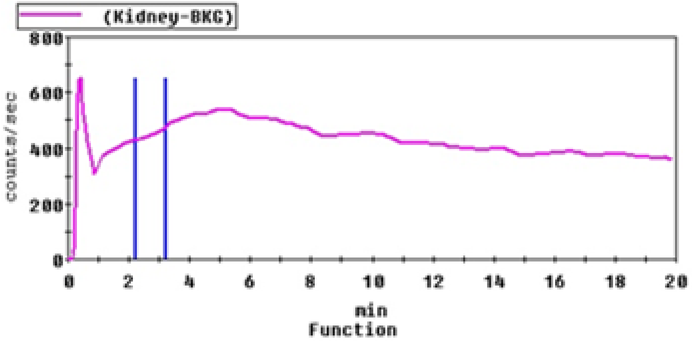
- Yazici B, Oral A, Gokalp C, Akgün A, Toz H, Ozbek SS, Yazici A. Evaluation of Renal Transplant Scintigraphy and Resistance Index Performed Within 2 Days After Transplantation in Predicting Long-Term Graft Function. Clin Nucl Med. 2015 Jul;40(7):548-52.

- Miguel MB, Roca I, Pi-Ferrer A, Callís LM, Aguadé S, Domènech-Torné FM. Renal transplantation in children: punction-aspiration biopsy and renogram
- with 99mTc-DTPA. Med Clin (Barc). 1992 Nov 7;99(15):561-4.

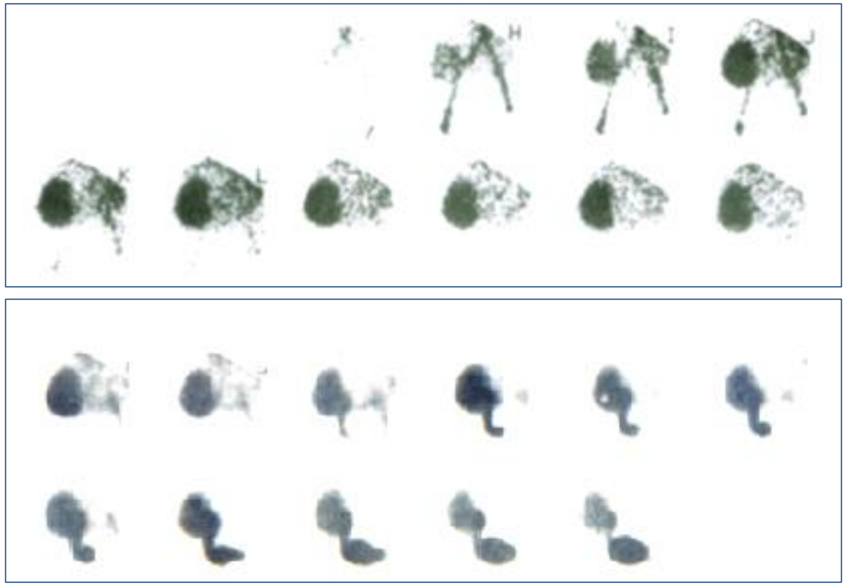
- Sundaraiya S, Mendichovszky I, Biassoni L, Sebire N, Trompeter RS, Gordon I. Tc-99m DTPA renography in children following renal transplantation: its value in the evaluation of rejection. Pediatr Transplant. 2007 Nov;11(7):771-6.

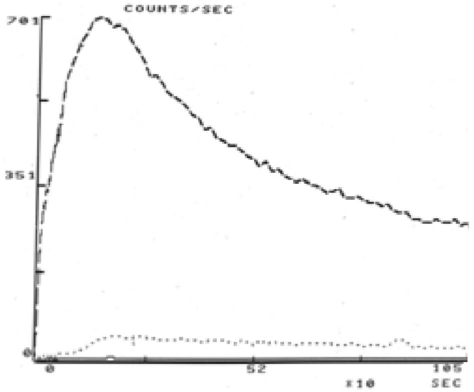
^{99m}Tc-DTPA

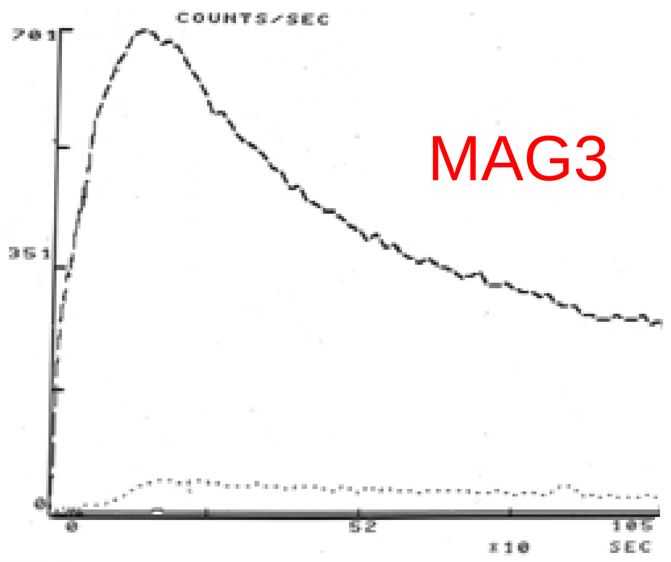


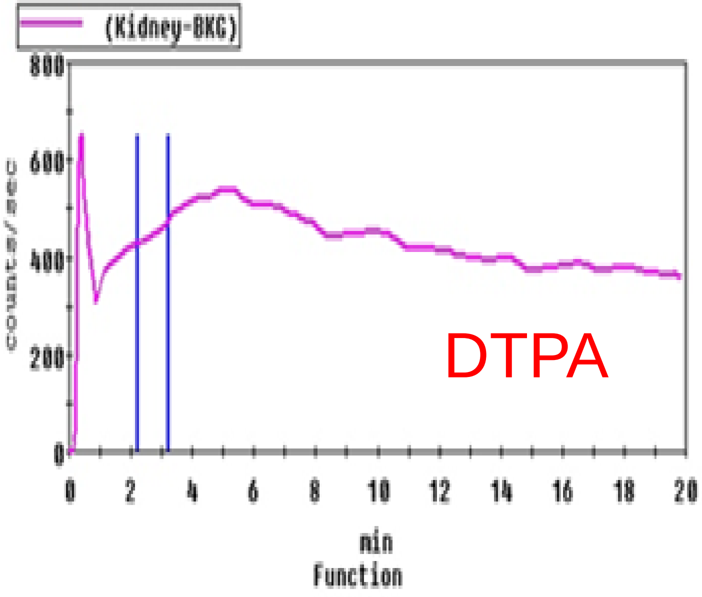


99mTc-MAG3

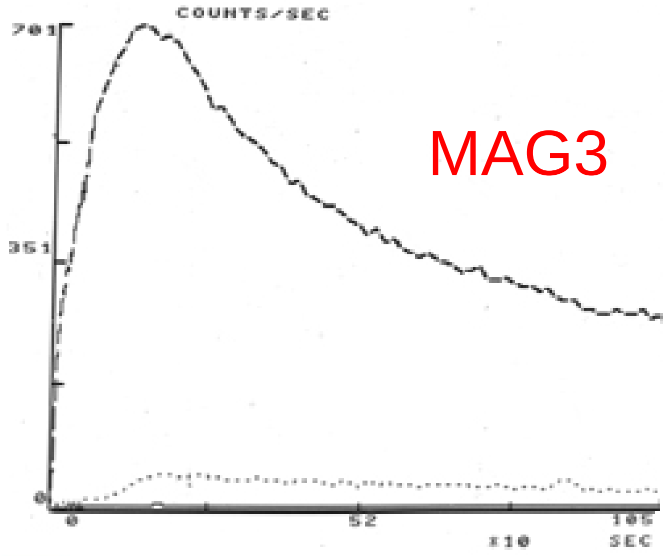


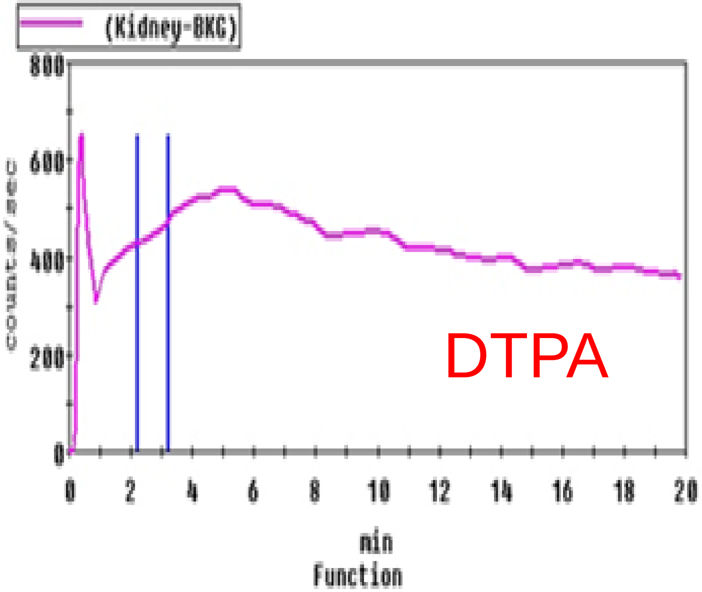






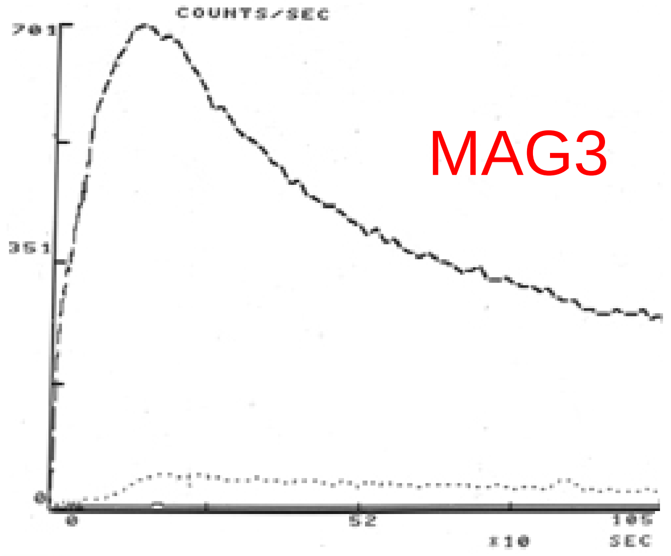
- MAG3 higher renal uptake
- DTPA higher background activity

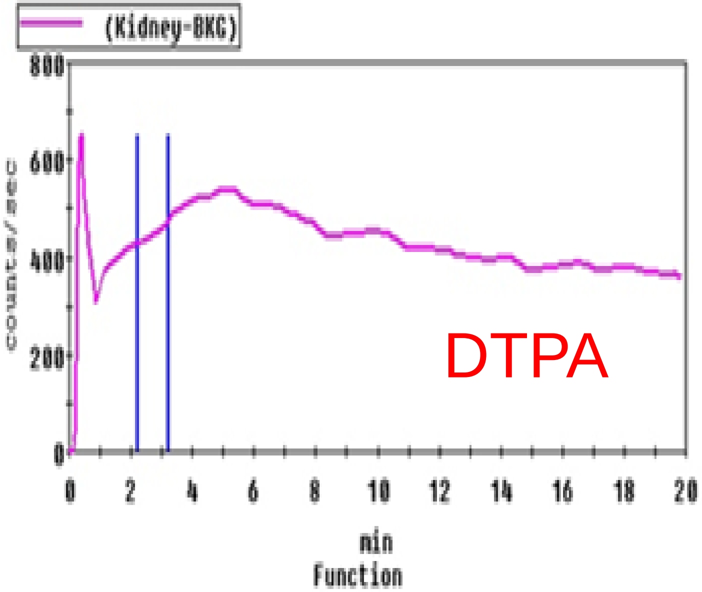




- MAG3 higher renal uptake
- DTPA higher background activity

- MAG3 is the reference for drainage obstruction
- MAG3 is the reference to detect urinary leakage

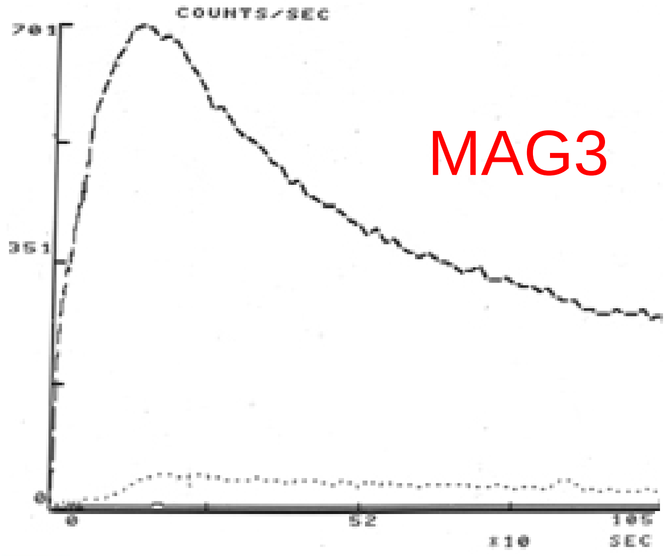


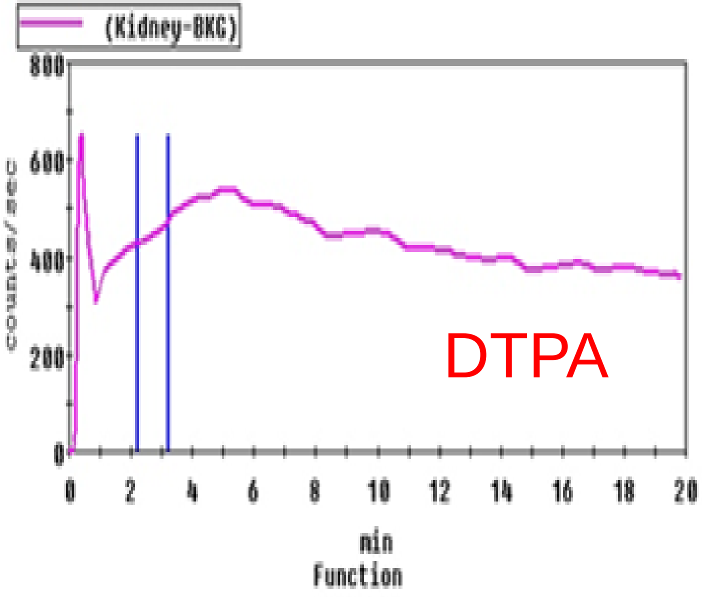


- MAG3 higher renal uptake
- DTPA higher background activity

- MAG3 is the reference for drainage obstruction
- MAG3 is the reference to detect urinary leakage

- MAG3 visualizes kidneys with renal impairment
- DTPA uptake varies very quickly with renal impairment





- MAG3 higher renal uptake
- DTPA higher background activity

- MAG3 is the reference for drainage obstruction
- MAG3 is the reference to detect urinary leakage

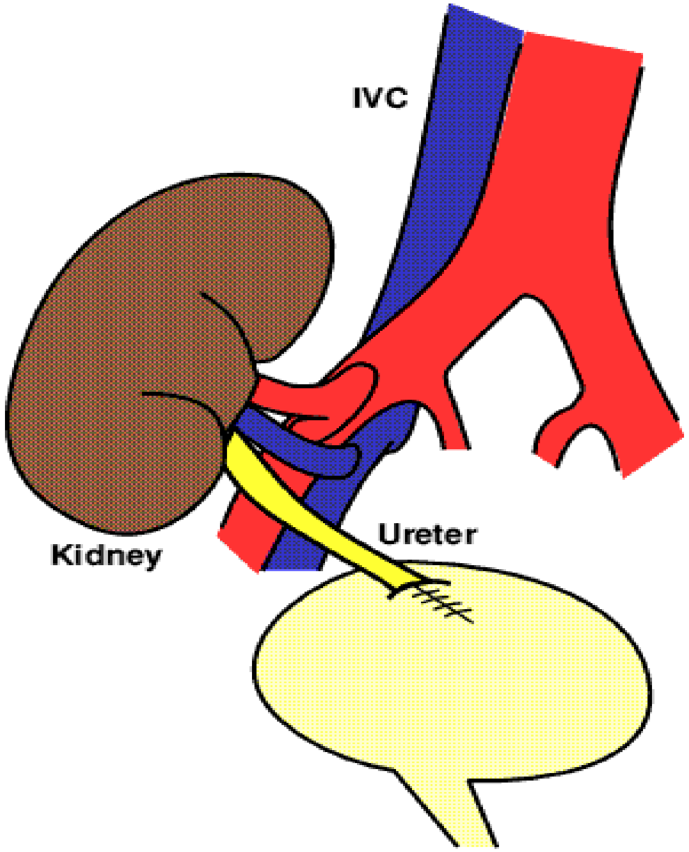
- MAG3 visualizes kidneys with renal impairment
- DTPA uptake varies very quickly with renal impairment

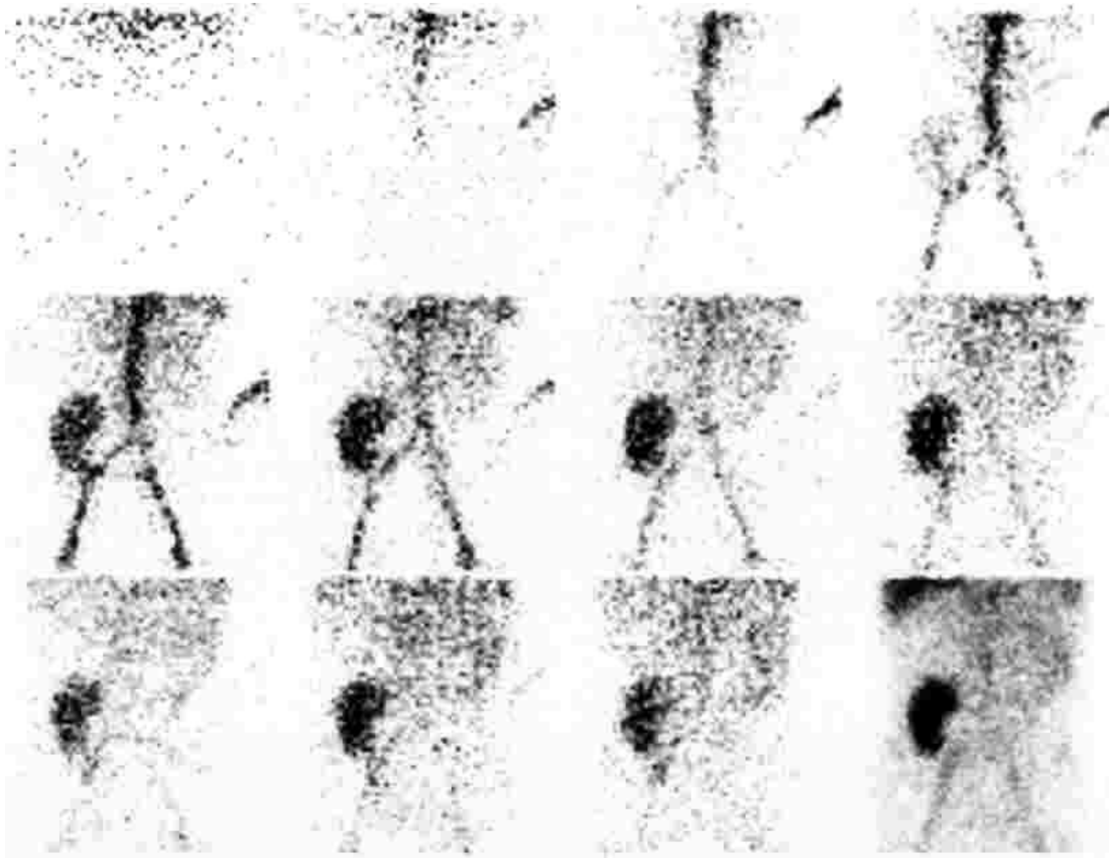
- DTPA is better to detect renal function deterioration or improvement

  Because it is a worse kidney tracer

VASCULAR PHASE

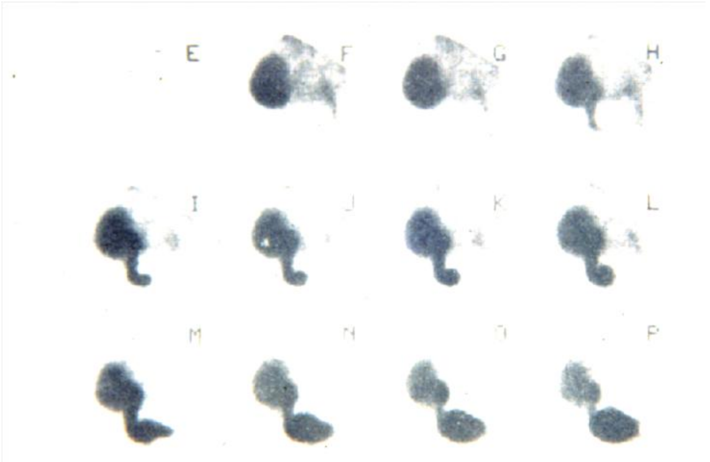
MAG3 = DTPA

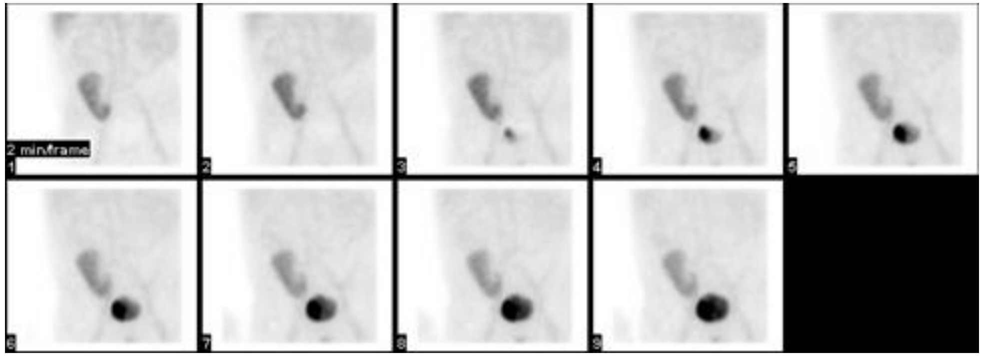


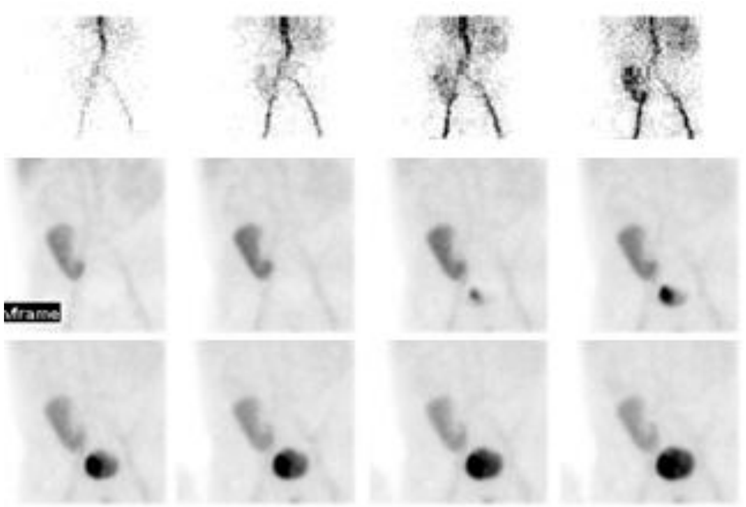


RENOGRAPHIC PHASE

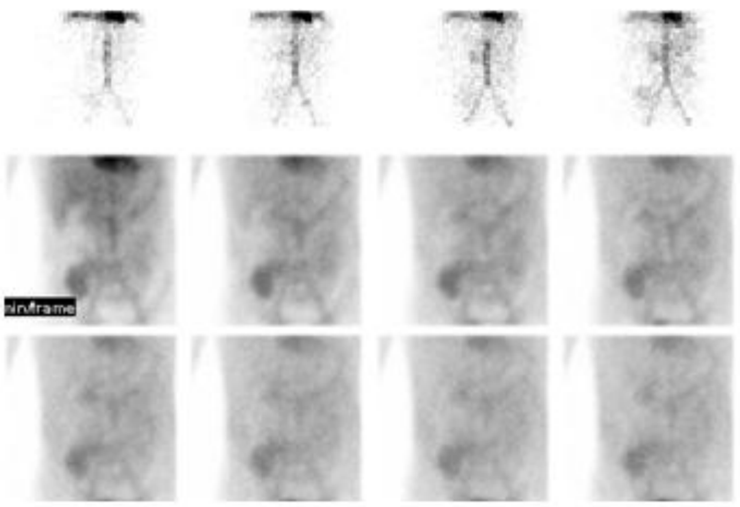
MAG3 ≠ DTPA







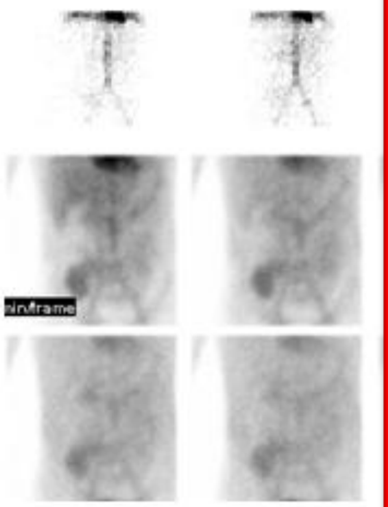
	VASCULAR PHASE	RENOGRAPHIC PHASE	
	MAG3=DTPA	DTPA	MAG3
NORMAL	N	biphasic curve	
ATN	mild decrease	Low uptake Curve: decreased, elution Recovery: uptake and slope increases progressively	Accumulative curve Recovery: slope is normalized
REJECTION	+++ decreased	impairment, loss of function compared to previous RNG	
TOXICITY	N	impairment, loss of function compared to previous RNG	
URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	



^{99m}TcDTPA

	VASCULAR PHASE	RENOGRAPHIC PHASE	
	MAG3=DTPA	DTPA	MAG3
NORMAL	N	biphasic curve	
ATN	mild decrease	Low uptake Curve: decreased, elution Recovery: uptake and slope increases progressively	Accumulative curve Recovery: slope is normalized
REJECTION	+++ decreased	impairment, loss of function compared to previous RNG	
TOXICITY	N	impairment, loss of function compared to previous RNG	
URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	

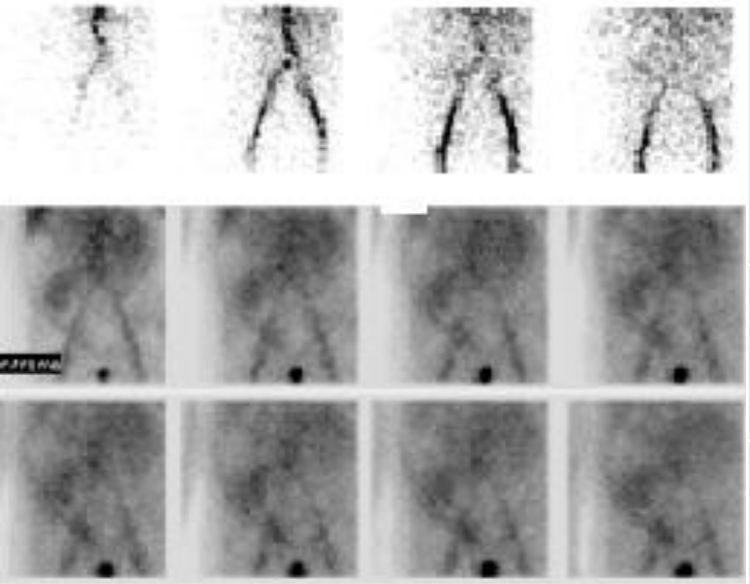
	VASCULAR PHASE	RENOGRAPHIC PHASE	
			MAG3
			ve
			umulative curve
			covery: slope is normalized
			on compared to G
			on compared to G
URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	



99m

REMEMBER: an ATN NEVER get WORSE

If there is a funcional worsening, think in other possibilities: rejection or toxicity, or urinary obstruction



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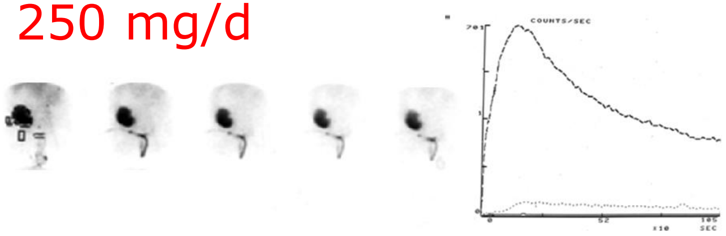
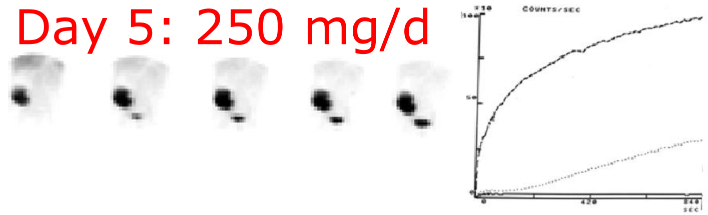
URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	

Cyclosporine toxicity

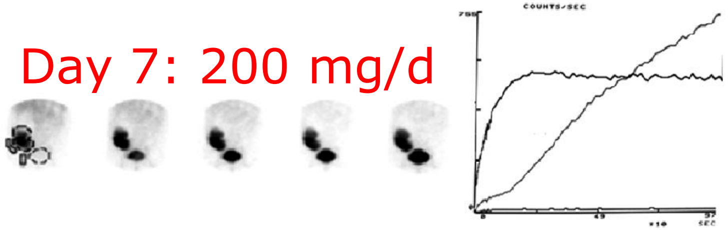
Day 1 – 3w after surgery
250 mg/d



Day 5: 250 mg/d

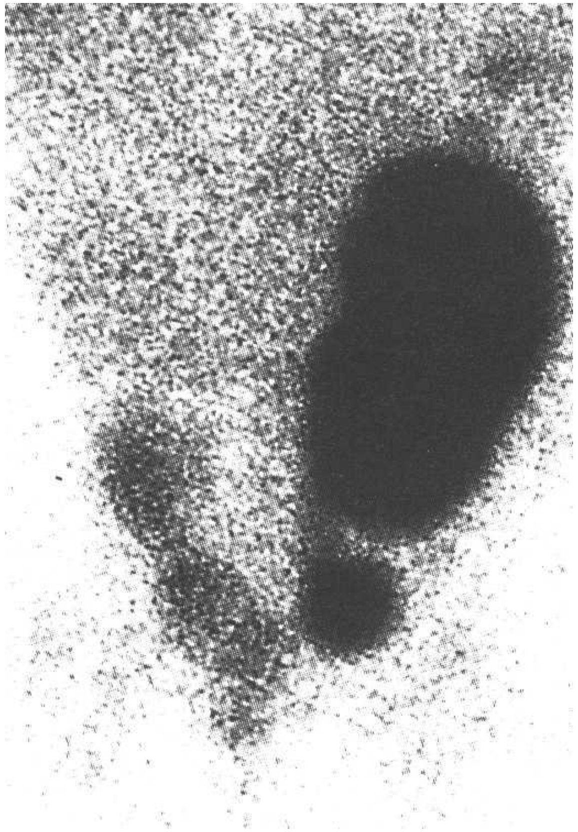


Day 7: 200 mg/d



	VASCULAR PHASE	RENOGRAPHIC PHASE	
	MAG3=DTPA	DTPA	MAG3
NORMAL	N	biphasic curve	
ATN	mild decrease	Low uptake Curve: decreased, elution Recovery: uptake and slope increases progressively	Accumulative curve Recovery: slope is normalized
REJECTION	+++ decreased	impairment, loss of function compared to previous RNG	
TOXICITY	N	impairment, loss of function compared to previous RNG	
URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	

24h image



	VASCULAR PHASE	RENOGRAPHIC PHASE	
	MAG3=DTPA	DTPA	MAG3
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URINARY LEAKAGE		delayed images MAG3 >>>> DTPA	

OVERVIEW

- DMSA RENAL CORTICAL SCINTIGRAPHY IN PAEDIATRIC FEBRILE UTIs
- LASIX RENOGRAPHY IN URINARY OBSTRUCTION
- DIRECT AND INDIRECT RADIONUCLIDE CYSTOGRAPHY
- RENAL TRANSPLANT RENOGRAPHY
- RADIONUCLIDE STUDIES IN RENAL VASCULAR HYPERTENSION

RENOVASCULAR HYPERTENSION

PHYSIOPATHOLOGY

RENAL ARTERY STENOSIS → Diminished renal perfusion

To try to **maintain / increase** the renal blood pressure → **ACTIVATION of the SYSTEM RENIN ANGIOTENSIN**

With production of:

- angiotensin II
  vasoconstriction
- aldosterone
  plasma expansion

RENOVASCULAR HYPERTENSION

PHYSIOPATHOLOGY

PHARMACOLOGICAL
BLOKADE
of the activated system
renin-angiotensin

DROP IN THE FUNCTION of the stenotic kidney

FUNCTION IMPAIRMENT DETECTABLE BY RENOGRAPHY

- renography:
  MORPHOLOGY + FUNCTION
- information about REVERSIBILITY of the arterial lesion

REVERSIBILITY

- HIGHER in initial phases
- prediction of a better result of the revascularization

RENOVASCULAR HYPERTENSION

CHRONIC PHASE

PHARMACOLOGICAL **BLOKADE** less effective

“FIXED” HYPERTENSION

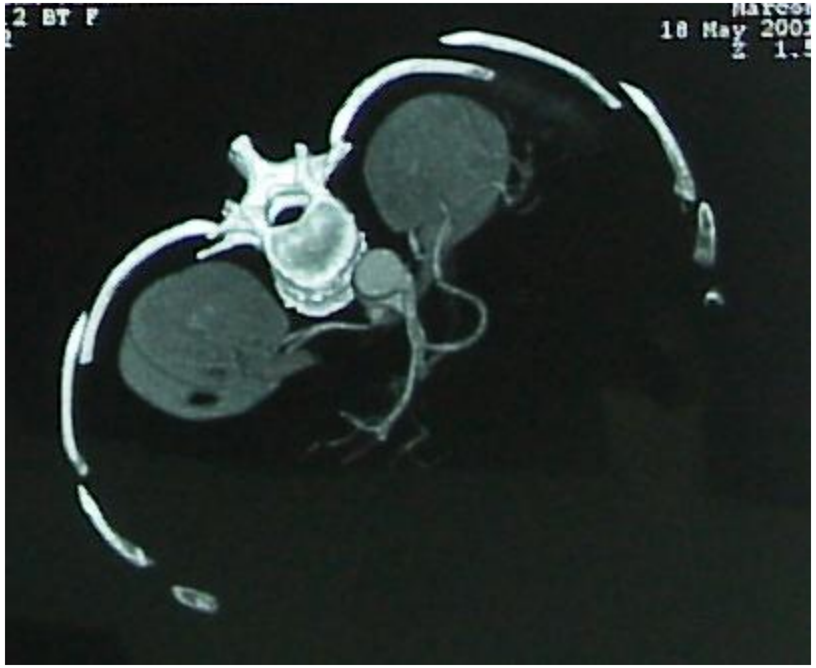
HYPERTENSION

NON

REVERSIBLE AFTER THE RENAL ARTERY STENOSIS DILATATION

RENAL ANGIOGRAPHY

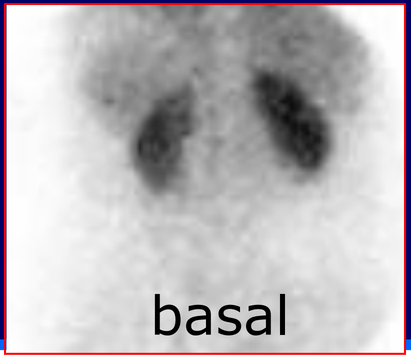
- "**gold standard**" : diagnostic of renovascular hypertension
- detects **anatomic abnormalities** of the renal artery
- does **not supply** information about
    - function
    - reversibility of the lesion

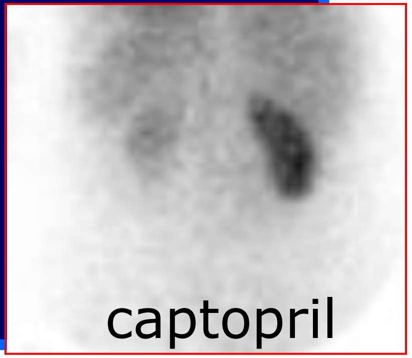


CAPTOPRIL RENOGRAPHY

- well standarized technique

- comparison 2 renographies:
    - basal
    - post-captopril





If reversible stenosis of the renal artery, captopril:

• diminishes the VC of the post-glomerular eferent arteriole

• disminishes the glomerular filtration of the stenotic kidney

• increases the transit time of this kidney

CAPTOPRIL RENOGRAPHY
preparation

- stop the treatment with ACE (angiotensin-converting enzym) inhibidors.
    - during 5-7 days before the renographies
- stop if possible the diuretic
- stop if possible the calcium channel blockers

- the technique can be used in patients with:
    - one kidney
    - renal transplantation
    - children

    Adjusting the captopril dose

CAPTOPRIL RENOGRAPHY
Technique

RENOGRAPHY : 99mTc-Mag3, 99mTc-DTPA
RENAL SCINTIGRAPHY : 99mTc-DMSA

PREPARATION
- oral hydration
- previous micturition
- 0.25 mg/kg frusemide IV F0 (tp avoid ectasia in calyces and pelvis)
- stop ACE blockers 7 days before
- if possible, stop diuretics and calcium cannel blockers

CAPTOPRIL
- captopril per or or IV 60 minutes before the renography
- doses:
  - 50 mg adults - 25 mg one kidney
  - children: doses adapted to body weight
- BP and heart rate monitoring:
  - before captopril
  - 15-30-45 min after captopril

CAPTOPRIL RENOGRAPHY
Technique

RENOGRAPHY : 99mTc-Mag3, 99mTc-DTPA
RENAL SCINTIGRAPHY : 99mTc-DMSA

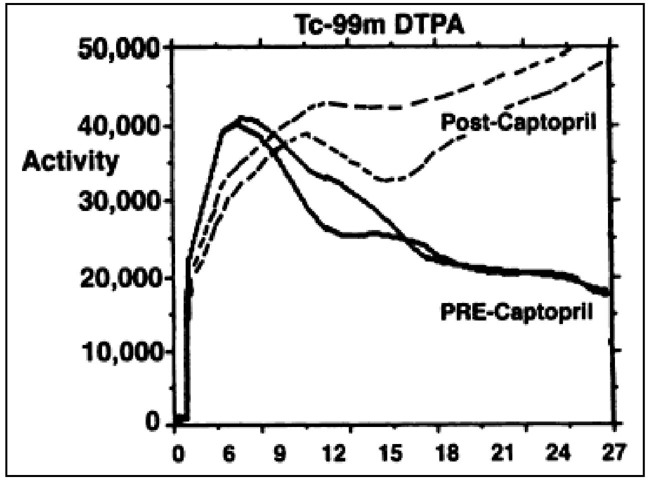
LIMITATION

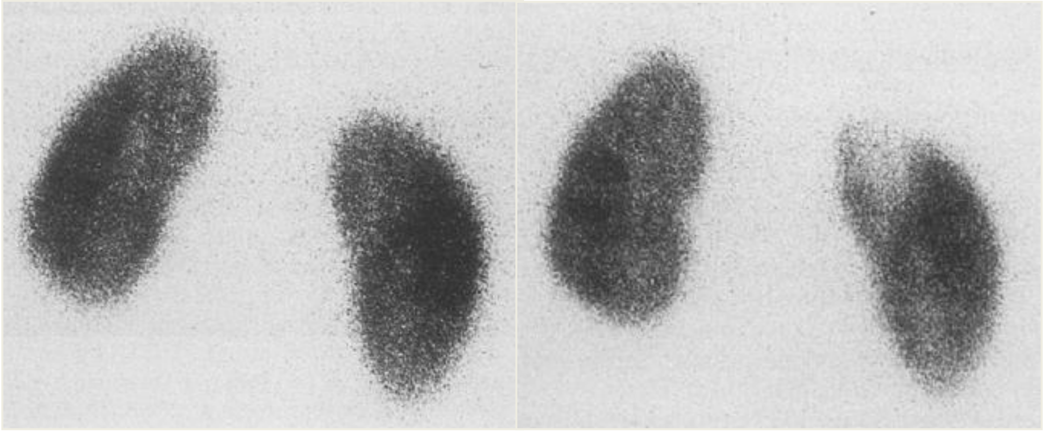
- LOW or very low function of the stenotic kidney
- transient impairment of the GFR secondary to
    - radiological contrast (CT, angiography)
    - from 15 days before
    - iònic and non-iònic contrast

RADIOPHARMACEUTICAL AND TECHNIQUE

- adults and older children
    - renography DTPA or MAG3
- babies and young children, and in case of suspected polar artery stenosis
    - renal DMSA scintigraphy

CAPTOPRIL RENOGRAPHY
INTERPRETATION
Comparison basal - captopril





RENOGRAPHY

^{99m}Tc-DTPA

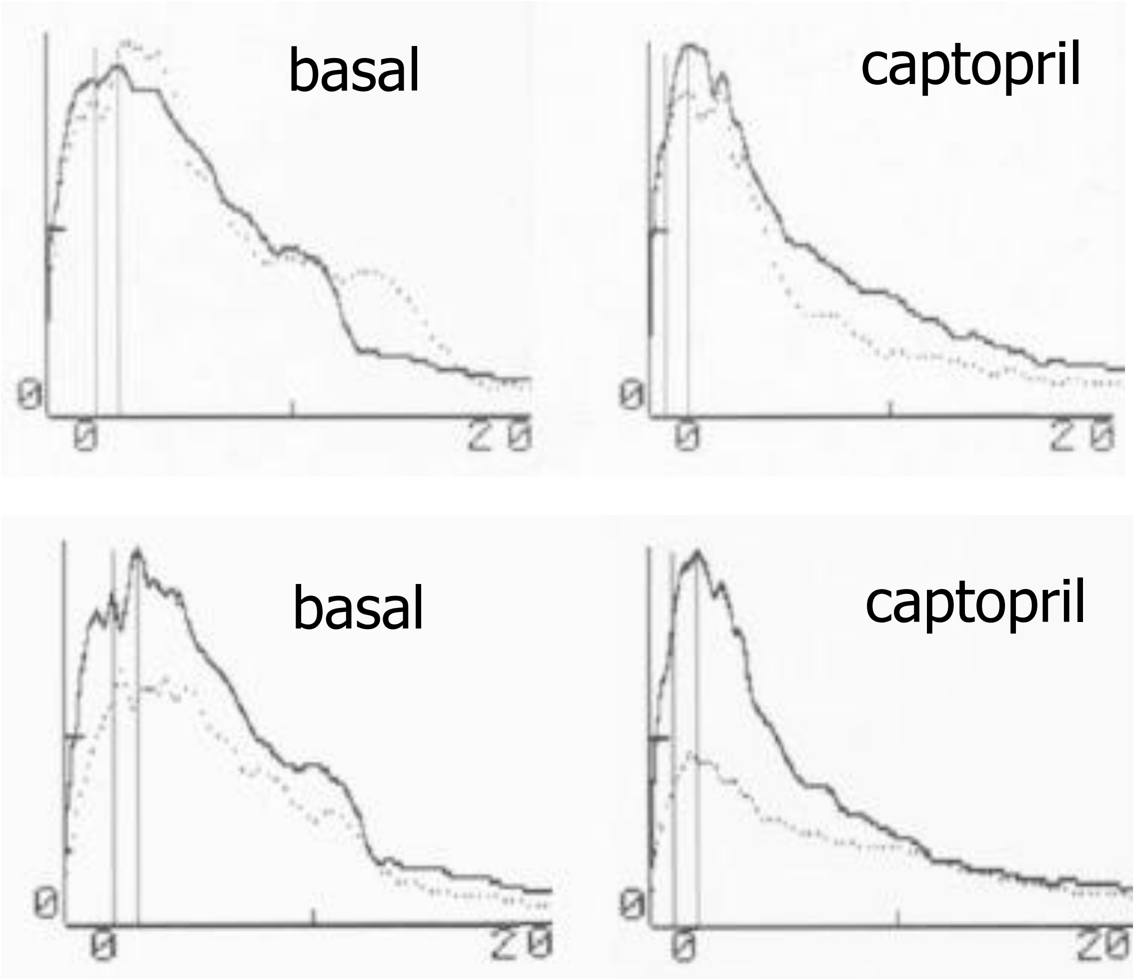
^{99m}Tc-MAG$_3$

- ↓ function
- ↑ transit time
- cortical tracer retention

RENAL DMSA SCAN

^{99m}Tc-DMSA

- ↓ function
- ↓ renal uptale, diffuse or
- focal

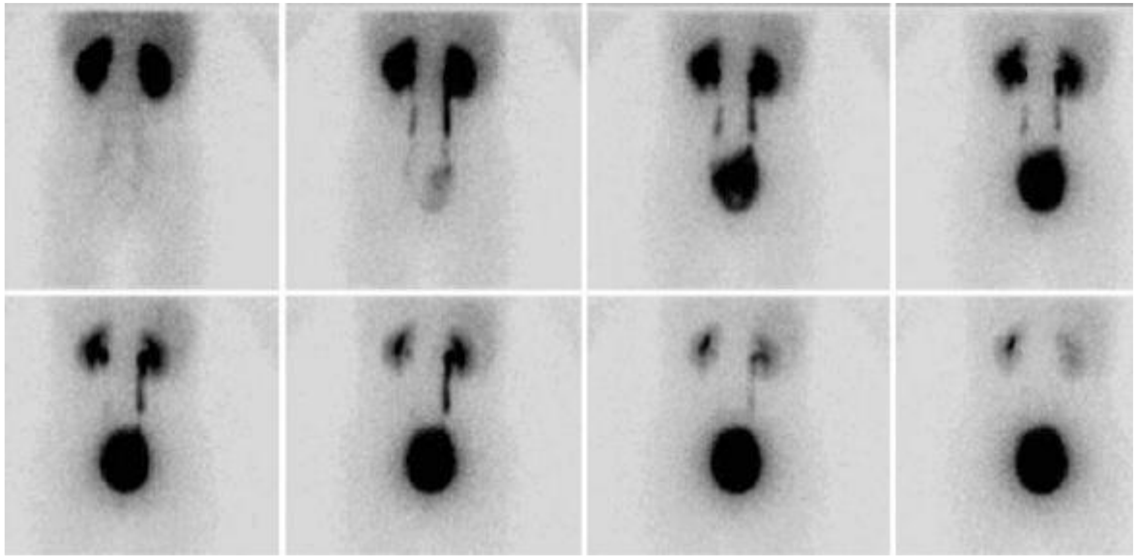


RENOGRAPHY
- **RK**
- **LK**
  - correct BILATERAL function and excretion

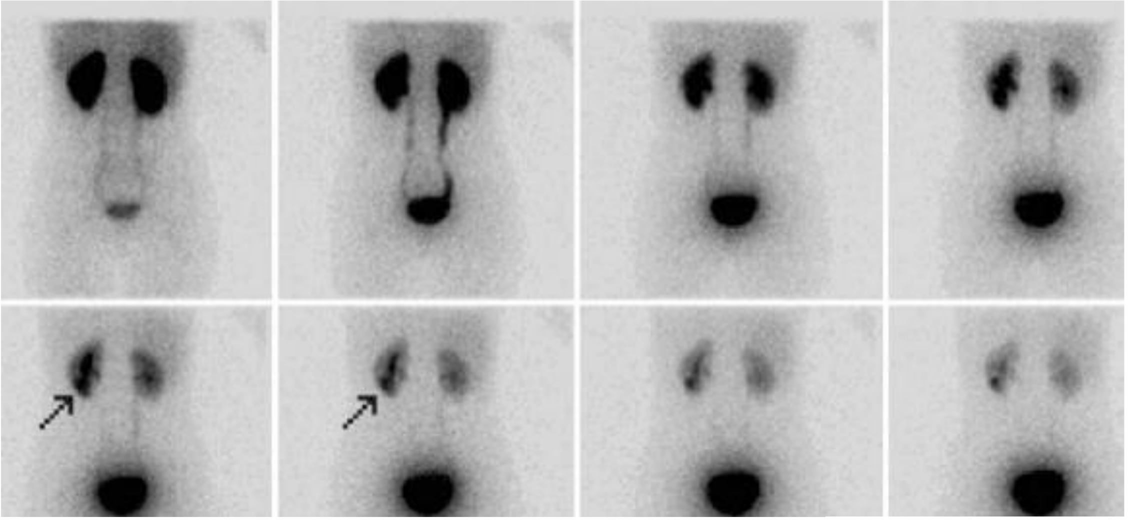
RENOGRAPHY of the LEFT KIDNEY
- **SUPERIOR MOIETY**
  - No changes
- **INFERIOR MOIETY**
  - Drop of function post-captopril

Segmental renal artery stenosis diagnosed with captopril renography in a child

Pediatr Radiol (2004) 34: 636–639



BASAL RENOGRAPHY
- **RK**
- **LK**
  - correcta función y excreción bilateral



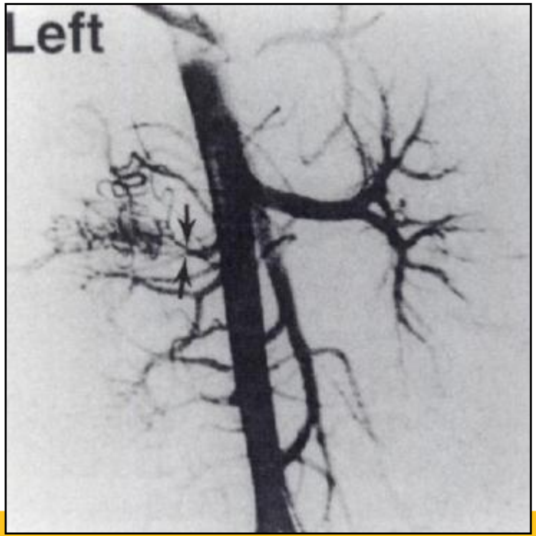
CAPTOPRIL RENOGRAPHY
- **LK: focal area with cortical retencion in lower pole, with prolonged TT**

Segmental renal artery stenosis diagnosed with captopril renography in a child

Pediatr Radiol (2004) 34: 636–639

basal

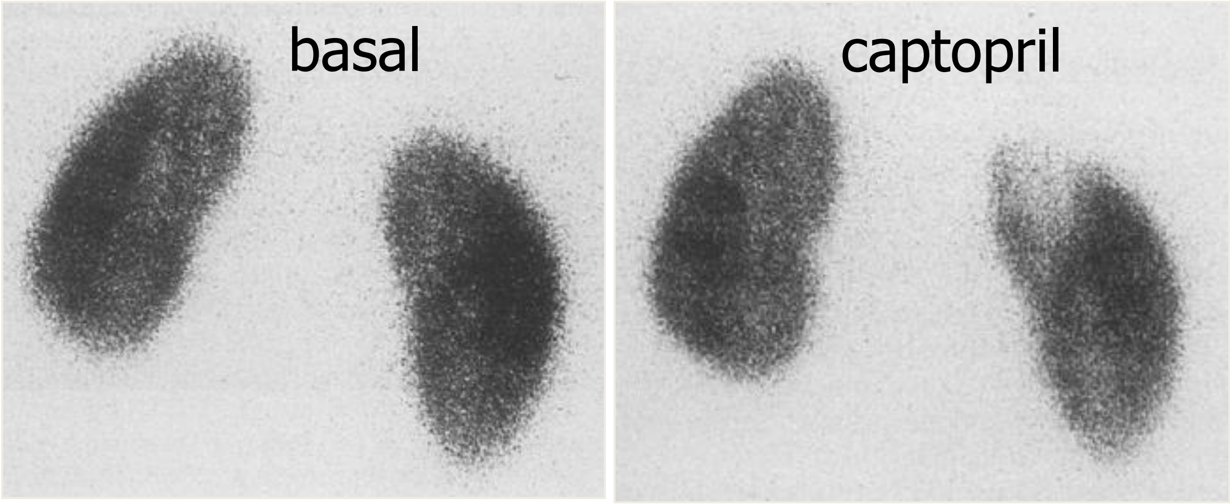
captopril



LEFT RENAL ARTERY STENOSIS

Hypotensive Response to Captopril:
A Potential Pitfall of Scintigraphic Assessment for Renal Artery Stenosis

J Nucl Med 1999; 40:406–411



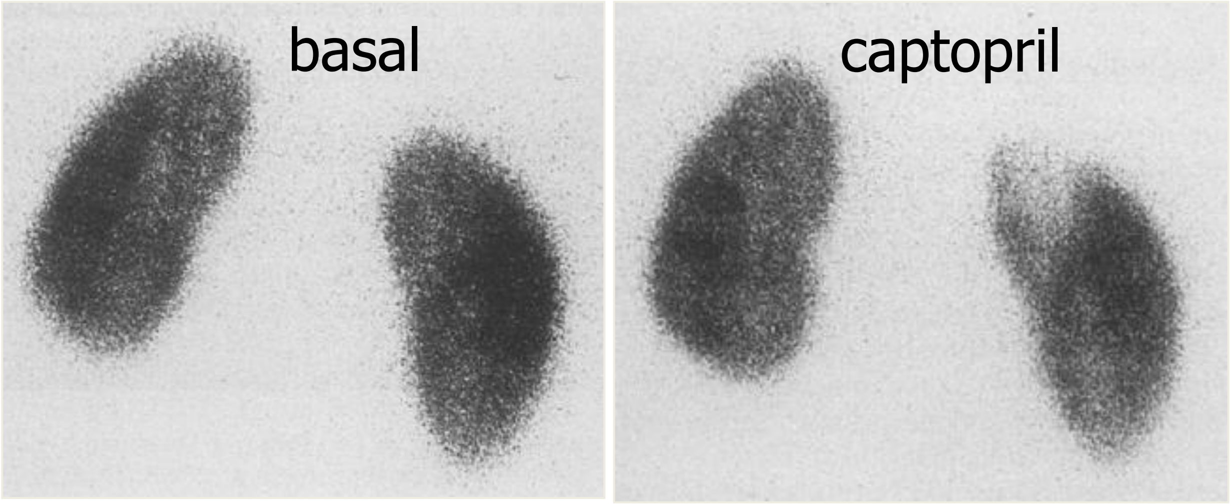
SENSITIVITY	64%
SPECIFICITY	44%

ARTERIOGRAPHY

DMSA basal		normal	abnormal
	normal	4	4
	abnormal	5	7

Hypertension in paediatrics: can pre- and post-captopril technetium-99m dimercaptosuccinic acid renal scans exclude renovascular disease?

Eur J Nucl Med (1993) 20:699–702



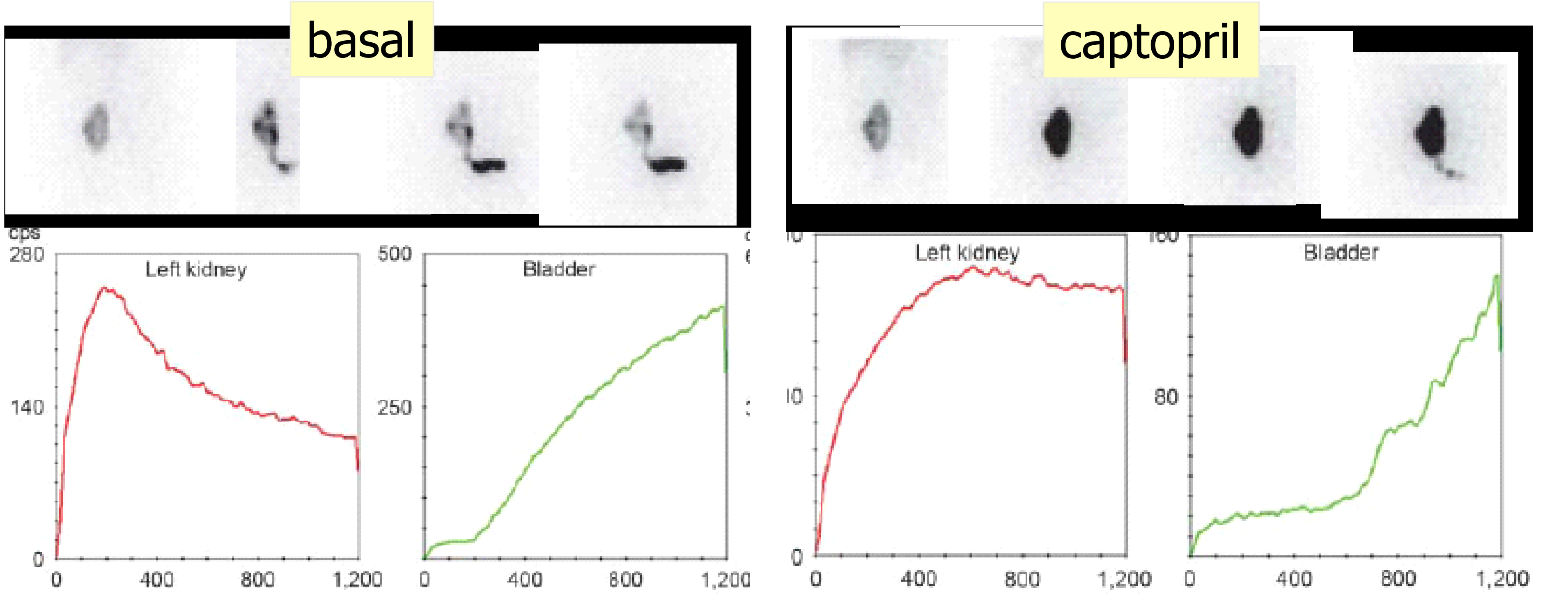
SENSITIVITY	91%
SPECIFICITY	50%

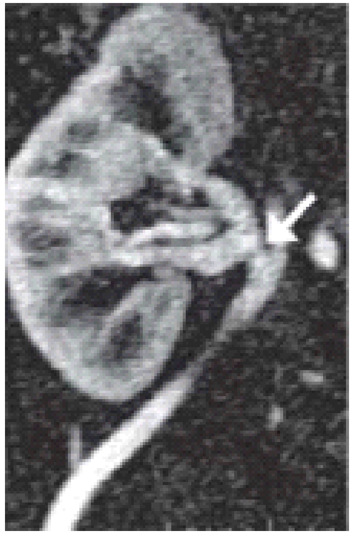
ARTERIOGRAPHY

DMSA captopril		normal	abnormal
	normal	4	1
	abnormal	4	10

Hypertension in paediatrics: can pre- and post-captopril technetium-99m dimercaptosuccinic acid renal scans exclude renovascular disease?

Eur J Nucl Med (1993) 20:699–702





RENAL TRASPLANT

- **max 25 mg captopril**
- **captopril:**
  - **↓ function**
  - **↑ TT**
  - **↓ urinary drainage**

Radionuclide Investigations of the Urinary Tract in the Era of Multimodality Imaging*

J Nucl Med 2006; 47:1819–1836

CAPTOPRIL RENOGRAPHY
COMMENTS

The **captopril renography** is a
morphologic and functional technique
with **low dosimetry**

It provides information about the existence or not of a
renal arterial stenosis

and about its
reversibility and
prognostic of response to the treatment

THANKS!

- DMSA RENAL CORTICAL SCINTIGRAPHY IN PAEDIATRIC FEBRILE UTIs
- LASIX RENOGRAPHY IN URINARY OBSTRUCTION
- DIRECT AND INDIRECT RADIONUCLIDE CYSTOGRAPHY
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