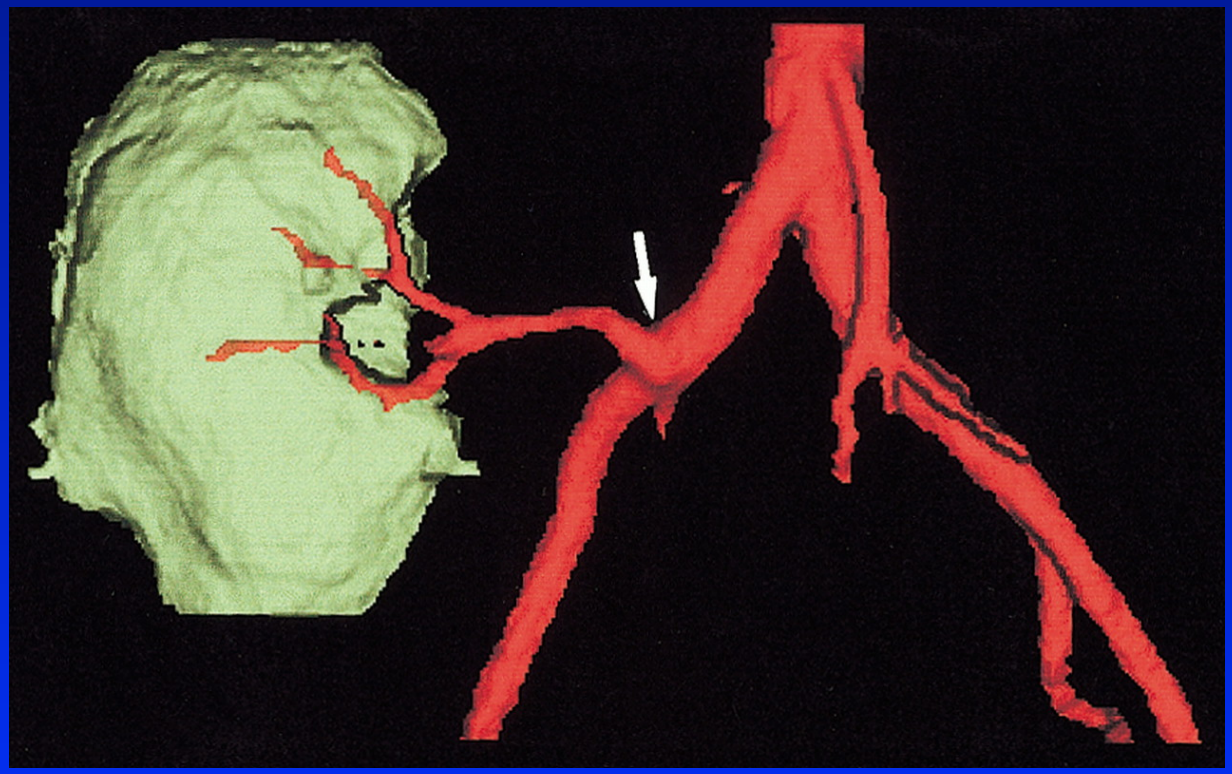
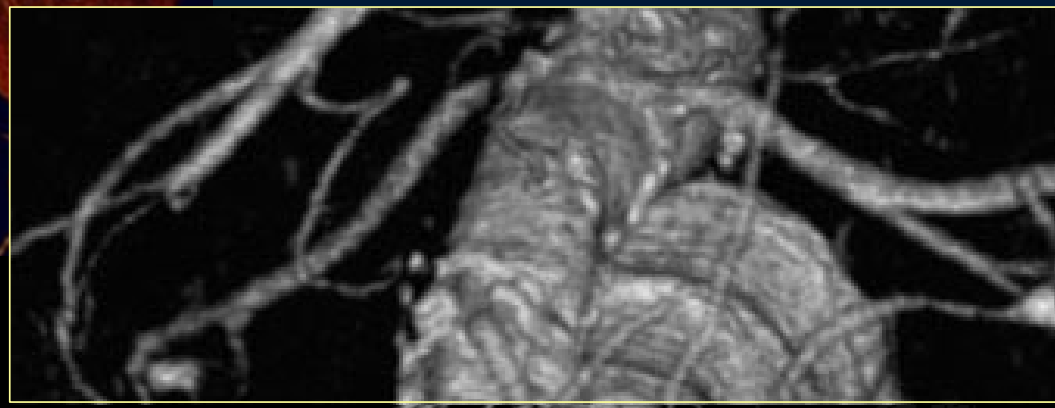
Renal Nuclear Medicine

John Buscombe

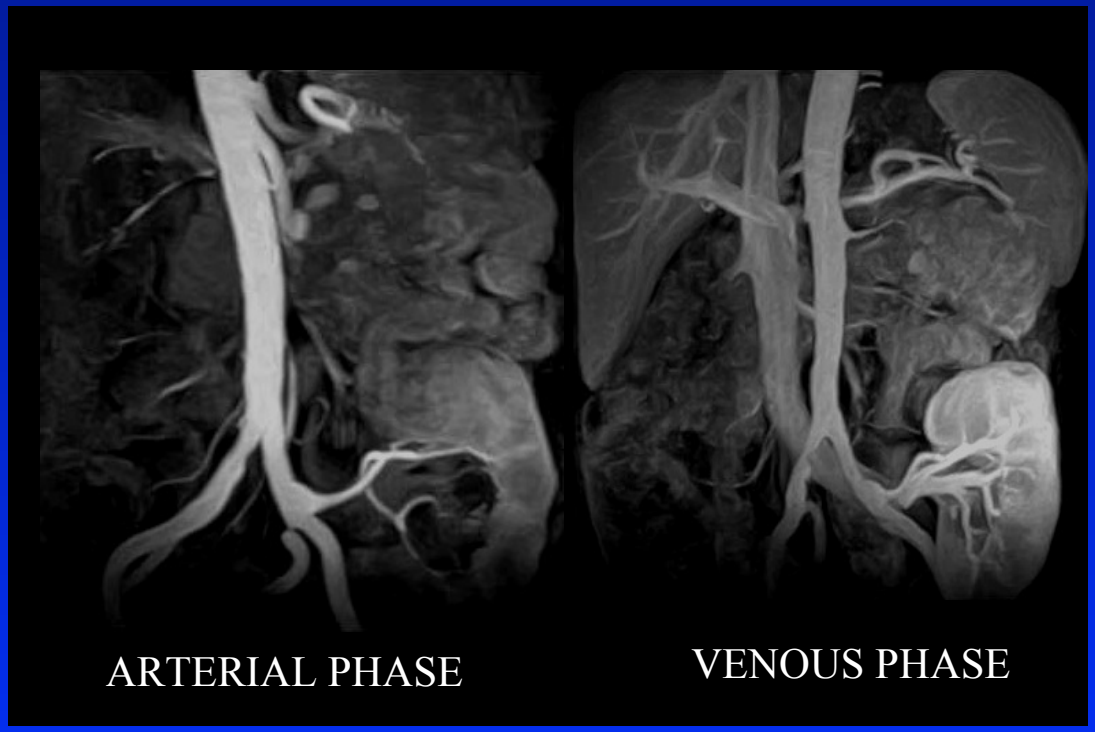
Why bother?
CT can do it



Concomitant Stenoses



Why bother?
MR can do it.



NUCLEAR MEDICINE
Is
Functional Imaging

- To visualise an organ needs a contrast with the surrounding tissue.
- Radiography/CT needs difference in density.
- MRI needs difference in protons.
- Ultrasound needs difference in reflectivity.
- Nuclear Medicine needs difference in function.

Functional Imaging

Tracers

- Tracer is substance added to a physiological pathway, which is handled by that pathway but does not disturb it.
- Requires small chemical amount of material, but high contrast with tissue which does not contain pathway.

- Tc-99m-DTPA is a tracer for glomerular filtration
- Intra-coronary angiographic contrast is not a tracer for coronary flow.

Functional Imaging

- FUNCTIONAL IMAGING NEEDS TRACERS
- Need to study whole organ over an appropriate time interval.

Renal Function?

Total renal function

- No pure imaging method works
- Best is to measure GFR with Cr-51-EDTA or Tc- 99m-DTPA and blood sampling.
- Single-kidney GFR from total + divided function.

Renal Blood Flow

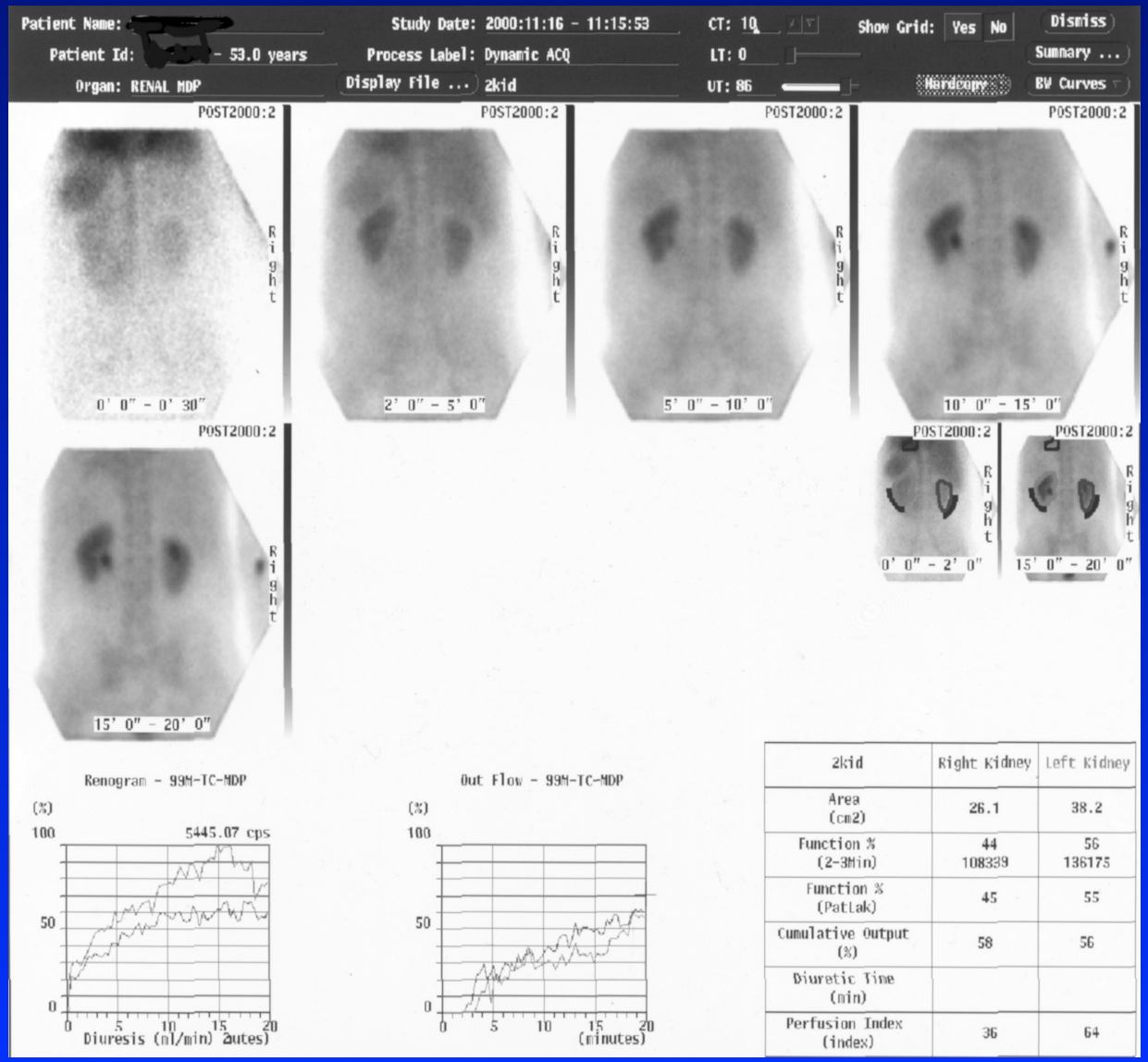
- No good measure of absolute RBF.
- Various *indices* of renal blood flow.
  - Peters RBF/CO
  - Transplant perfusion index
  - (ERPF/MAG3)

Imaging Function

Which Function?
Which Agent?

- Glomerular Filtration
  - Tc-99m-DTPA
  - Tc-99m-MDP
- Glomerular Filtration + Tubular Function
  - Tc-99m-MAG3
- Tubular Function
  - Tc-99m-DMSA

MDP (Medronate) renal imaging



2kid	Right Kidney	Left Kidney
Area (cm2)	26.1	38.2
Function % (2-3Min)	44 108339	56 136175
Function % (PatLak)	45	55
Cumulative Output (%)	58	56
Diuretic Time (min)		
Perfusion Index (index)	36	64

Imaging divided function

- Rate of uptake of dynamic tracer
  - Integral/slope methods
  - Rutland/Patlak plot
- Degree of retention of static tracer
- NB Need to correct for background activity

Function involves time

Radiation Dose in Nuclear Medicine does not depend on time - therefore:

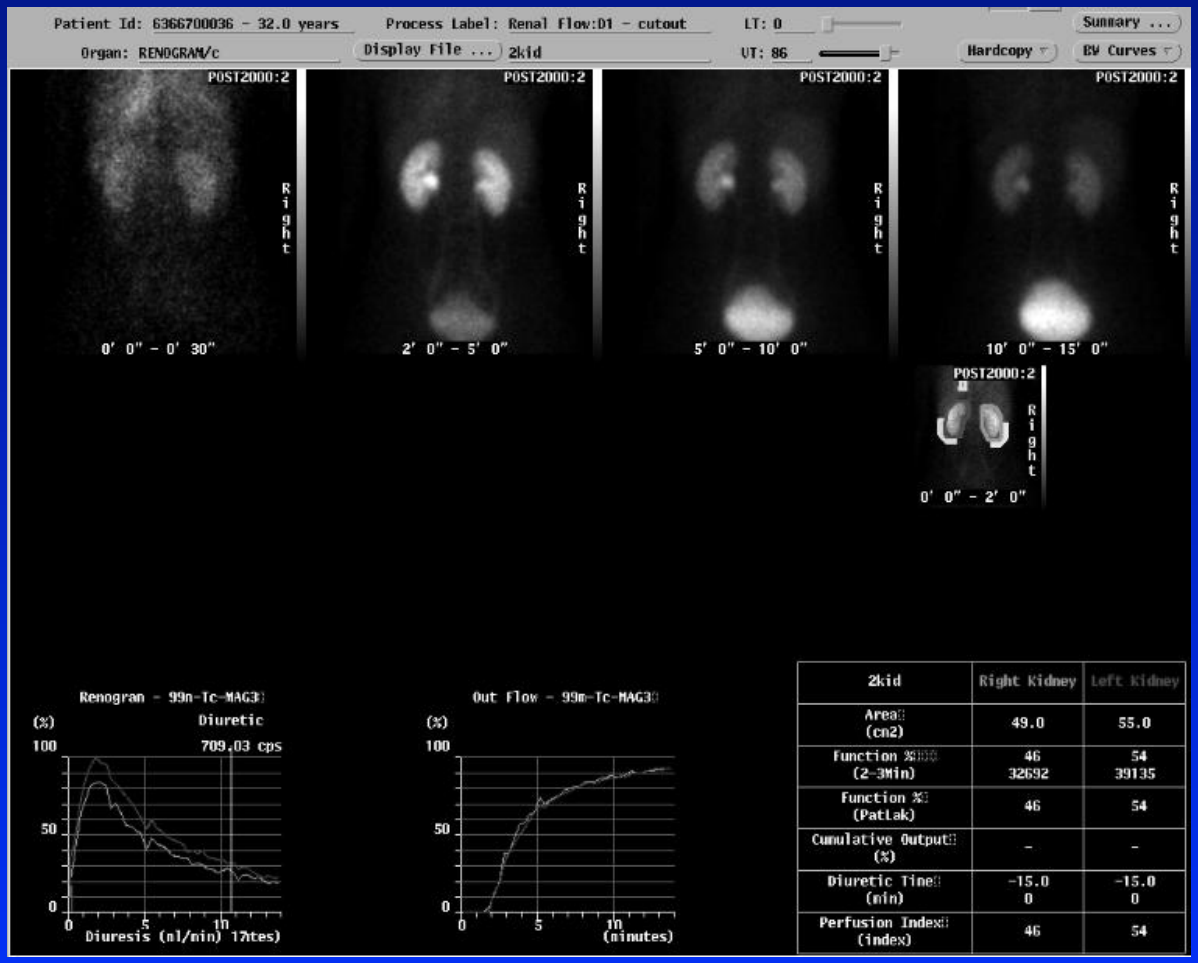
- Can image time-dependent changes
  - Transit
  - Ureteric peristalsis
- Can *measure* changes
  - Response to stimulus
    - <Frusemide
    - <Captopril
    - <Aspirin
    - <Exercise

Functional Imaging

Dynamic renal imaging

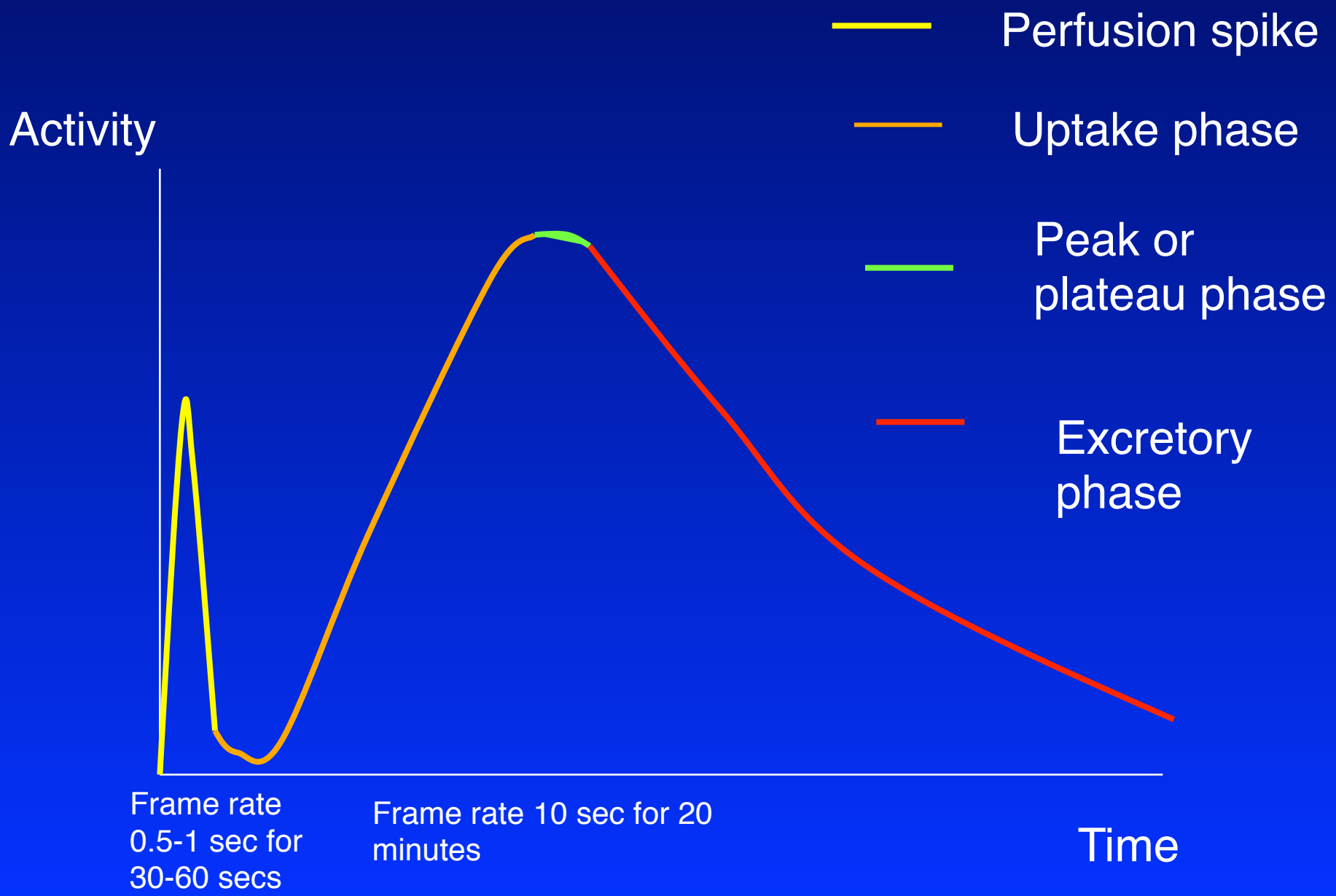
- Assess relative renal perfusion
- Estimate divided function
- Estimate parenchymal clearance and retention
- Assess drainage
- Measure response to diuresis
- Image ureteric peristalsis

Normal renal study MAG3

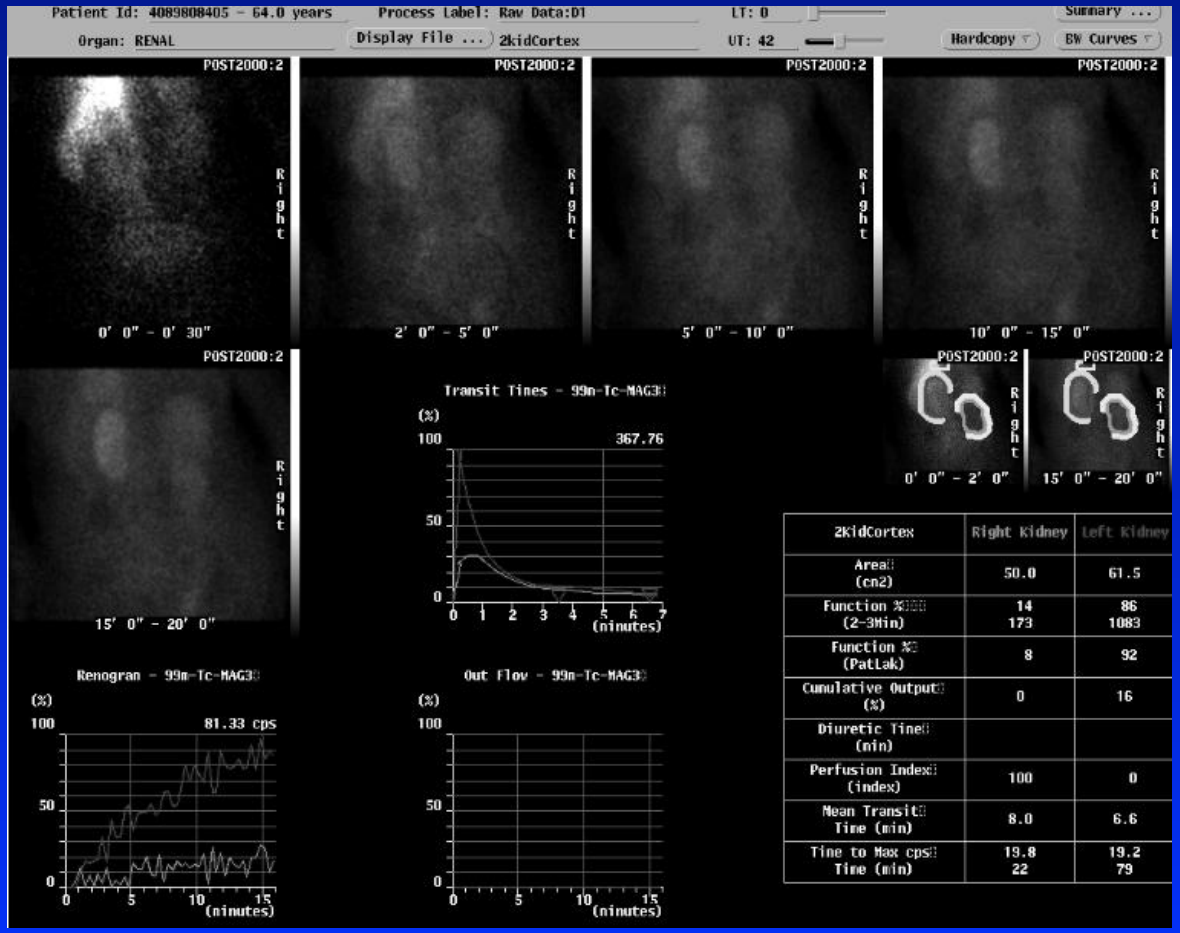


2kid	Right Kidney	Left Kidney
Area (cm2)	49.0	55.0
Function % (2-3Min)	46 32692	54 39135
Function % (PatLak)	46	54
Cumulative Output (%)	-	-
Diuretic Time (min)	-15.0 0	-15.0 0
Perfusion Index (index)	46	54

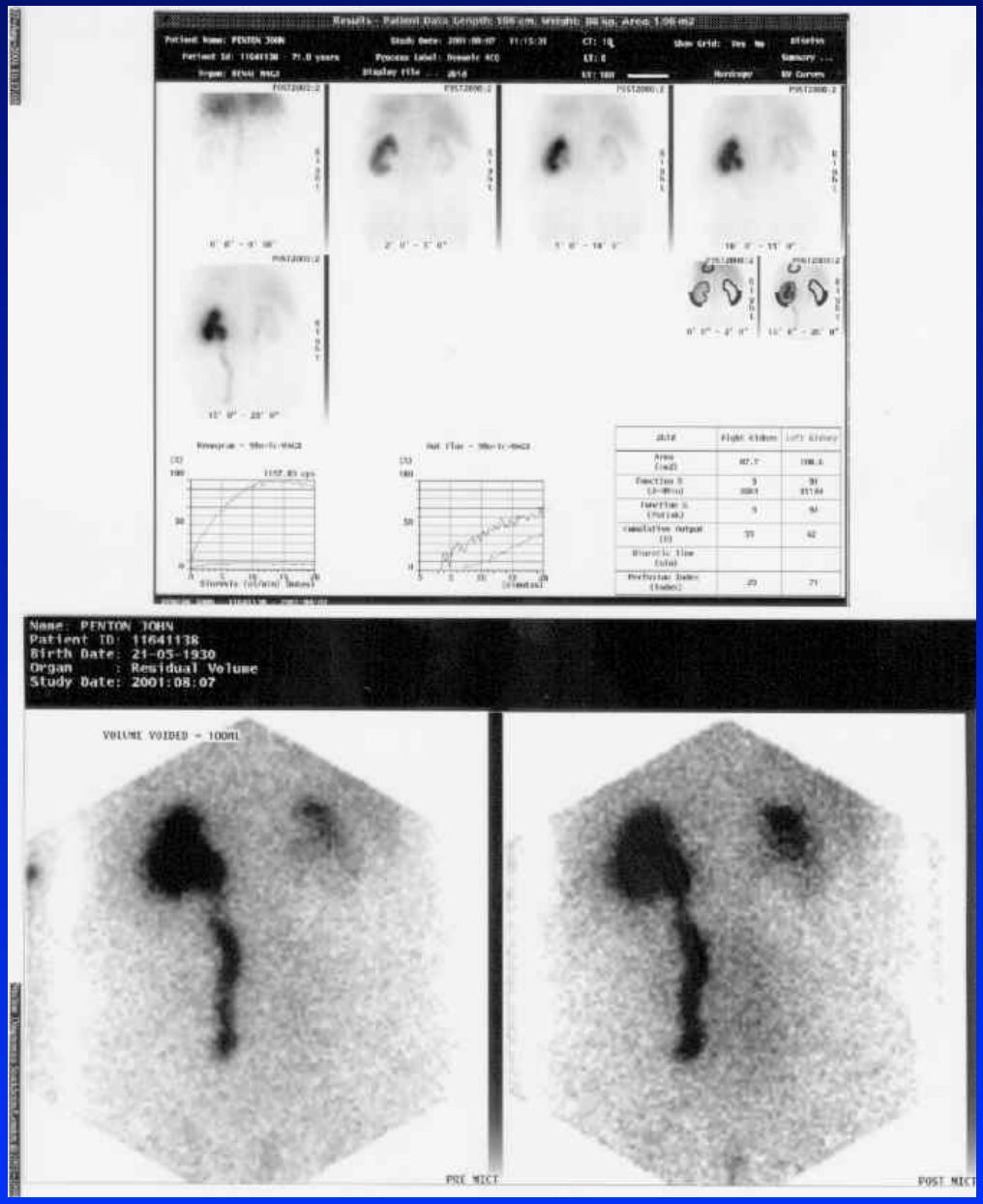
The renogram



Renal impairment



We can only show current, not *potential*, function



Functional Imaging

Response to Stress

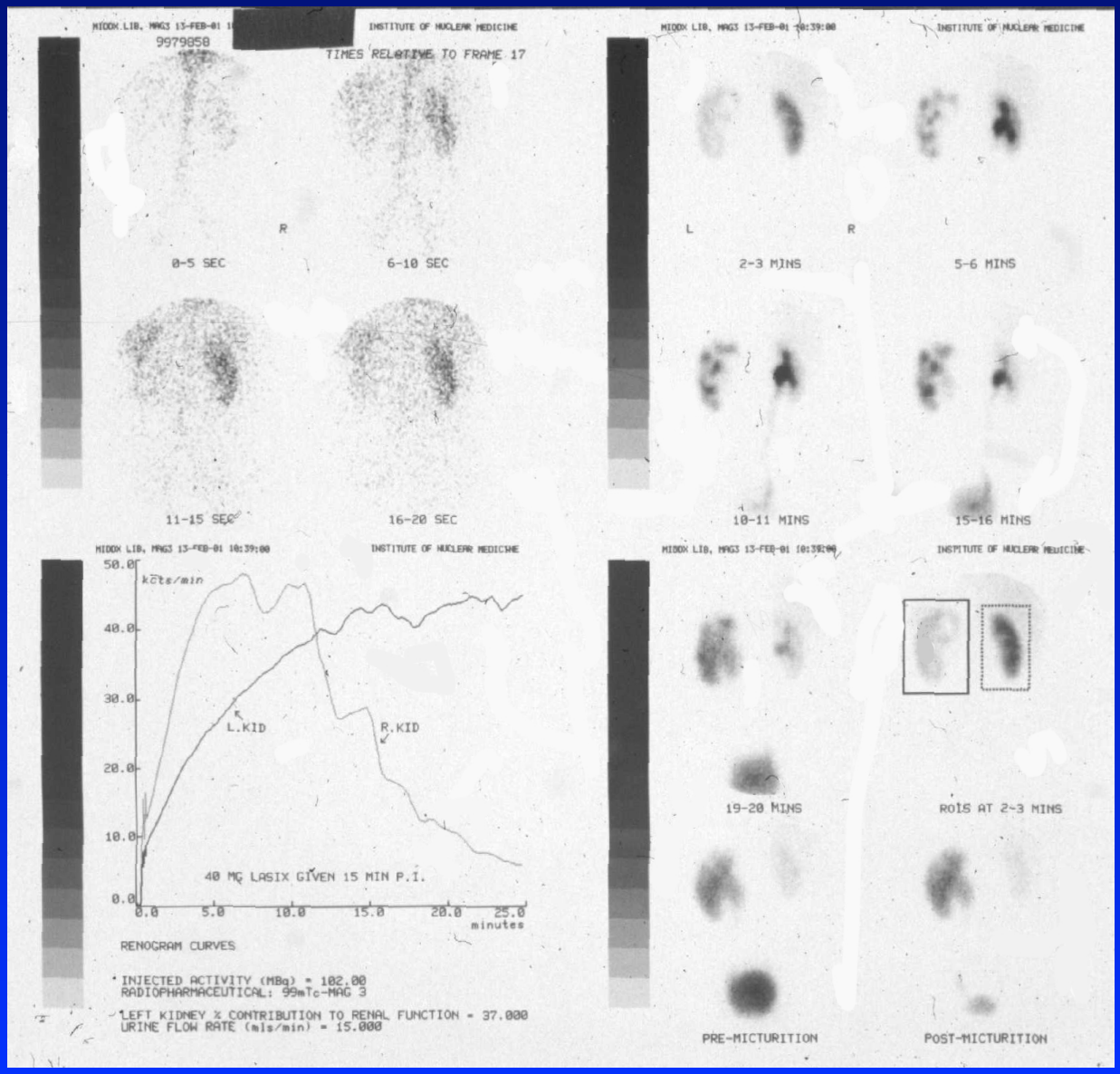
- Frusemide-induced Diuresis
- Renal Vascular Stress
  - Captopril
  - Aspirin
  - Exercise
- Prostaglandin Inhibitors
  - Diclofenac (Voltarol)

Stress Response

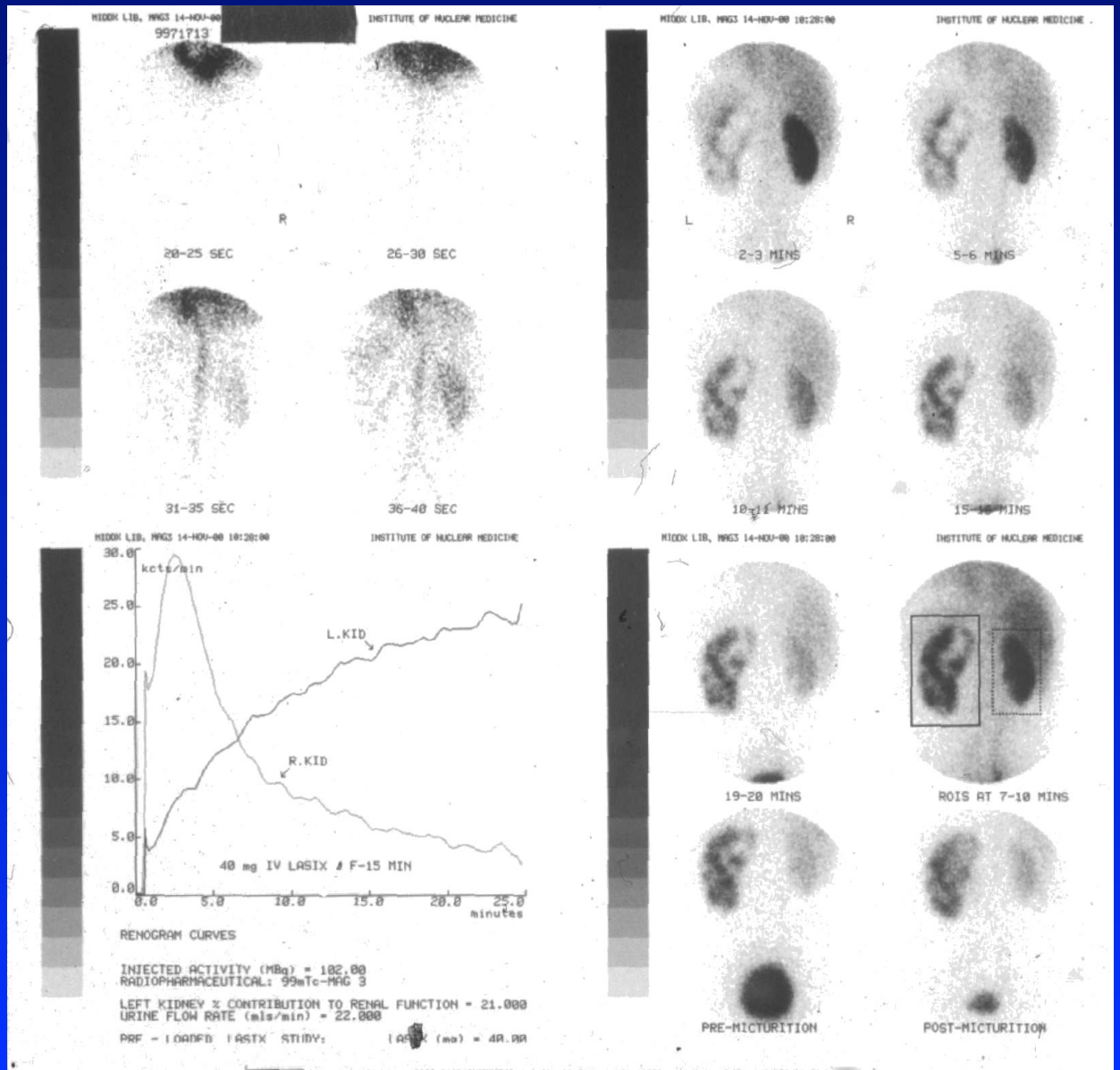
Diuresis

- Definition of obstruction
  - <Inability to cope with urine flow
- ˆ Need adequate diuresis
  - Adequate hydration
  - Lasix 15 min before (F-15)
  - Measure diuresis
- Quantitate response
  - Cumulative output

F + 15


INSTITUTE OF NUCLEAR MEDICINE
9979858
TIMES RELATIVE TO FRAME 17
R
0-5 SEC
6-10 SEC
11-15 SEC
16-20 SEC
L
R
2-3 MINS
5-6 MINS
10-11 MINS
15-16 MINS
kcts/min
50.0
40.0
30.0
20.0
10.0
0.0
L.KID
R.KID
40 MG LASIX GIVEN 15 MIN P.I.
0.0
5.0
10.0
15.0
20.0
25.0
minutes
RENOGRAM CURVES
INJECTED ACTIVITY (MBq) = 102.00
RADIOPHARMACEUTICAL: 99mTc-MAG 3
LEFT KIDNEY % CONTRIBUTION TO RENAL FUNCTION = 37.000
URINE FLOW RATE (mls/min) = 15.000
19-20 MINS
ROIS AT 2-3 MINS
PRE-MICTURITION
POST-MICTURITION

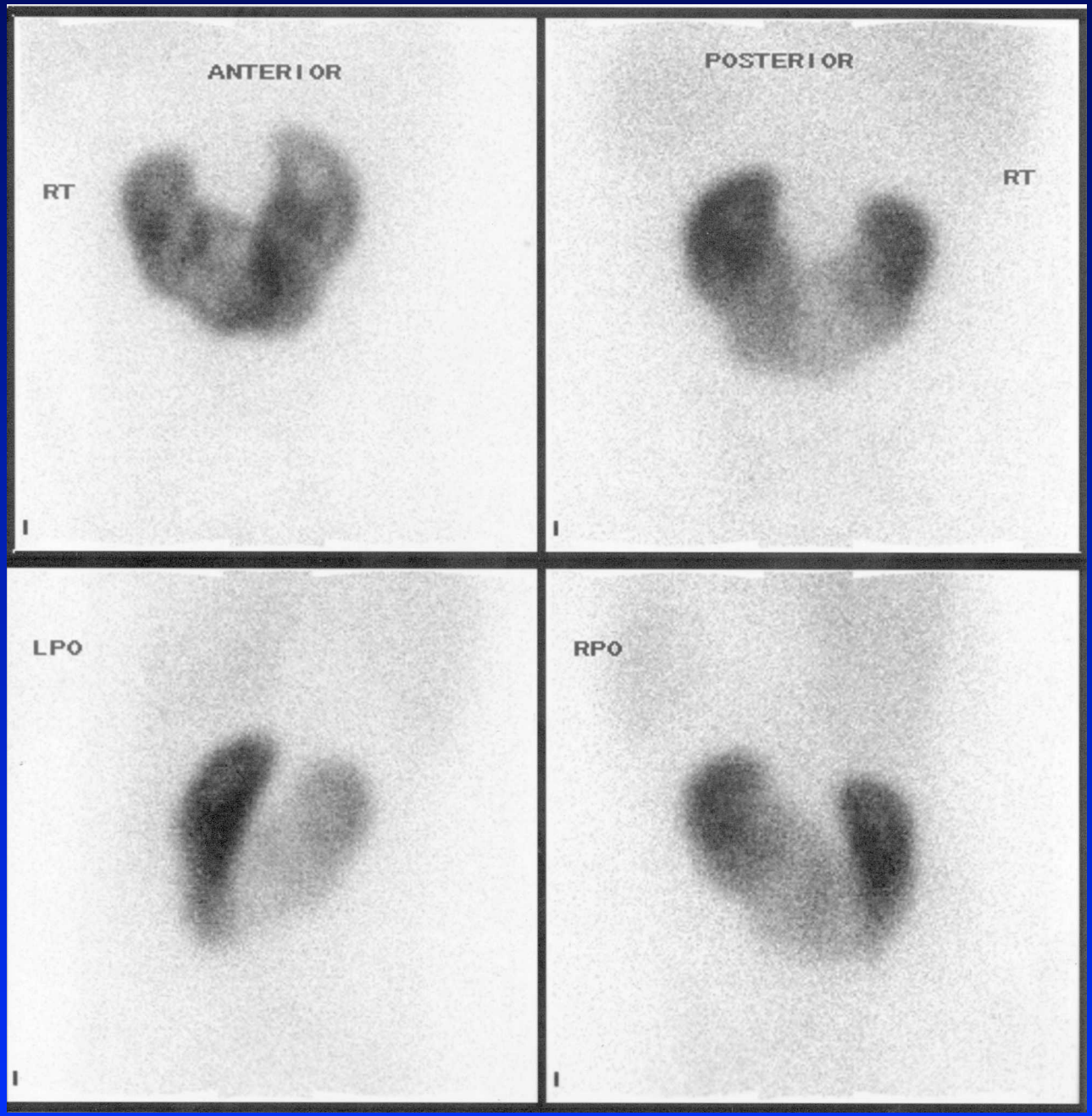
F-15


MIDDX LIB, MAG3 14-NOV-00
INSTITUTE OF NUCLEAR MEDICINE
9971713
R
20-25 SEC
26-30 SEC
31-35 SEC
36-40 SEC
MIDDX LIB, MAG3 14-NOV-00 10:20:00
INSTITUTE OF NUCLEAR MEDICINE
L
R
2-3 MINS
5-6 MINS
10-11 MINS
15-16 MINS
MIDDX LIB, MAG3 14-NOV-00 10:20:00
INSTITUTE OF NUCLEAR MEDICINE
kcts/min
30.0
25.0
20.0
15.0
10.0
5.0
0.0
L.KID
R.KID
40 mg IV LASIX @ F-15 MIN
0.0
5.0
10.0
15.0
20.0
25.0
minutes
RENOGRAM CURVES
INJECTED ACTIVITY (MBq) = 102.00
RADIOPHARMACEUTICAL: 99mTc-MAG 3
LEFT KIDNEY % CONTRIBUTION TO RENAL FUNCTION = 21.000
URINE FLOW RATE (mls/min) = 22.000
MIDDX LIB, MAG3 14-NOV-00 10:20:00
INSTITUTE OF NUCLEAR MEDICINE
19-20 MINS
ROIS AT 7-10 MINS
PRE-MICTURITION
POST-MICTURITION

Functional Imaging

Static renal imaging

- Images localisation of function (and of loss of function)
- Estimate divided function
- Allows localisation of kidney tissue
- SPECT gives better impression of shape
- BUT is non-specific (what is a scar?)
- Does it happen in adults? If so whom?

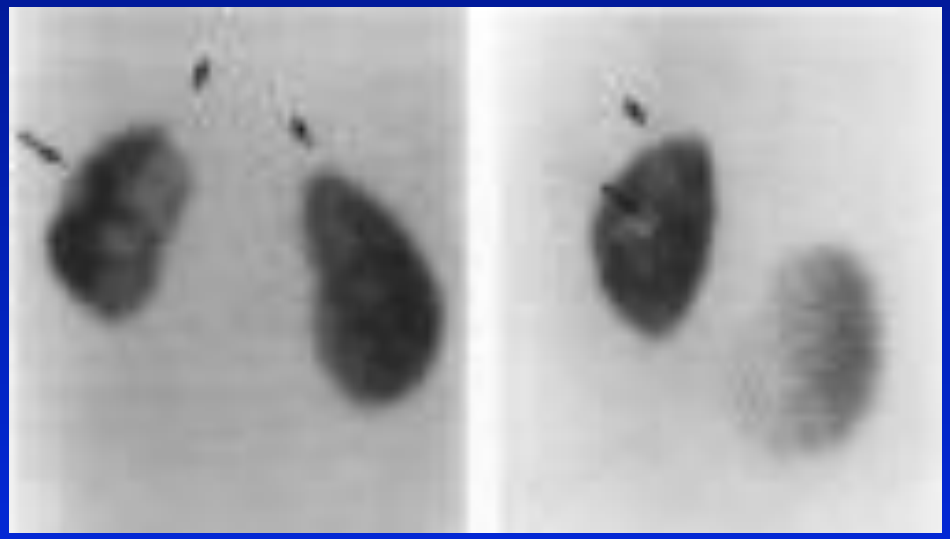

ANTERIOR
RT
I
POSTERIOR
RT
I
LPO
I
RPO
I

Use of DMSA

- In children most commonly used to look for scars
- Can be used to look for acute infection (which is why 4-6 months must elapse after last UTI till DMSA)
- Use in children liver 5 and adults less clear
- But can be combined with GFR to predict GFR after nephrectomy

Patters of activity

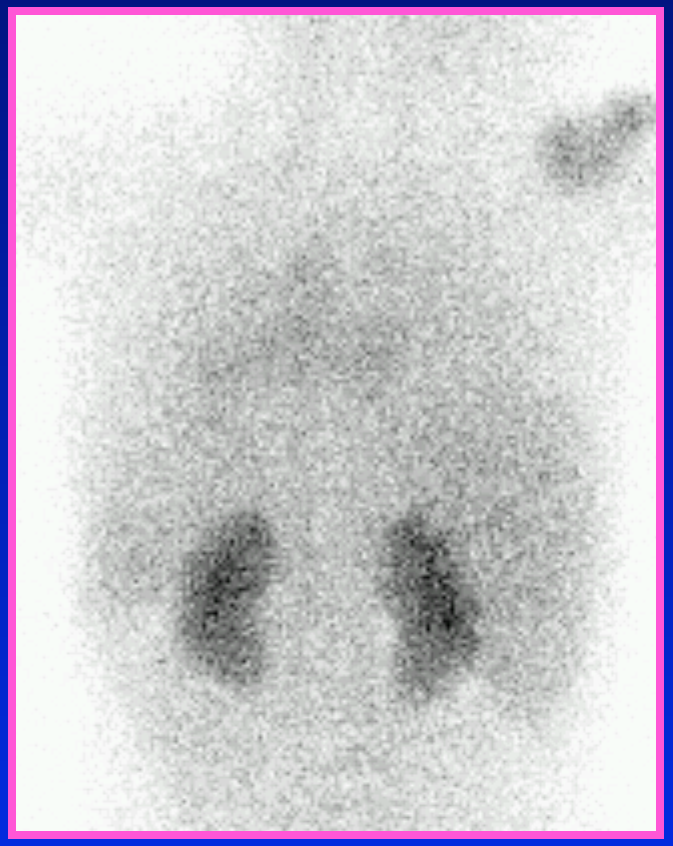
- Convex defect
- Concave defect
- Fuzzy edge
- Will need re-scanning 6 months later to see if scars

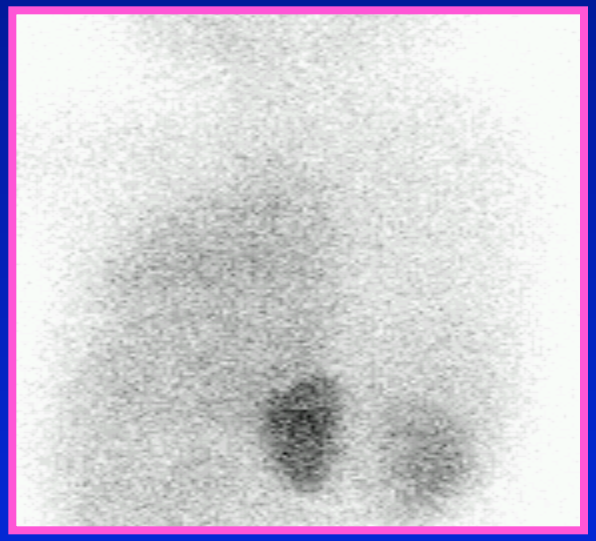


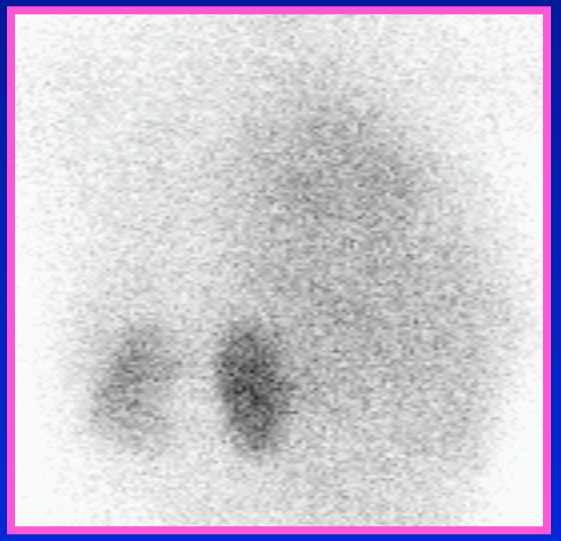
POST

2 week old only one kidney seen on intra-uterine ultrasound

RPO







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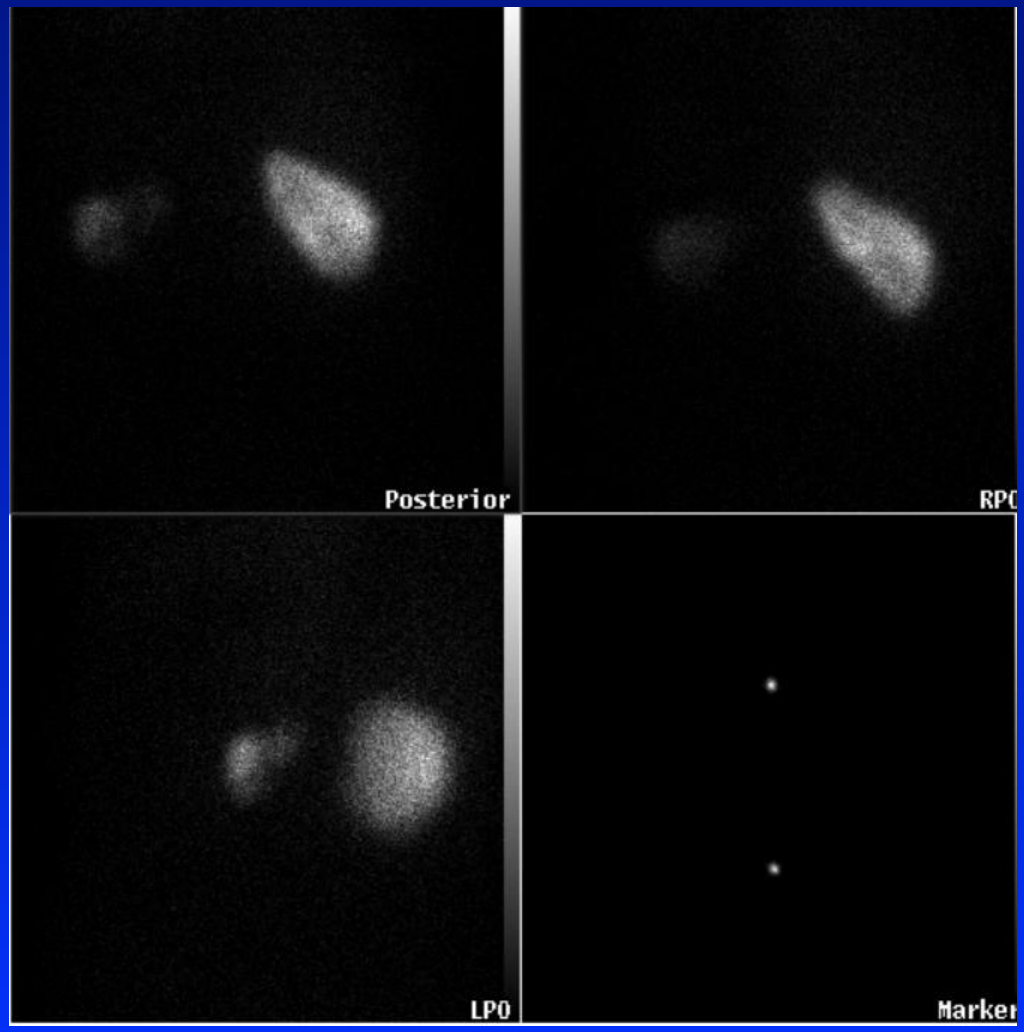
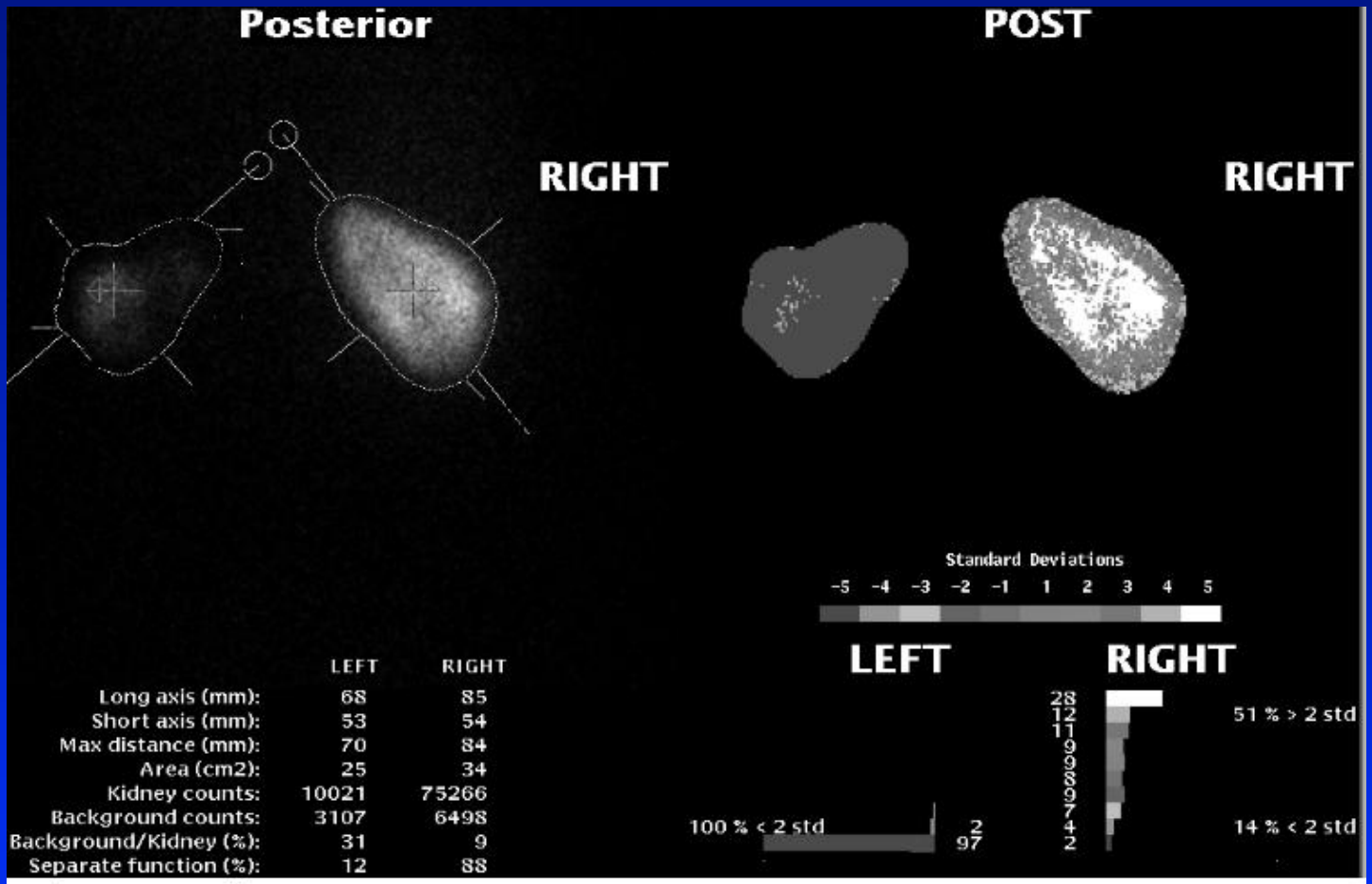
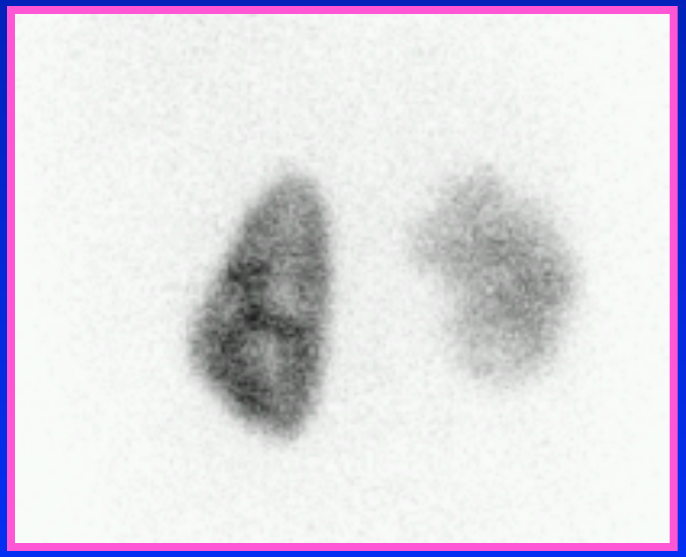
5 year old with Hx of UTIs




Posterior
POST
RIGHT
RIGHT
Standard Deviations
-5 -4 -3 -2 -1 1 2 3 4 5
LEFT
RIGHT
LEFT RIGHT
Long axis (mm): 68 85
Short axis (mm): 53 54
Max distance (mm): 70 84
Area (cm2): 25 34
Kidney counts: 10021 75266
Background counts: 3107 6498
Background/Kidney (%): 31 9
Separate function (%): 12 88
28
12
11
9
9
8
7
4
2
51 % > 2 std
14 % < 2 std
100 % < 2 std
2
97

Scars in right kidney



Who to scan?

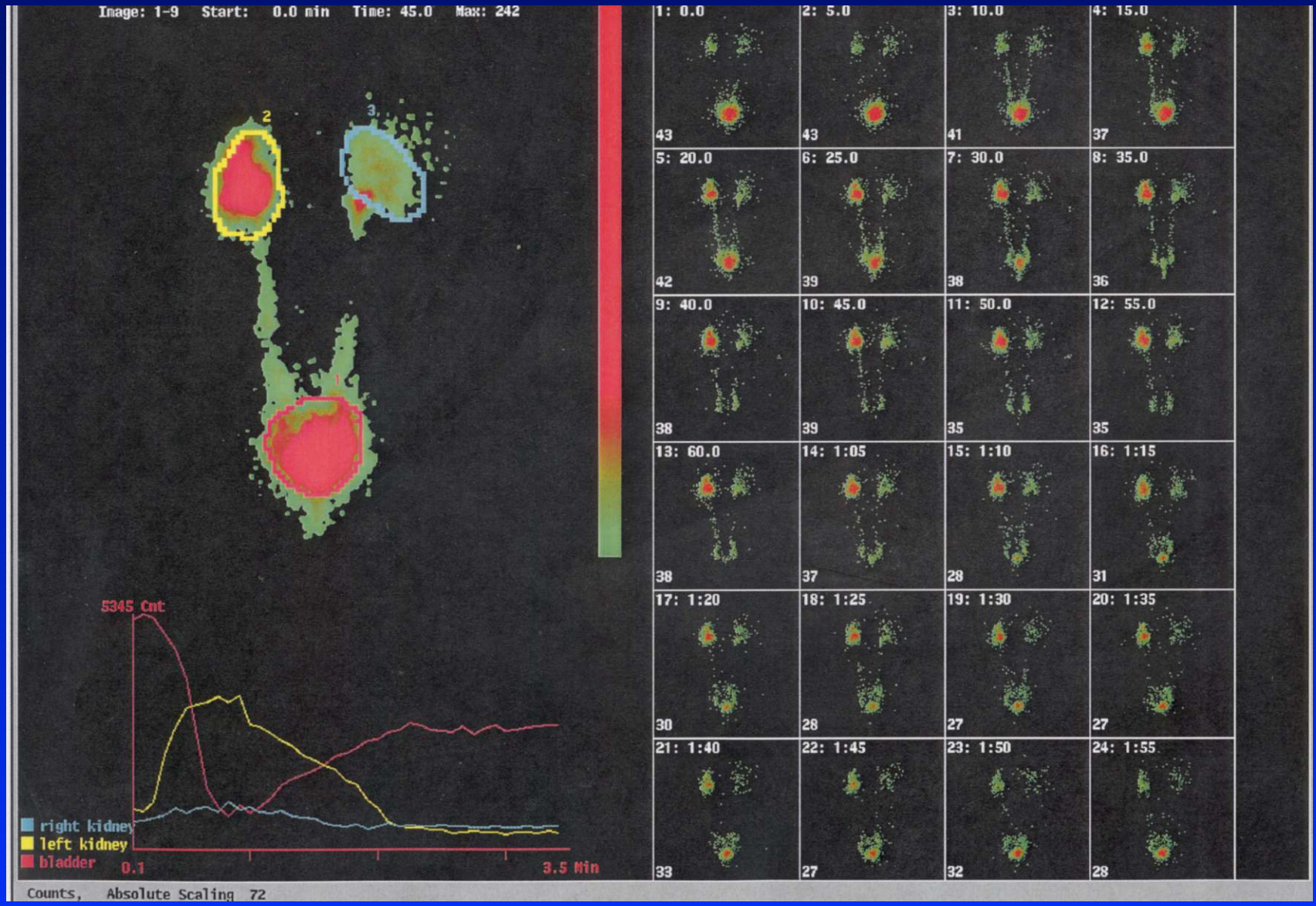
- Controversy re-started
- Was any child under 6 with one episode of UTI
- Now less clear the we can justify radiation
- Now needs more than one infection unless with an organism other than *e.coli*
- No evidence that old or new approach WILL reduce adult hypertension

Functional Imaging

Isotope Cystography

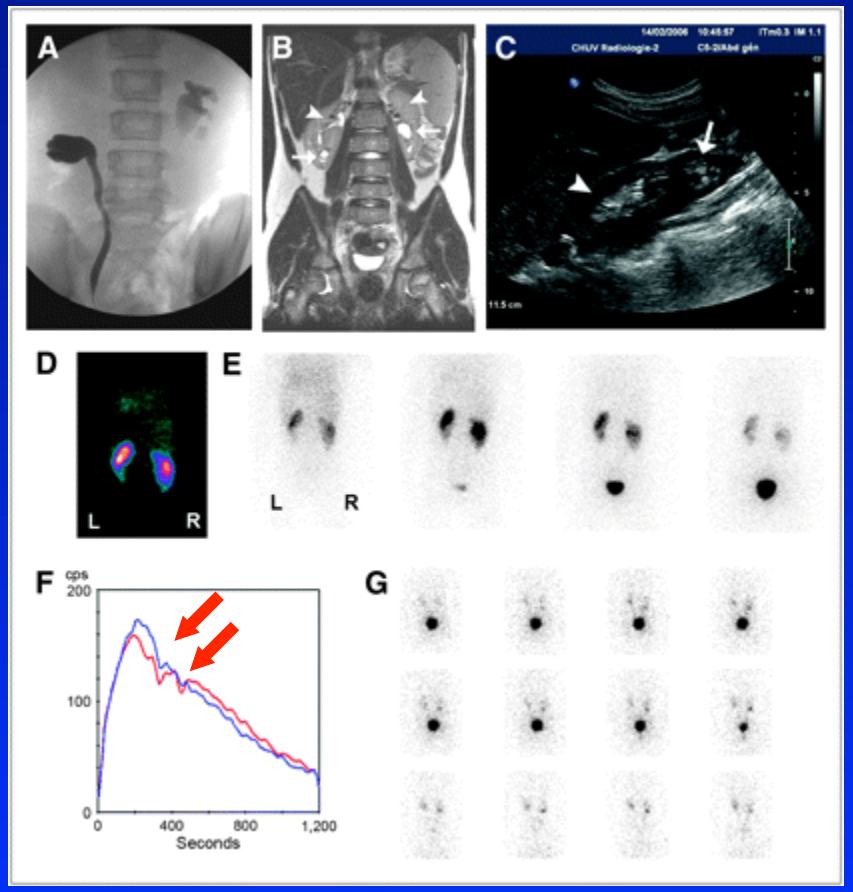
- Direct cystography is not functional (even if it gives some functional/volume answers).
- Indirect cystography is functional.
  - Good in children with bladder control
  - Good for follow-up
  - Doesn't show anatomy
  - Needs good patient co-operation for acquisition

Reflux study



Reflux in a duplex kidney

Arrows show episodes of yo-yo reflux form lower to upper moeity



Functional Imaging

Single Kidney GFR

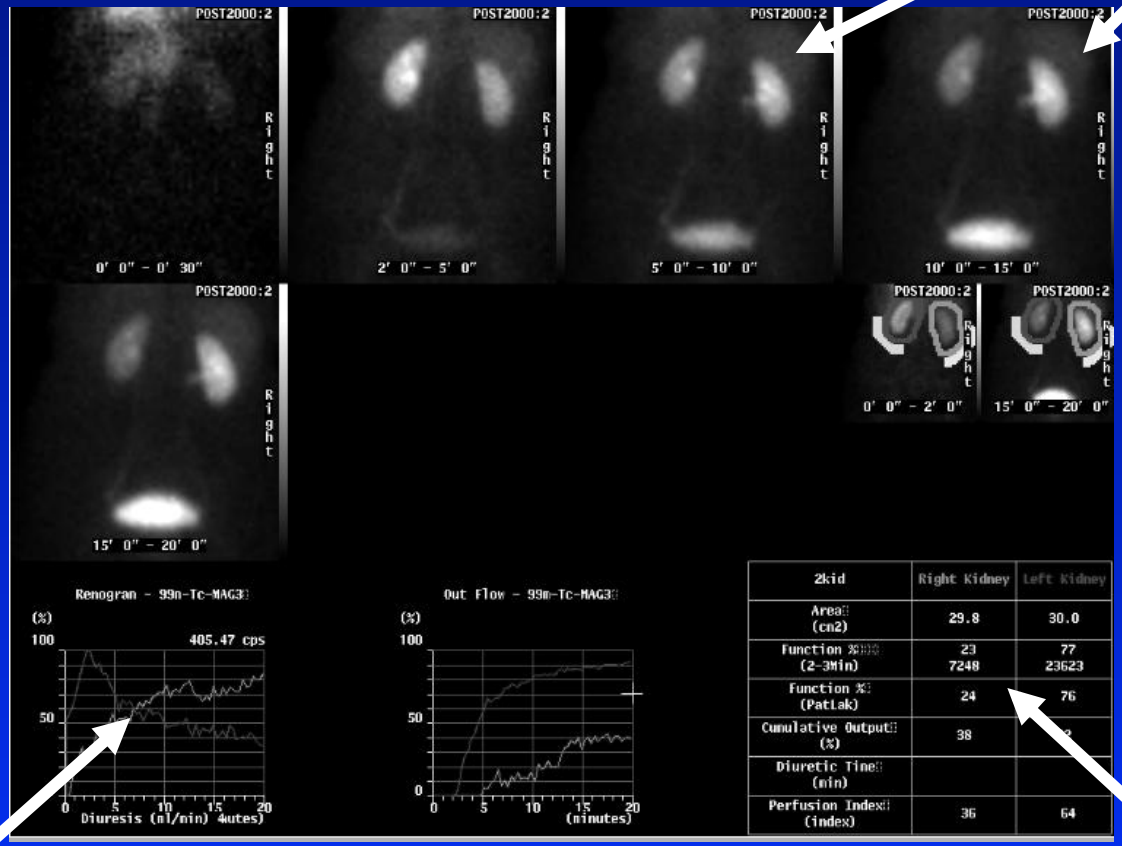
- Probably most useful parameter for looking at change.
- Needs total + divided function
- Proven value in RAS and UTI

Captopril renography

- To look for renovascular disease
- 2 peaks young FMD and older AthScl
- Do base line study if abnormal then do not do post captopril
- If baseline normal give 25mg captopril
- If RVD captopril will shut down ACEdrive on affected kidney
- Delayed peak, reduced divided function and delayed parenchymal transit

Renogram in RAS (on ACEI)

Parenchymal retention



Delayed peak

Reduced divided function

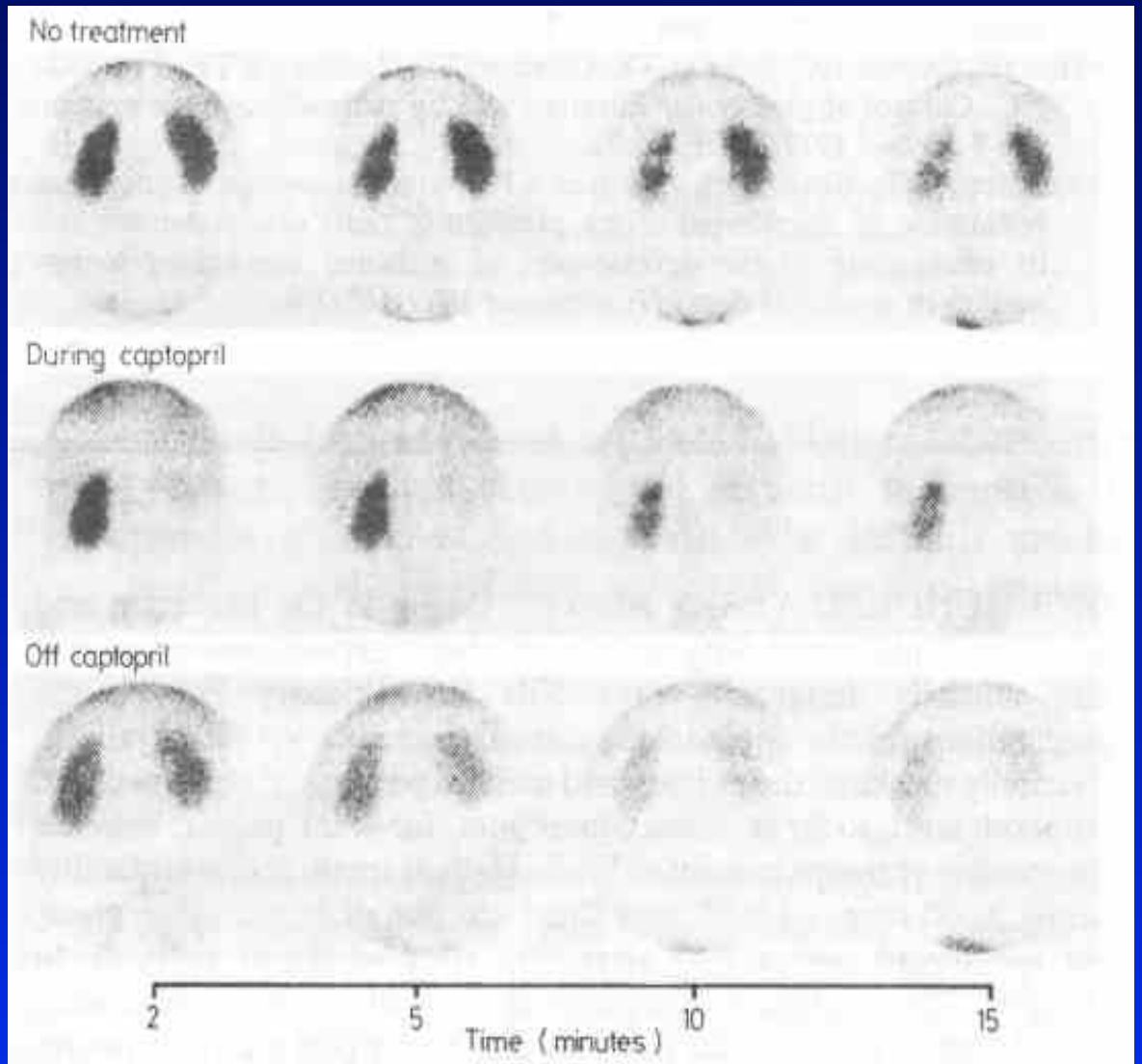


FIG 4—Sequential ^{99m}Tc-DTPA kidney scans in patient with unilateral renal artery stenosis (case 3; table I) before captopril, after four weeks of captopril 150 mg daily, and one week after stopping captopril. Time after radioisotope injection indicated.

Effect of chronic Captopril on GFR / DTPA Wenting 1984

Effect of chronic Captopril Wenting 1984

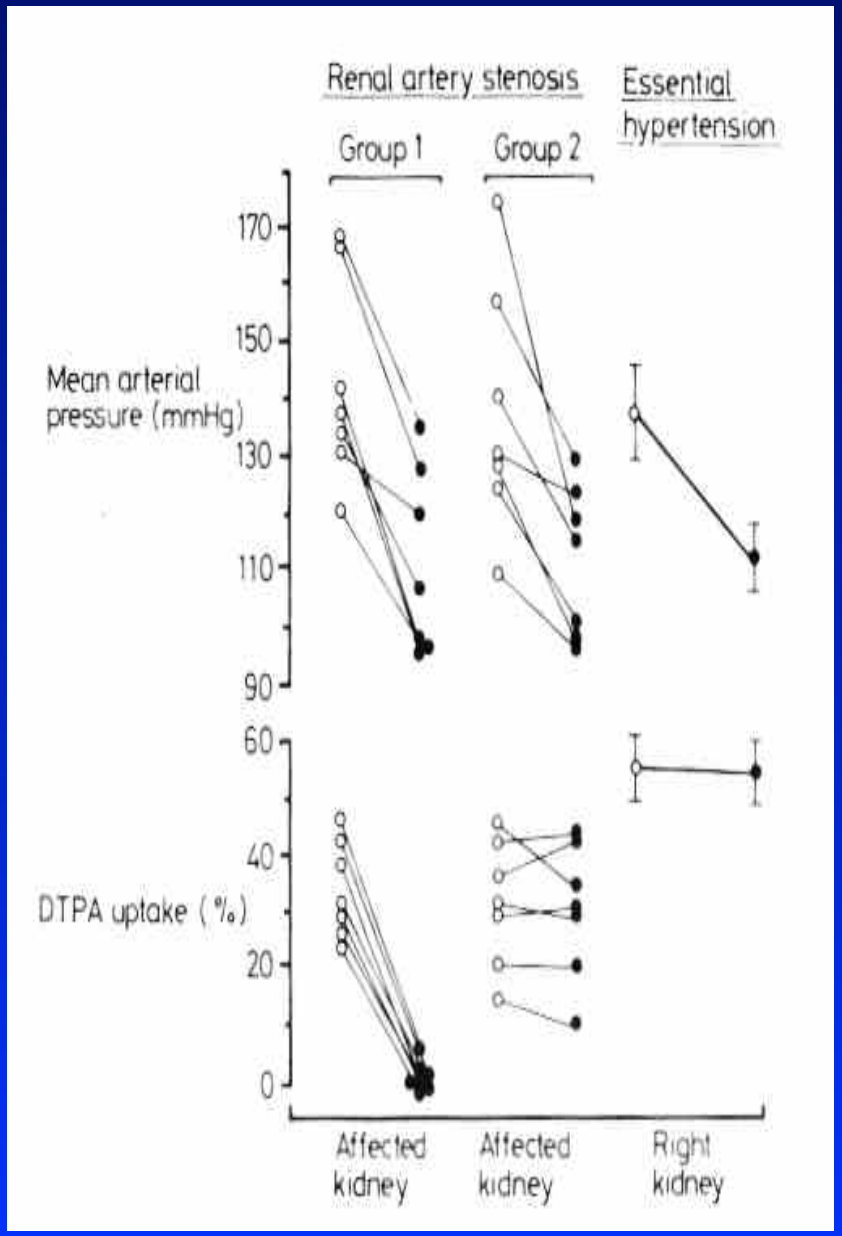


FIG 3—Effect of long term captopril 150 mg daily on blood pressure and single kidney uptake of ^{99m}Tc-DTPA in 14 patients with unilateral renal artery stenosis and 17 patients with essential hypertension. Patients with renal artery stenosis divided into two groups according to change in DTPA uptake (see table III for statistics). Values in patients with essential hypertension presented as means and SEM. Mean arterial pressure calculated as diastolic pressure + 0·3 × pulse pressure. London School of Hygiene sphygmomanometer used. Three consecutive readings with patient in recumbent position were averaged. Effect of captopril on mean arterial pressure in patients with essential hypertension was not different from effect in two groups of patients with renal artery stenosis.

Selection of hypertensive patients

- Presented to hospital
- Asymmetric renal size
- Unexpected renal failure
  - especially after ACE inhibitor therapy
- Diabetes
- Difficulty in control of hypertension
- “Flash” pulmonary oedema

European Multicentre Study

- 454 patients from 19 centres
  - ALL had angiography
- 244 with renal artery stenosis
- Tc-99m-DTPA
  - 183 normal
  - 197 stenosis
  - 124 (33%) > 70% stenosis

European Multicentre Study

- Interventions:
  - 76 angioplasty
  - 39 surgical bypass
  - 6 nephrectomy
- Follow-up
  - 87 3 months
  - 57 6 months
  - 36 12 months

European Multicentre Study

- Best sensitivity:
  - Post-Captopril DTPA – 95%
- Best specificity:
  - Change in function or transit – 85%
- Correlation with blood pressure normalisation – 90%

Selection of hypertensive patients

- Presented to hospital
- Asymmetric renal size
- Unexpected renal failure
  - especially after ACE inhibitor therapy
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Captopril protocol 1

- Baseline renogram (DTPA or MAG3)
- Repeat study 60-90 min after 25 mg oral Captopril
  - Stop oral ACEI / Losartan 3-5 days
  - Stop diuretics 5 days
  - Avoid sodium depletion
  - Clear fluids only for 4h

Captopril protocol 2

- On arrival, check compliance
- Put on couch
  - check veins
  - put on b/p cuff
  - check doctor present
- Give captopril (?crushed) + fluids
- Monitor blood pressure
- Give i/v saline (if necessary).

Captopril renography

- Patient voids - time noted
- Supine renography with MAG3 or DTPA
- Bolus injection
- 1/sec for 40 secs; 1/20 secs for 20 min
- Erect image
- Patient voids - time and volume noted

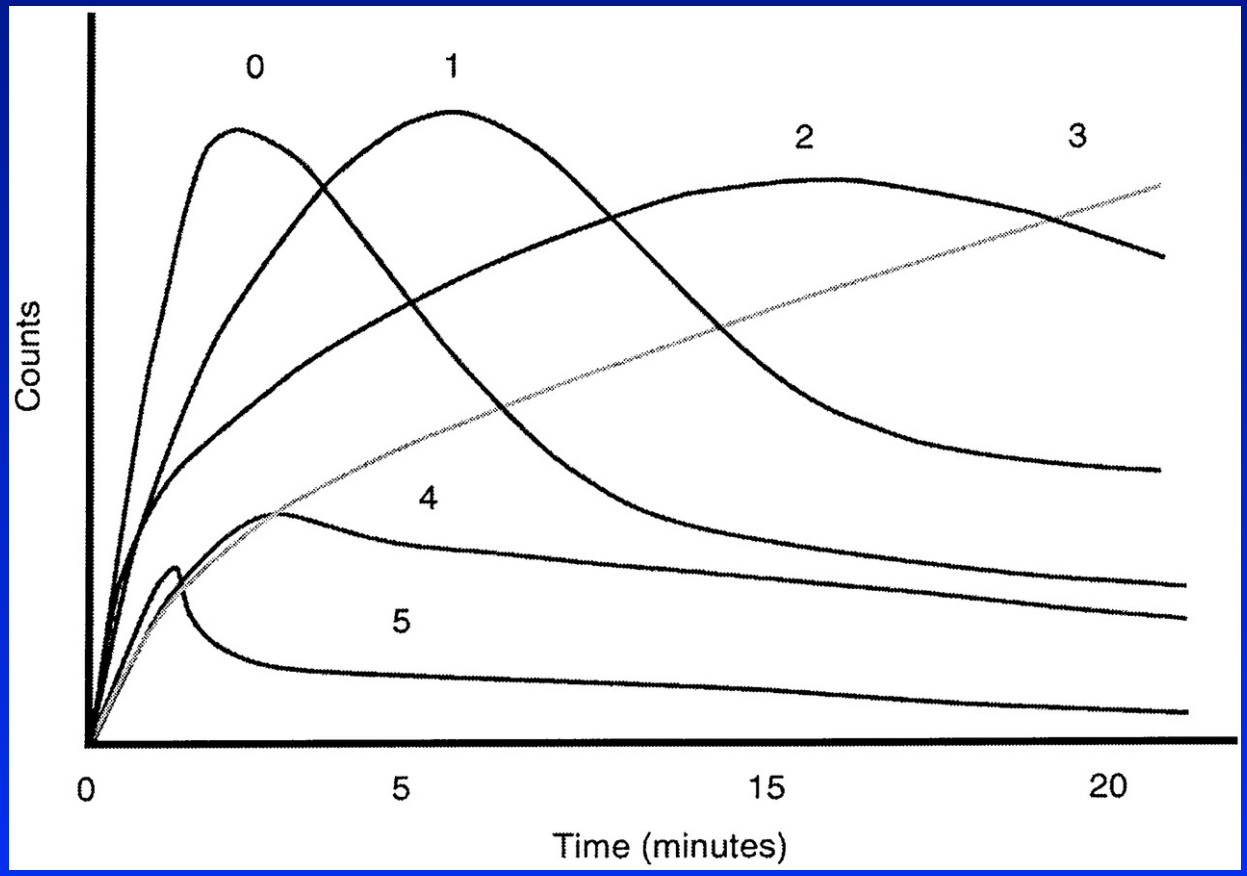
Data analysis

- Summed images, displayed on absolute scale
  - 0-2 min
  - 4-6 min
  - 12-14 min
  - 18-20 min
- Automatic renal ROIs based on 2-min image
- Peri-renal background
- Basic curve analysis

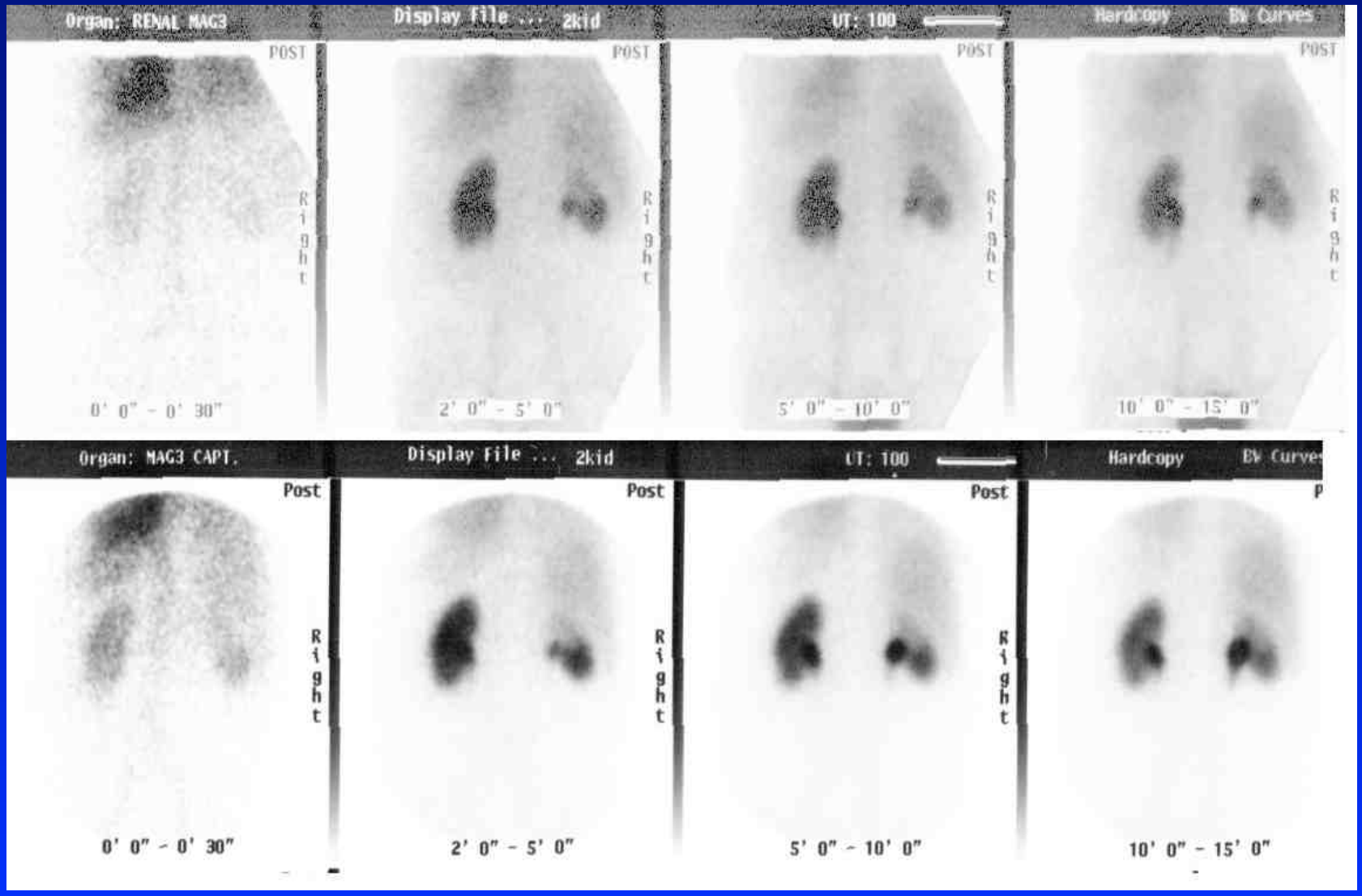
Criteria for analysis

- 5% or greater change in divided function
- >1 grade change in renogram = high probability
- 1 grade change in cortex = high probability

Consensus meeting grading of renogram curves for Captopril



It's not always so easy…..



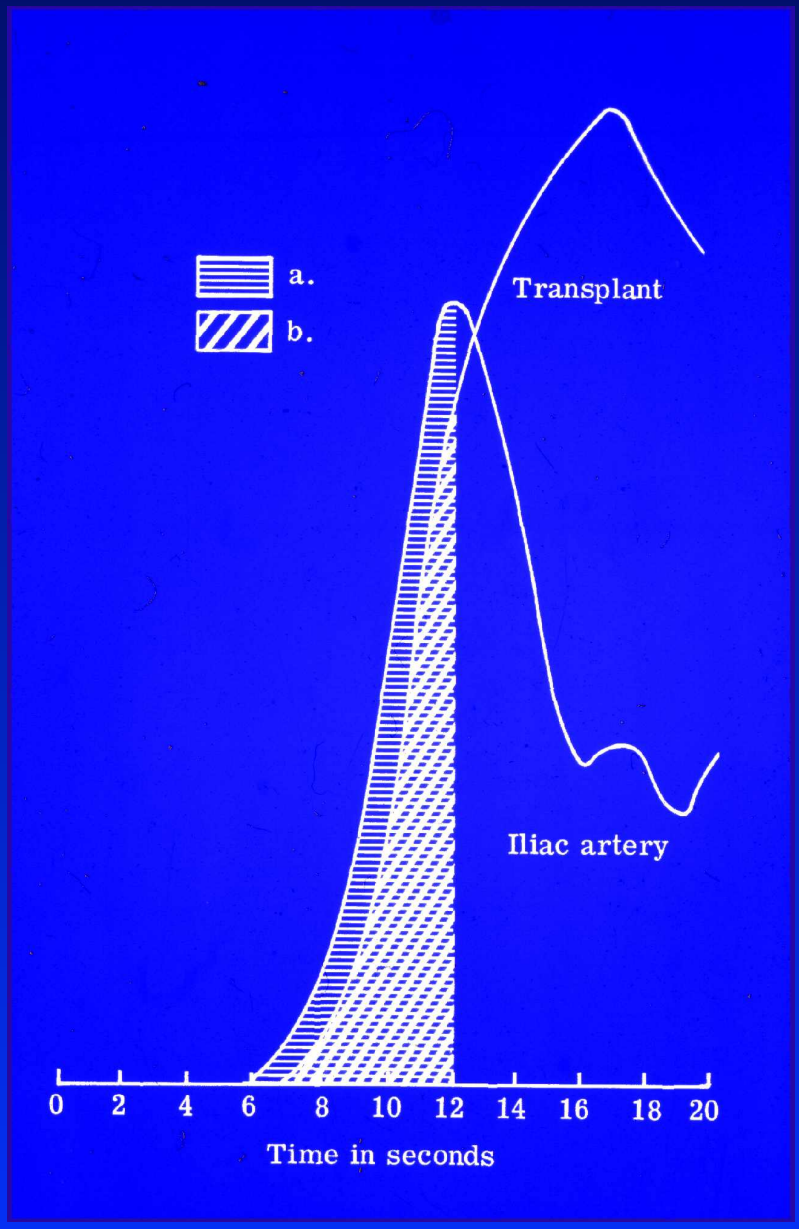
Renal transplantation
Where can imaging help?

- Donor assessment
- Acute post-operative complications
- Early post-transplant period
- Late post-transplant period

Perfusion Index Hilson 1976!

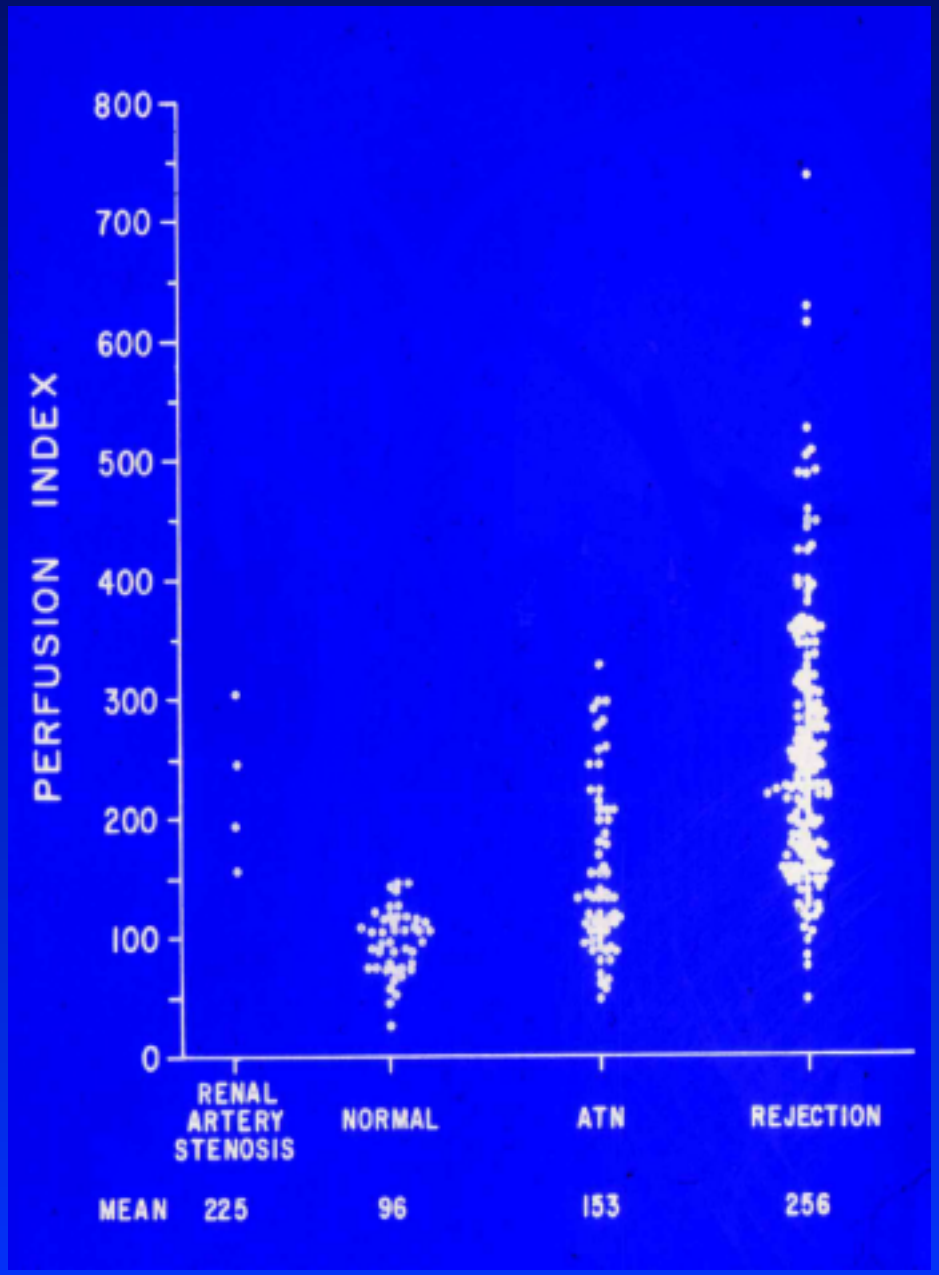
Since 1976

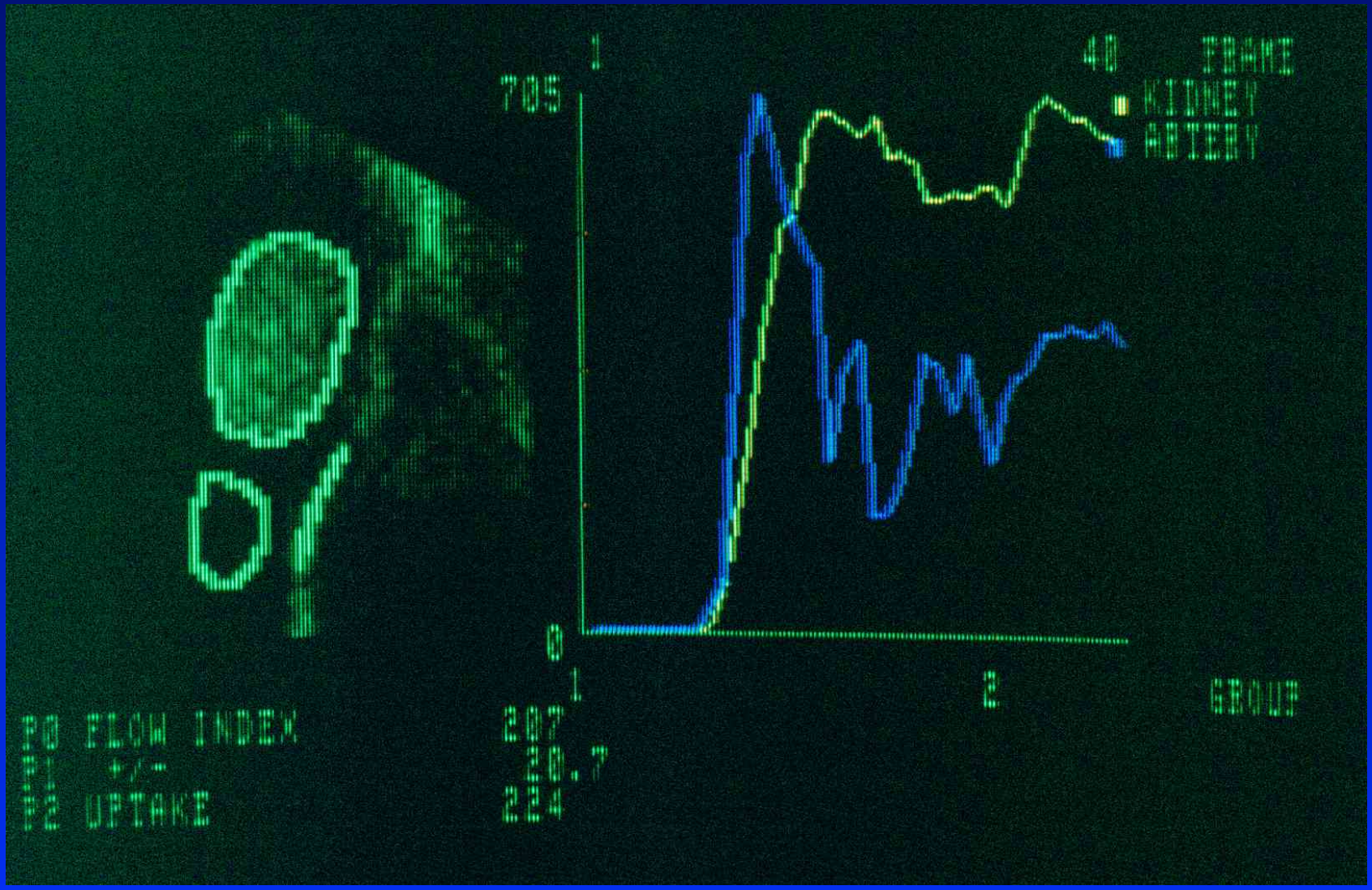
- FNA/biopsy have become safer
- New drugs have slowed down rejection



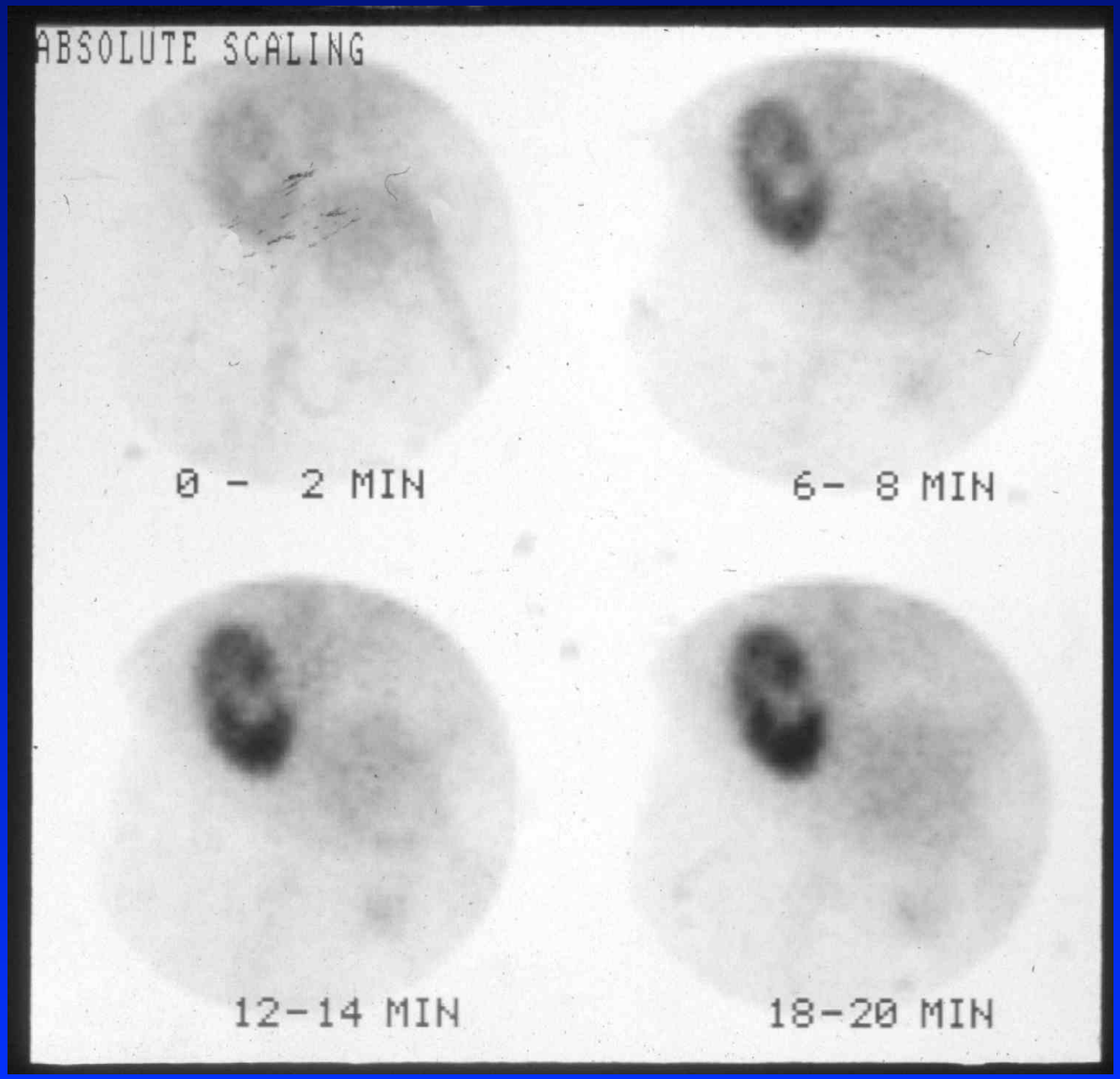
Results

CHANGE Is Important

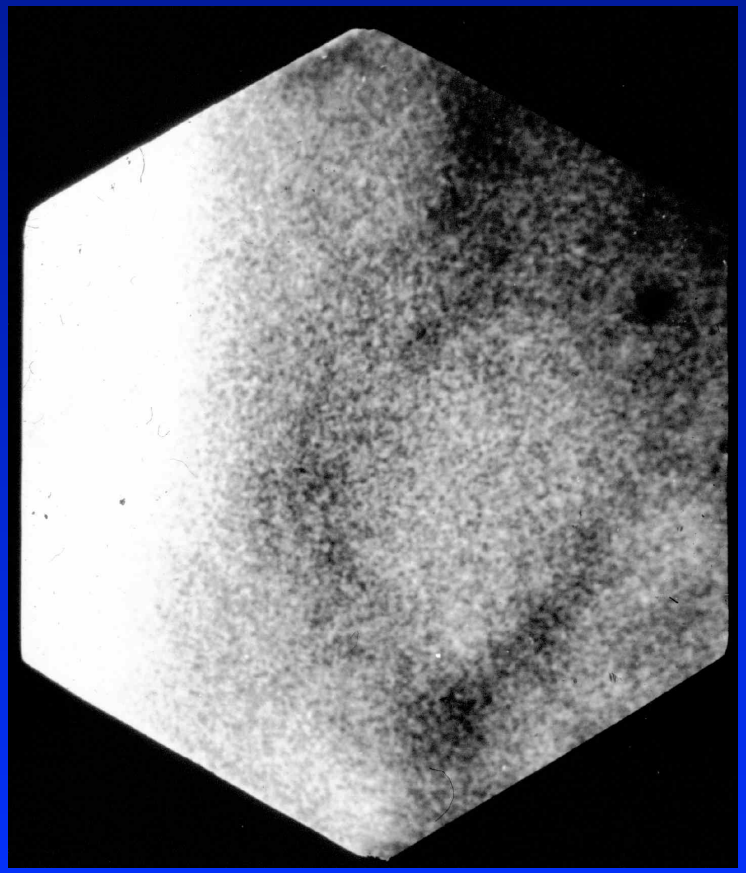


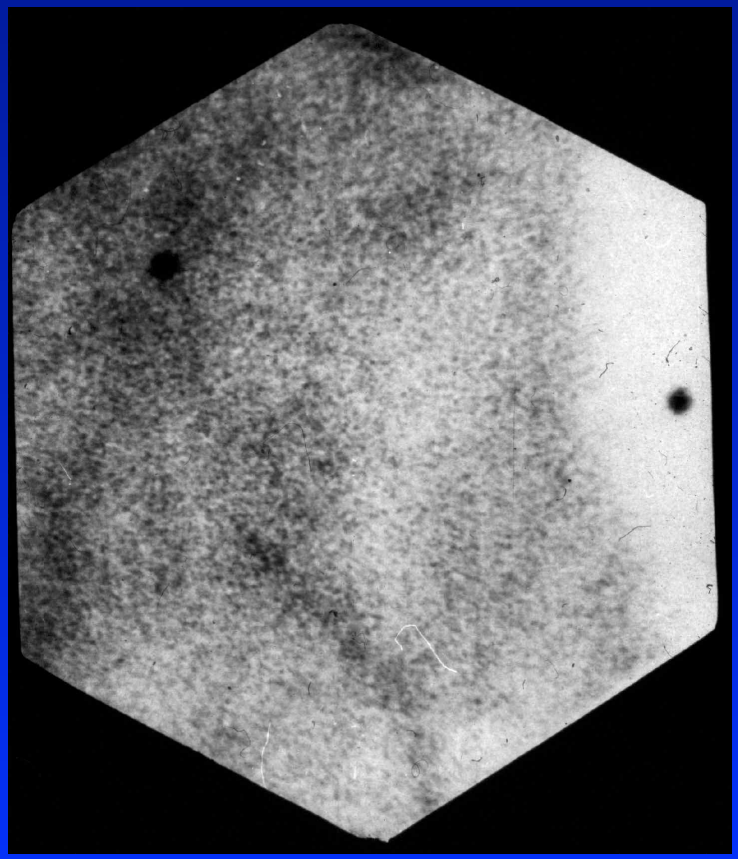

1
705
40
UPTAKE
KIDNEY
AORTA
0
1
2
GROUP
RO FLOW INDEX
P1 +/-
P2 UPTAKE
207
20.7
224

ATN – MAG3

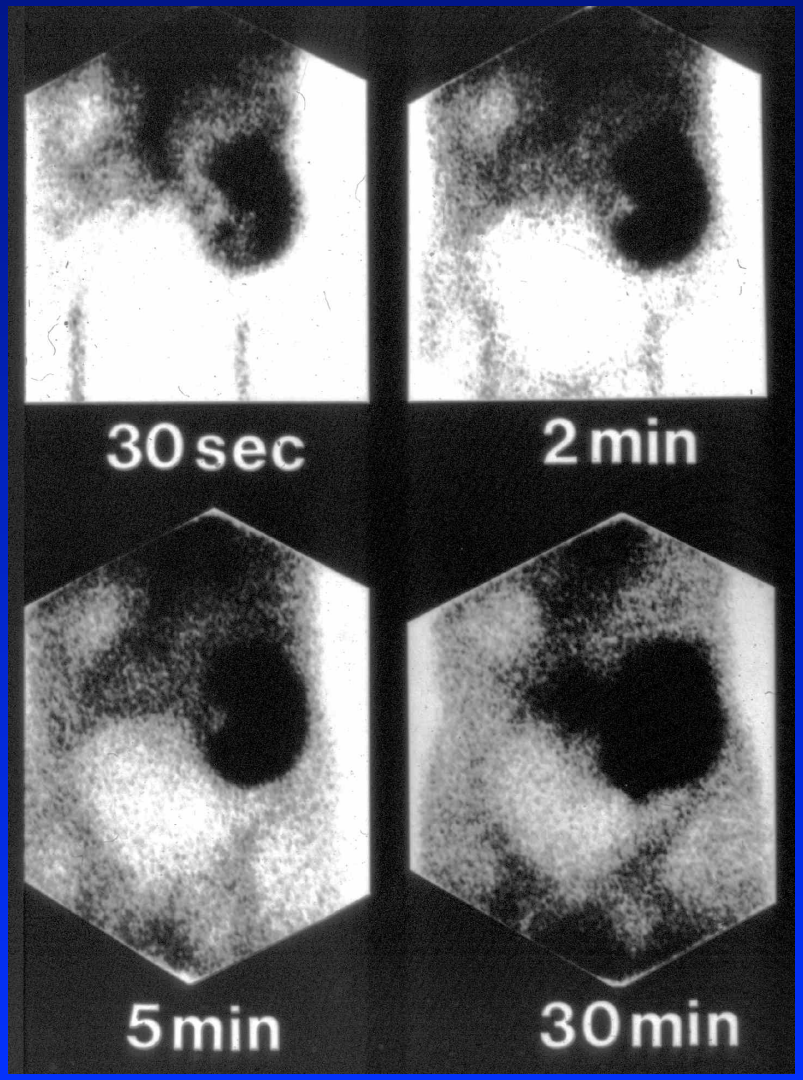


“Black Holes”

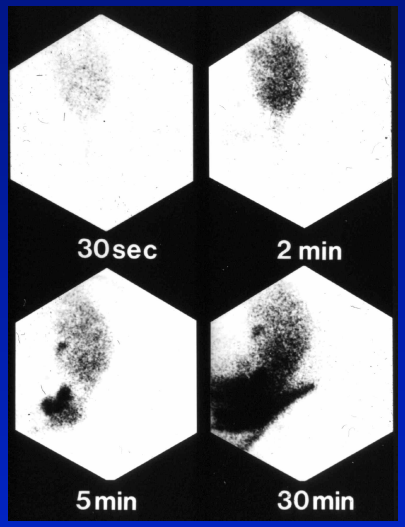


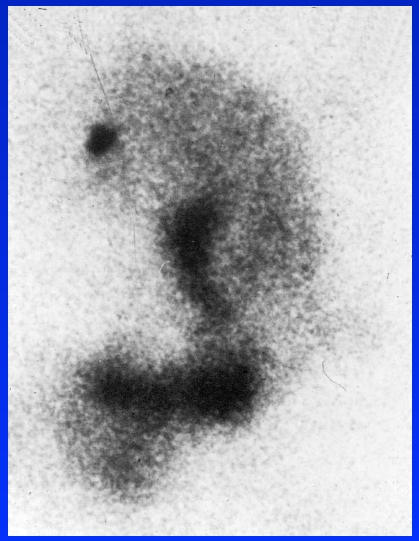


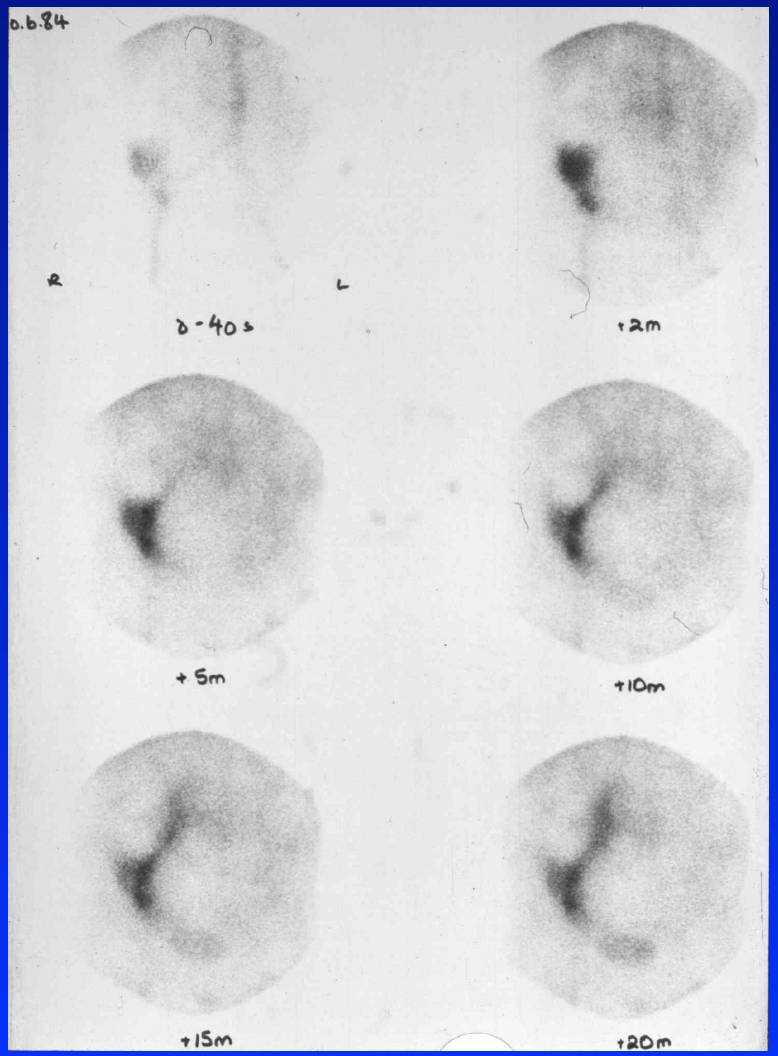
Lymphocoele



Leaks







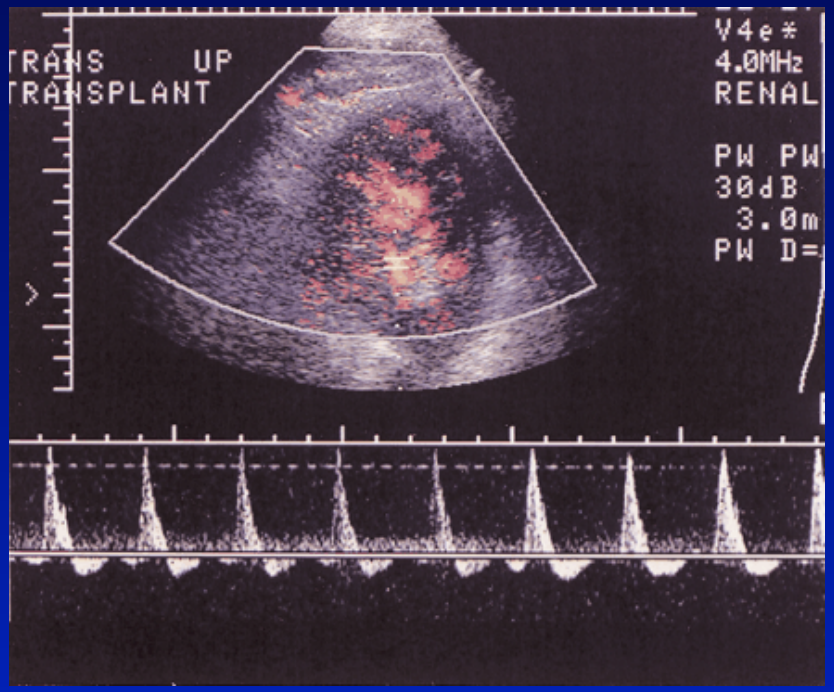


Figure 18a. Severe transplant rejection. **(a)** Duplex color Doppler US image shows a spectral waveform in which the arterial flow in diastole is reversed. Differential diagnosis for this finding includes acute tubular necrosis and renal vein thrombosis. **(b)** On another duplex image, the spectral waveform shows that the renal vein is patent, thus the diagnosis of renal vein thrombosis is excluded. Findings from biopsy confirmed transplant rejection.

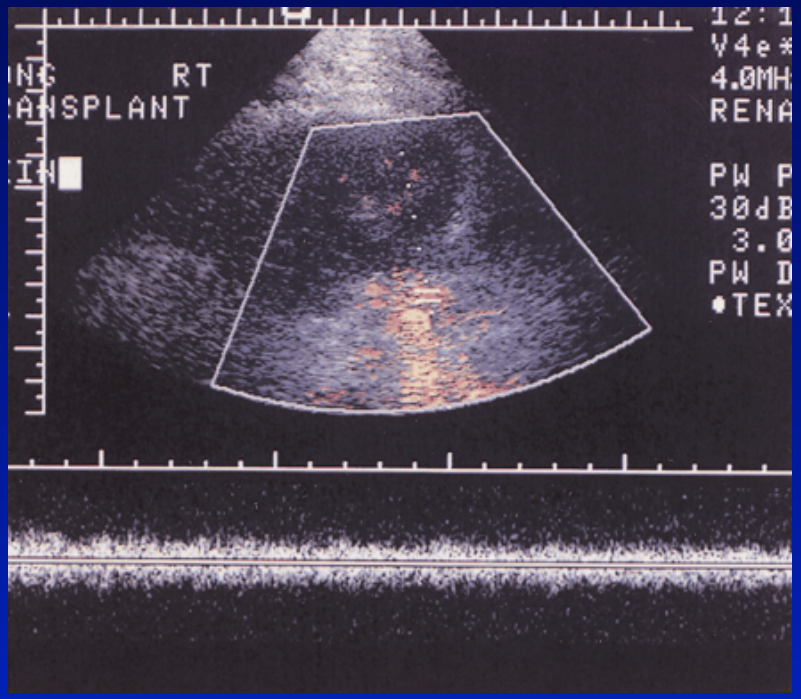


Figure 18b. Severe transplant rejection. **(a)** Duplex color Doppler US image shows a spectral waveform in which the arterial flow in diastole is reversed. Differential diagnosis for this finding includes acute tubular necrosis and renal vein thrombosis. **(b)** On another duplex image, the spectral waveform shows that the renal vein is patent, thus the diagnosis of renal vein thrombosis is excluded. Findings from biopsy confirmed transplant rejection.

From Brown et al, RadioGraphics, 20, 607-622, 2000

MAG3 vs Doppler US

- MAG3
- Quantifiable and reporducable
- Can reliably identify infarcted kidney
- Able to find slow leaks

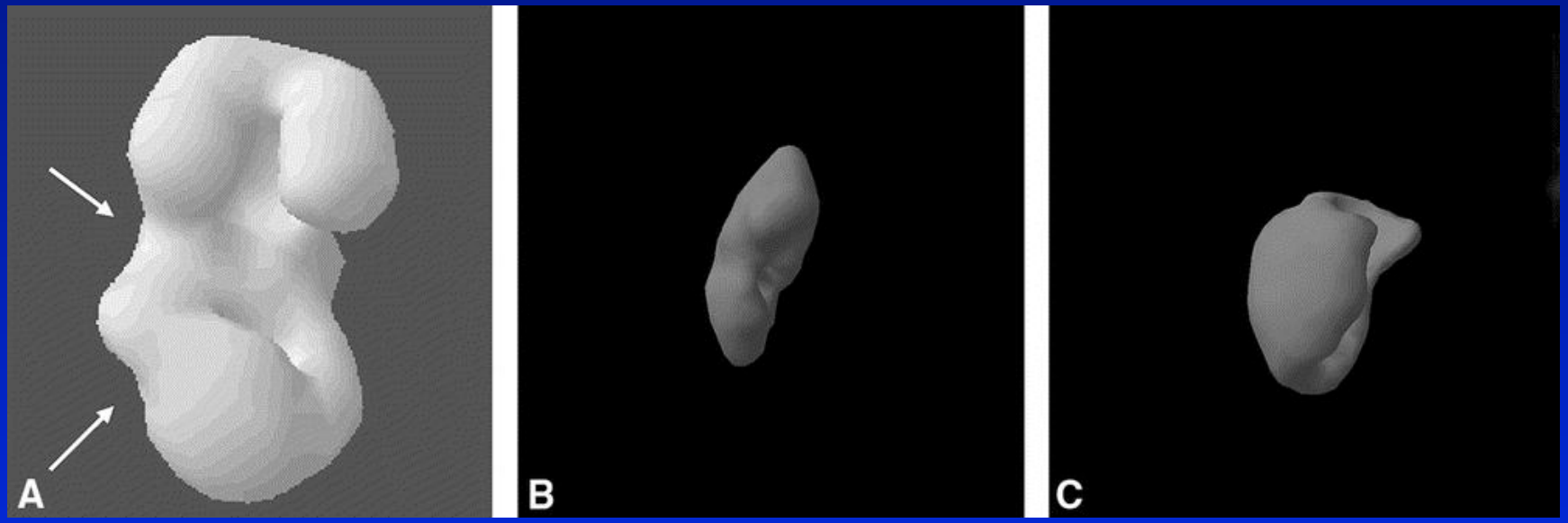
- Doppler US
- No radiation
- Bed side test
- Resisitve index correlates well with rejection but not reproducable

Dupont et al Transplantation 2007

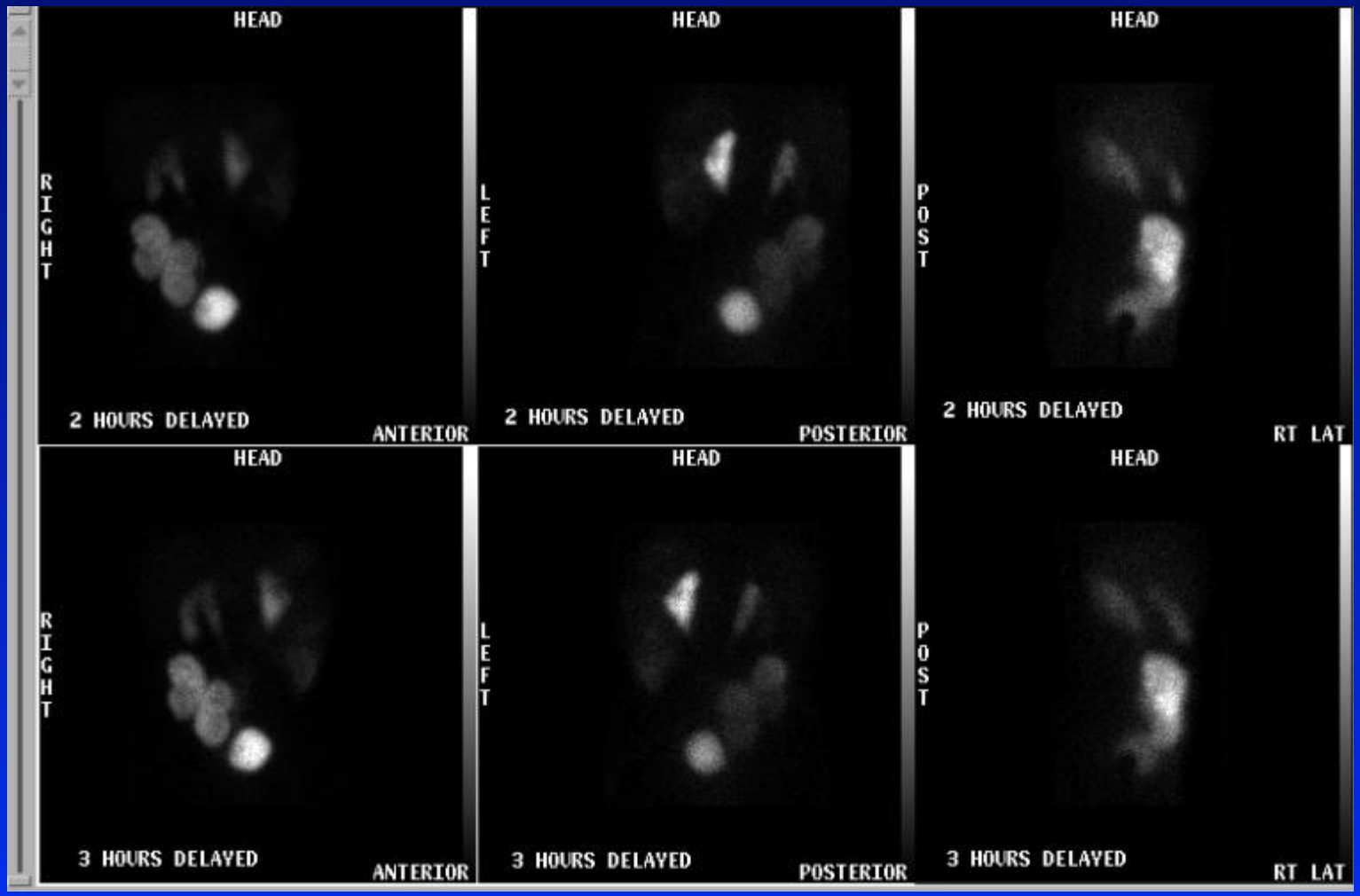
TABLE 2. Comparison of 99m Tc-DMSA SPECT findings in renal allograft recipients with and without a history of recurrent urinary tract infection.

	Recurrent UTIs (%)		Controls (%)	
	Reflux	No reflux	CAN	Vascular occlusion
N	15	17	11	8
No scars	2 (13)	6 (33)	8 (73)	0 (0)
One focal defect	5 (33)	3 (18)	3 (27)	0 (0)
Two focal defects	2 (13)	3 (18)	0 (0)	0 (0)
>Two focal defects	6 (40)	5 (29)	0 (0)	0 (0)
Any focal defect	13 (87)	11 (65)	3 (27)	0 (0)
Segmental defect	0 (0)	0 (0)	0 (0)	8 (100)

Dupont et al
DMSA SPECT in Tx



A=scar, B=rejection , C=vascular damage


HEAD
RIGHT
2 HOURS DELAYED
ANTERIOR
HEAD
LEFT
2 HOURS DELAYED
POSTERIOR
HEAD
POST
2 HOURS DELAYED
RT LAT
HEAD
RIGHT
3 HOURS DELAYED
ANTERIOR
HEAD
LEFT
3 HOURS DELAYED
POSTERIOR
HEAD
POST
3 HOURS DELAYED
RT LAT

Chinese Proverb

"It's not what a cat looks like that matters, it's how well he catches mice"