Uroradiology
For Medical Students

Lesson 5

Nuclear Renography – 1

American Urological Association

Objectives

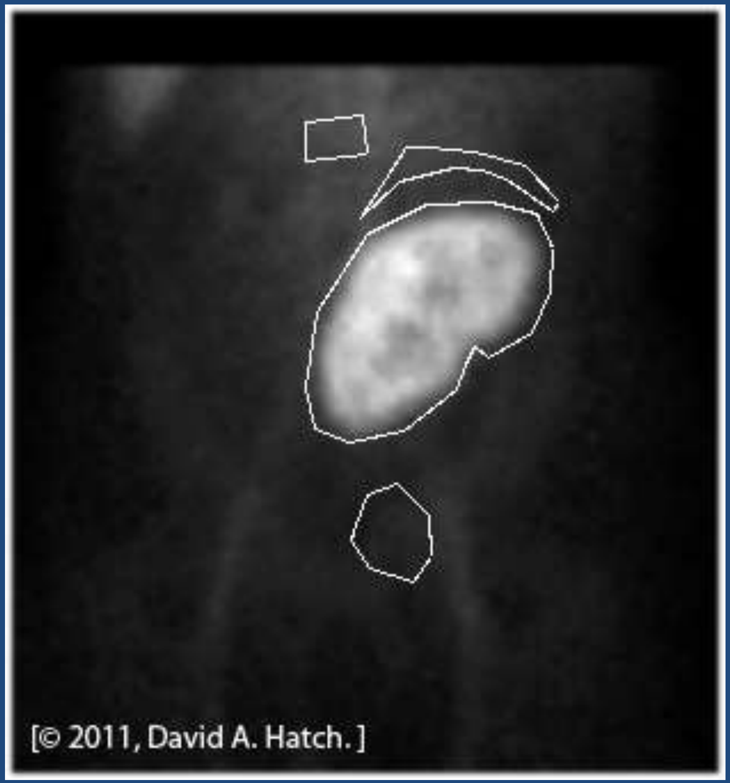
- In this lesson you will learn
  - How a nuclear renogram is performed
  - Three classes of radionuclides used in renography
  - How to read nuclear renogram images
- Plus
  - You will learn about three congential anomalies for which nuclear renography is useful. We're not going to spoil the surprise by mentioning them here, but we expect you to know them by the time you complete this tutorial.

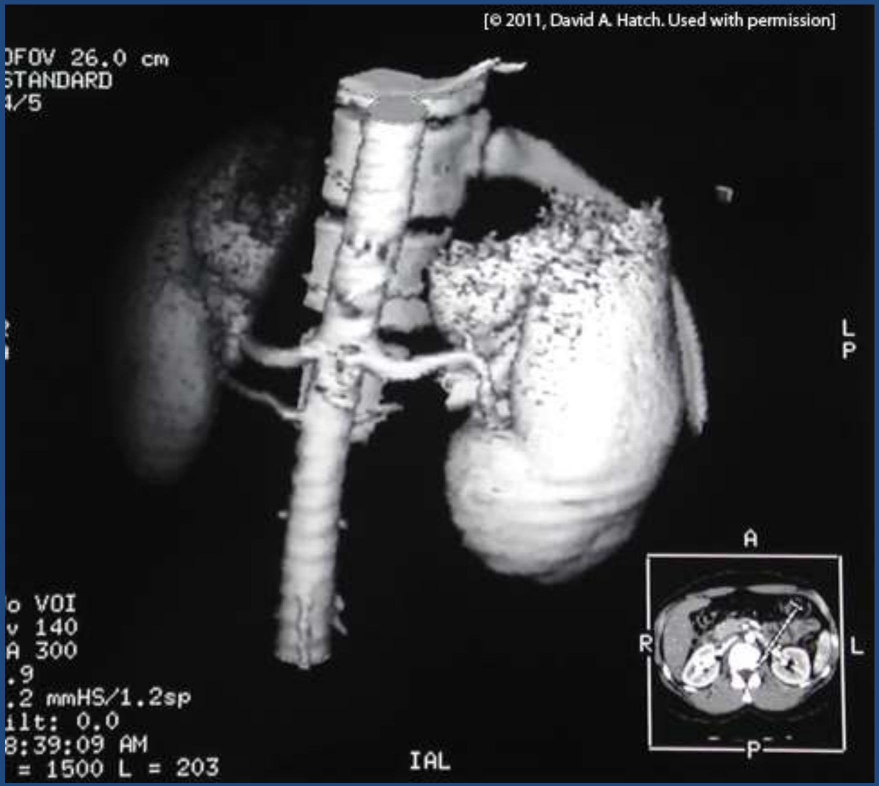
Introduction

- Ultrasound and cystography give us a lot of information about the urinary tract, but neither imaging technology tells us about the function of the kidneys. Nuclear renography gives a very detailed representation of the function and drainage of the kidneys.

Introduction

- Nuclear renography is highly accurate at measuring kidney function, but the images are low resolution. Compare a kidney image from a nuclear renogram (left) with 3D-CT scan.





Technique

- Nuclear renography is performed by injecting a radionuclide into the venous circulation. The uptake and passage of the radionuclide is detected by a nuclear medicine camera. Various radionuclides are handled by the kidney in different ways. We can use those differences to answer questions about the urinary tract.

Synonyms

- The terms radionuclide, radioisotope, radio tracer or nuclear imaging agent all refer to the radioactive material that is used to make the nuclear medicine images. These substances are molecules that contain radioactive atoms. When those atoms decay, they emit energy in the form of gamma rays or alpha or beta particles that are detected by the nuclear medicine camera.

Radionuclides

- Three basic classes of radionuclide are employed in nuclear renography.
  - Filtered agents
  - Excreted agents
  - Cortical imaging agents

Filtered Radionuclides

- DTPA and MAG3 are filtered through the glomerulus. This is useful in evaluating:
  - Perfusion
    - Vascular supply
  - Filtration
    - Measuring renal function (glomerular filtration rate)
  - Drainage
    - Detects obstruction

Excreted Radionuclides

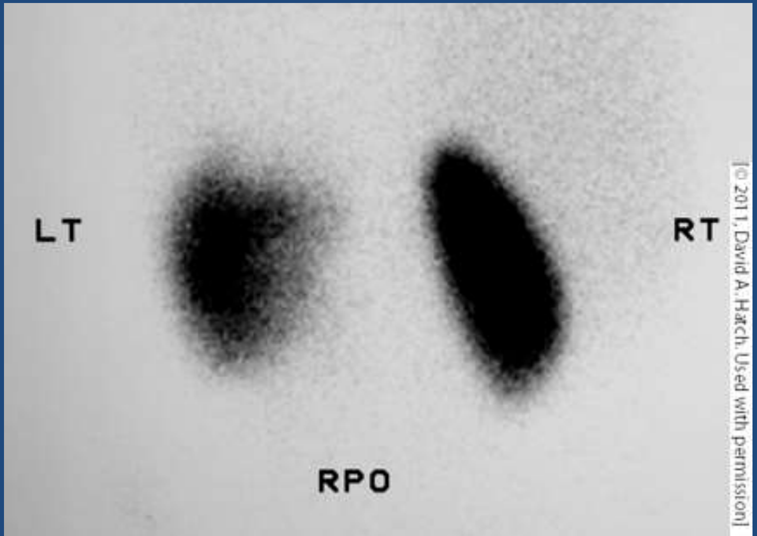
- MAG3 and Hipuran are excreted by the renal tubules. These radionuclides are helpful in evaluating patients with:
  - Diminished renal function
  - Kidney transplants
- MAG3 is both filtered and excreted so some radiologists prefer it to other radionuclides.

Cortical Imaging Radionuclides

- DMSA and Glucoheptonate are accumulated in the cortex so they are helpful in evaluating:
  - Renal scarring from chronic infection
  - Infarction
  - Renal mass
  - Differential renal mass (proportion of total renal mass contributed by each kidney)

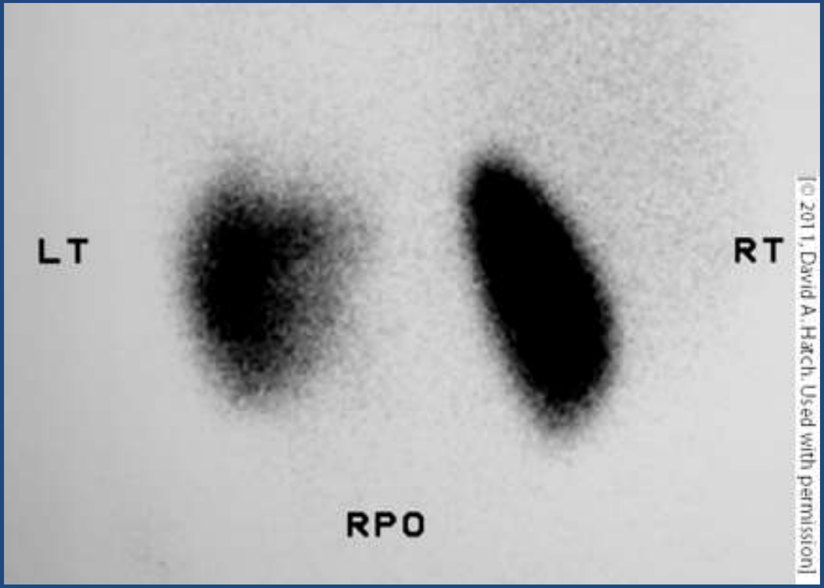
Nuclear Renography – Conventions

- After intravenous injection of the radionuclide the nuclear camera (radiation detection instrument) is usually placed behind the patient, so the image of the left kidney is on the left, unlike conventional radiography or axial CT scans. As with other imaging studies, image labels will help to orient you. Why does the right kidney image look sharper than the left?



Nuclear Renography – Orientation

- Notice the label? RPO means right posterior oblique. The patient is lying on her right side rotated about 45 degrees. The camera is closer to the right kidney so that image is somewhat sharper.



- Are you ready to see a patient?

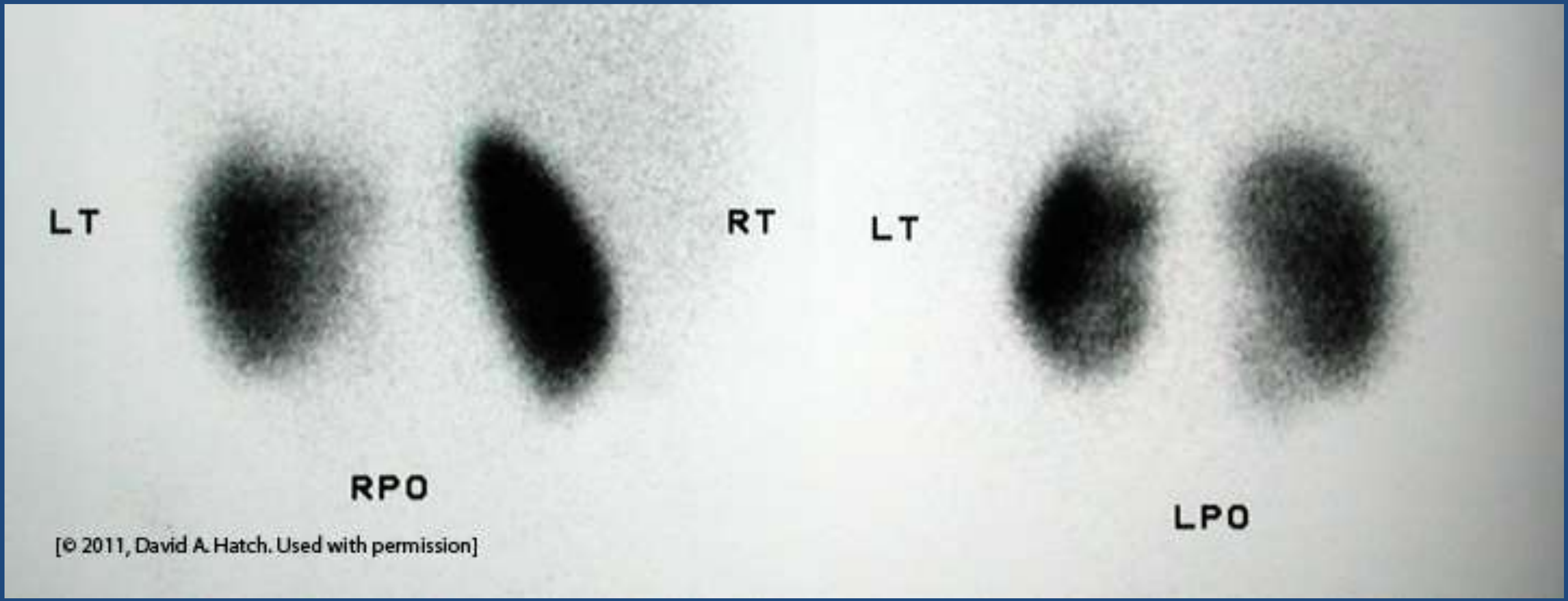
Case History

- A six year old girl with known vesicoureteric reflux has had febrile urine infections despite prophylactic antibiotics. Pyelonephritis can cause renal scarring. Previously, this patient had no renal scars. In order to determine if this girl has new renal scars, what radionuclide would you use?
- Filtered imaging agent
- Excreted imaging agent
- Cortical imaging agent ←

Cortical Imaging Scan

- The radioisotope is injected intravenously.
- Images are obtained in various orientations
  - Posterior (because the kidneys are closer to the back)
  - LPO (left posterior oblique)
  - RPO (right posterior oblique)
- We examine the images to detect defects. A scarred area will have no uptake of the radionuclide and, therefore, no radioactivity detected by the camera. Such areas are described as **photopenic**.

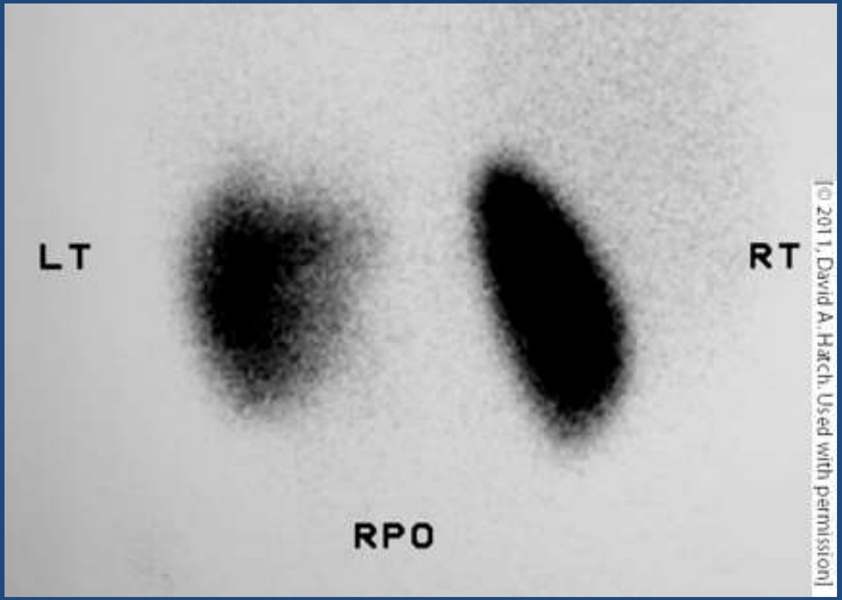
Let’s look at her DMSA (cortical agent) scan.



DMSA Cortical Scan

- Her right kidney is smooth and reniform (bean-shaped).

- The left kidney is irregular. It looks as if someone took a bite out of the upper pole. The lower pole is irregular too.



- Besides renal scarring from chronic infection, what could give this appearance (photopenic areas)?

- Infarction, for example from an arterial embolus, or severe atherosclerosis in the renal artery can also give this appearance.

Case Summary

- Renal scars show up as photopenic areas where one would expect to see cortical uptake.
- Scar formation represents a loss of renal parenchyma.
- This girl has suffered renal scarring from recurrent pyelonephritis. Many urologists would consider this to be an indication for surgical correction of reflux.
- Infarction of a portion of a kidney would also show up on a cortical imaging scan as a **photopenic** area.

Case History

- A 4-year-old male is referred for evaluation of colicky right flank pain. Ultrasound showed grade IV right hydronephrosis. Past history is otherwise negative. This is the same boy whose renal ultrasound you saw in the Ultrasound – 1 tutorial.
- Exam: healthy male. BP = 116/72 (high for a 4-year-old). Non-tender fullness in the right upper quadrant.
- You review the ultrasound and agree that it shows right grade IV hydronephrosis. We suspect that he has an obstruction, but we need to confirm. What radionuclide class should we use to evaluate his kidney drainage?

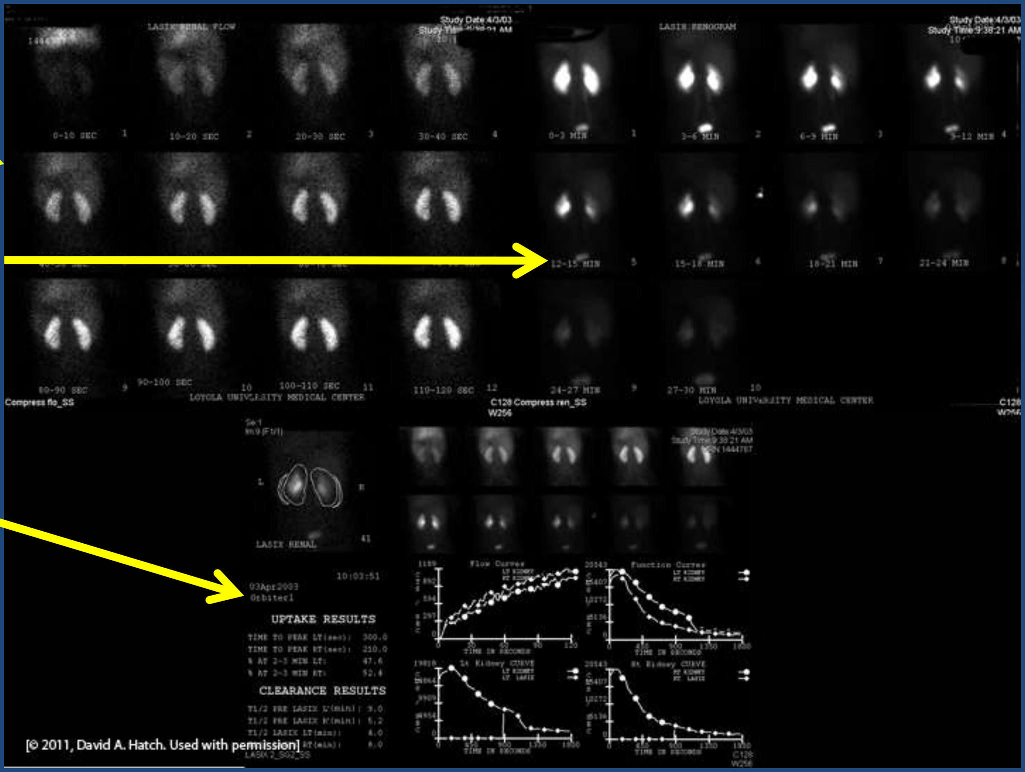
Evaluation of Hydronephrosis

- A filtered agent is best for evaluating filtration and drainage. The nuclear imaging study used to evaluate obstruction is called a lasix renogram.

- A lasix renogram is dynamic study performed over time.
  - A filtered radionuclide is injected intravenously.
  - The radionuclide is followed continuously.
  - After the radionuclide has circulated thoroughly (usually after peak concentration and active drainage from the kidneys) lasix is given intravenously in order to maximize urine production. This helps to demonstrate obstruction.

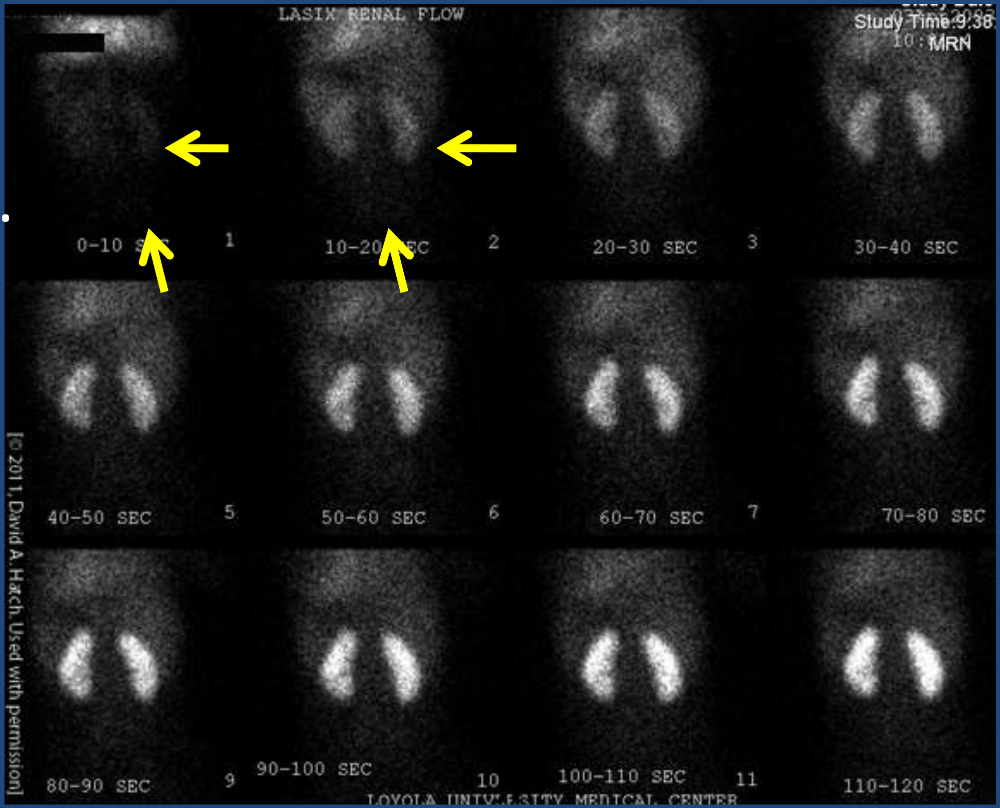
Let’s look at a normal lasix renogram.

- The scans you will read will vary in appearance, but you should see three image panels:
  - Perfusion
  - Excretion/drainage
  - Analysis/curves



Perfusion Panel

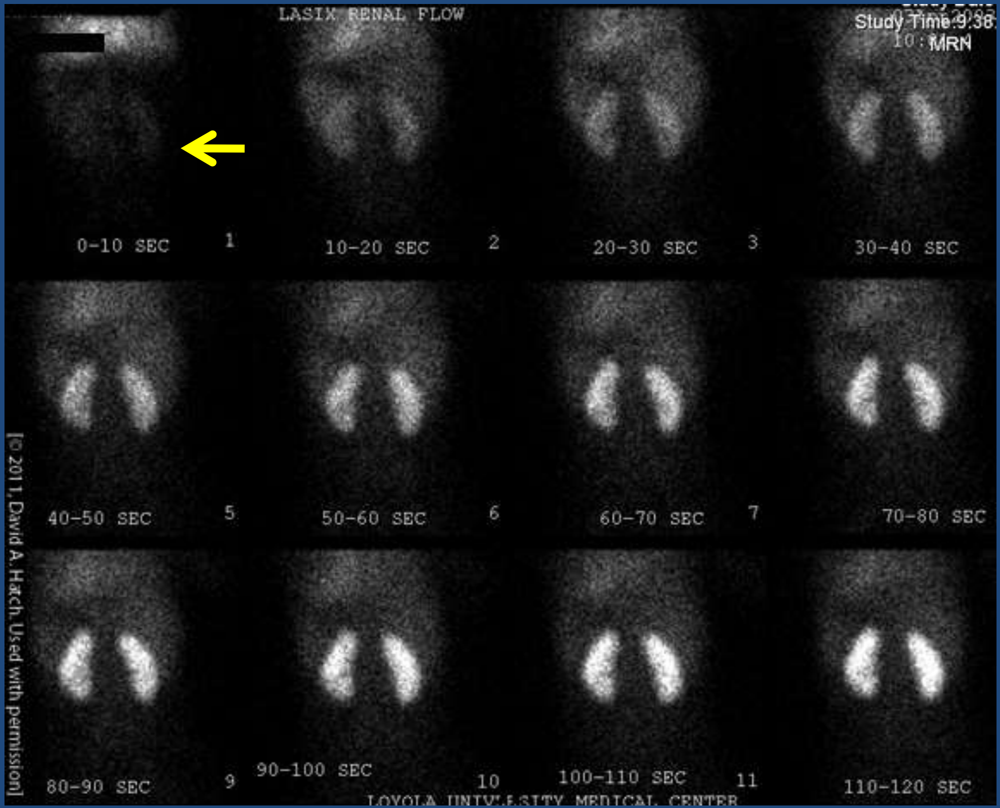
- Images are accumulated over intervals of 10 seconds. You can tell when you're looking at a perfusion image. The images appear a bit more fuzzy than those from the drainage phase, and the time intervals will be in seconds, rather than minutes.



- The kidneys should show uptake simultaneously within one frame of the appearance of the great vessels (arrows).

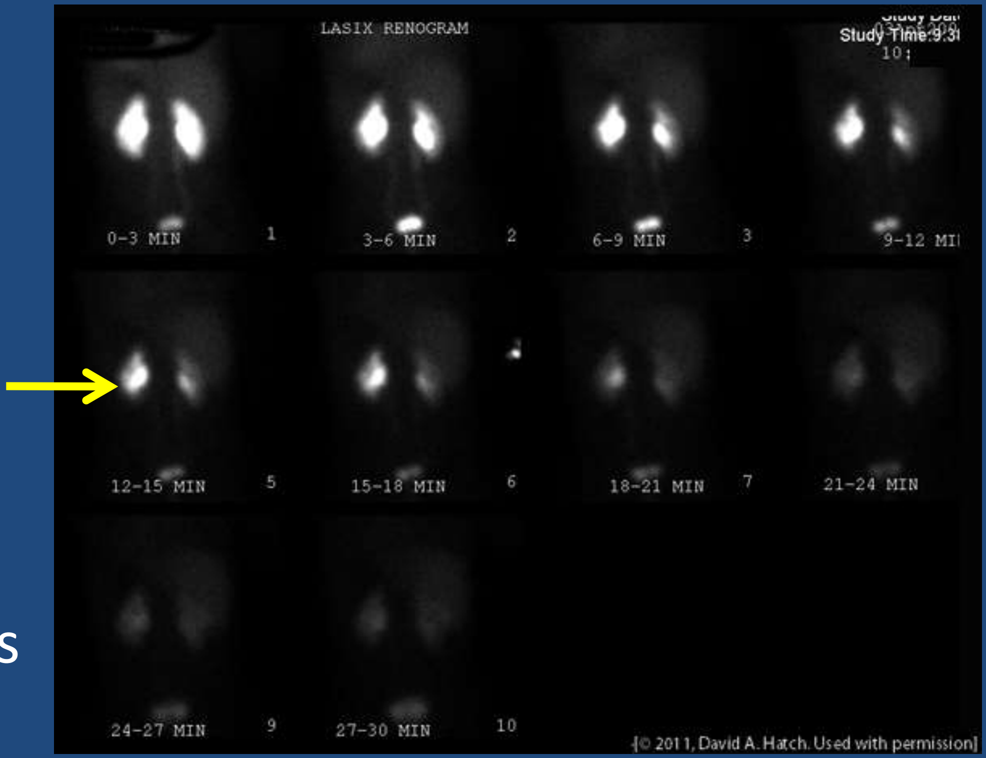
Perfusion Panel

- Look at image #1 (1 – 10 SEC). This frame represents the activity that occurred during the first 10 seconds following injection of the radionuclide. Subsequent frames represent seconds 10 to 20, 20 to 30 and so on. Follow the frames.
- You can see uptake in both kidneys equally. Both kidneys get brighter in the first 5 or 6 frames.
- Uptake (perfusion) appears to be uniform throughout both kidneys. What would a perfusion image look like if a patient had thrown an embolus into the renal artery?



Excretion / Drainage Panel

- As on the perfusion panel, these images are accumulated over time. However, they represent activity over minutes, rather than seconds (3 minute intervals on this scan).
- You may find it useful to ask yourself two questions:
  - Which frame on the excretion/ drainage panel is the brightest for each kidney?
  - Do the kidneys look less bright in subsequent frames (do both kidneys show drainage)?

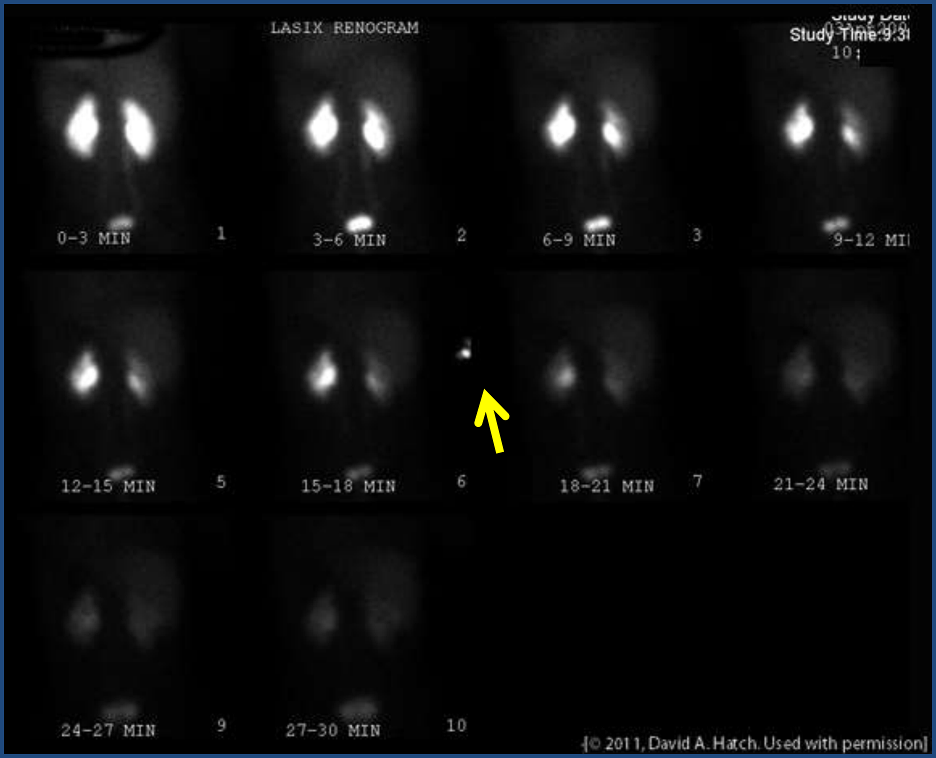


- On this scan, both kidneys are brightest in the first frame. The left kidney drains a bit more slowly than the right (image #5).

Excretion / Drainage

- About 15 minutes after injection of the radionuclide, lasix is given intravenously. On many scans you can tell when the lasix was injected because the syringe holding radionuclide is placed next to the patient (arrow).

- Unless obstruction is complete, there will be some drainage. If the obstruction is partial, it may be detected only with high urine flow. Lasix helps to demonstrate partial obstruction by maximizing urine output.

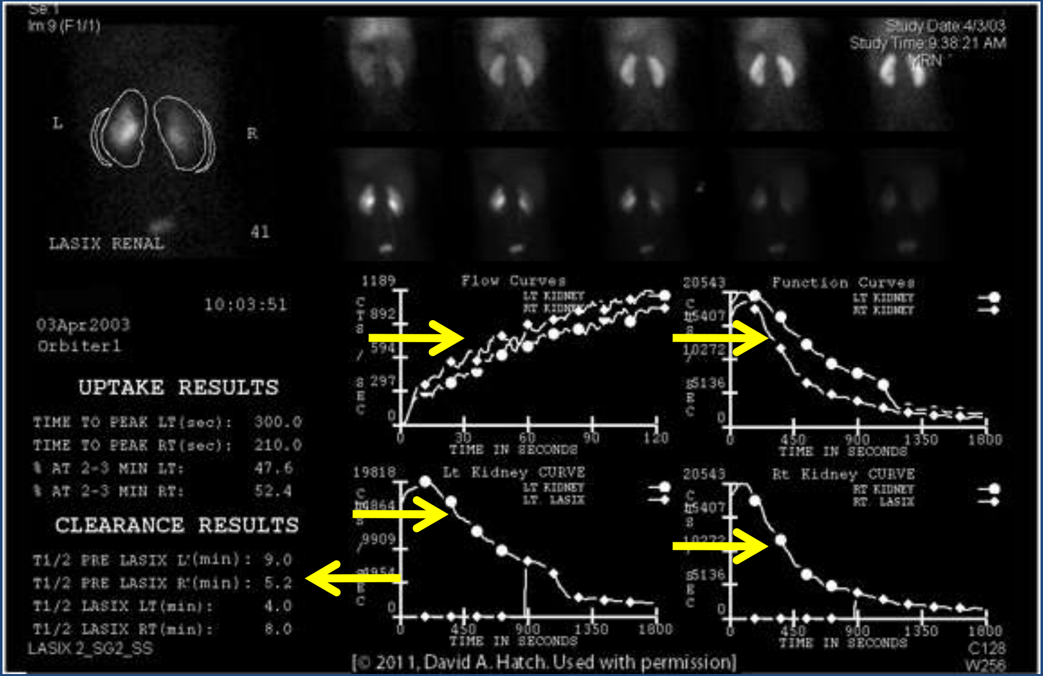


Notice how rapidly both kidneys drain in response to the intravenous lasix. The image of the kidneys fades rapidly.

Curves / Analysis Panel

The computer generated curves give a graphical representation of the scan images over time. They vary in appearance depending on the equipment used, but there are some common elements you will find on any study:

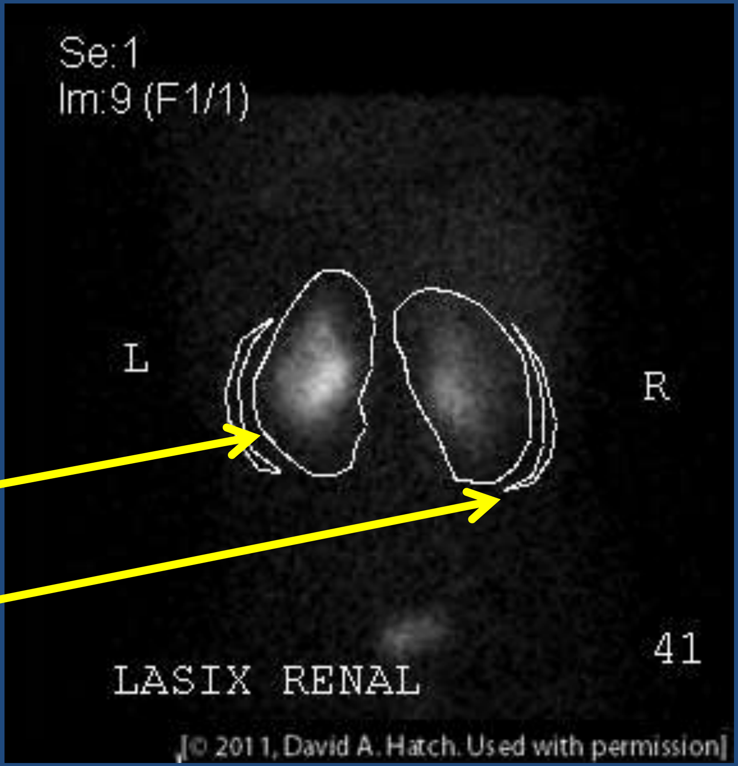
- Curves representing early uptake (perfusion phase)
- Curves representing drainage
- Tables for differential function and clearance



On the line graphs, radioactivity counts are plotted on the Y axis while time is plotted on the X axis. Look at the labels for each graph to see what each line represents.

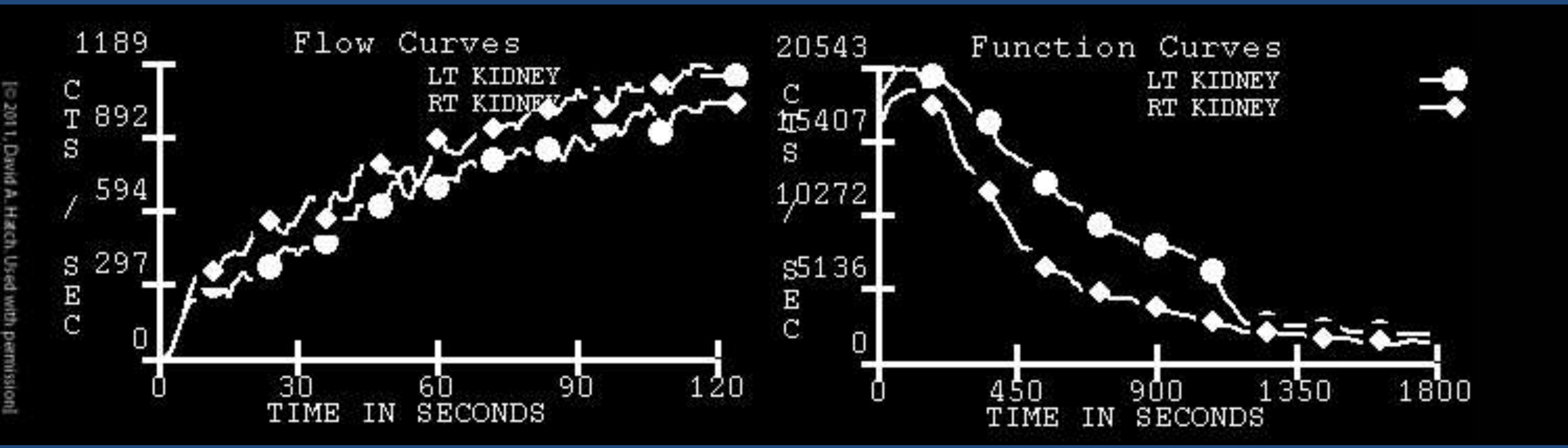
Curves / Analysis Panel

- Area of interest
  - This is a graphical representation of the area from which radioactivity is measured in the analysis. There are two such areas for each kidney.
    - Kidney area
    - Background area
  - The radioactivity detected in the background area is subtracted from that detected from the kidney to eliminate background noise.

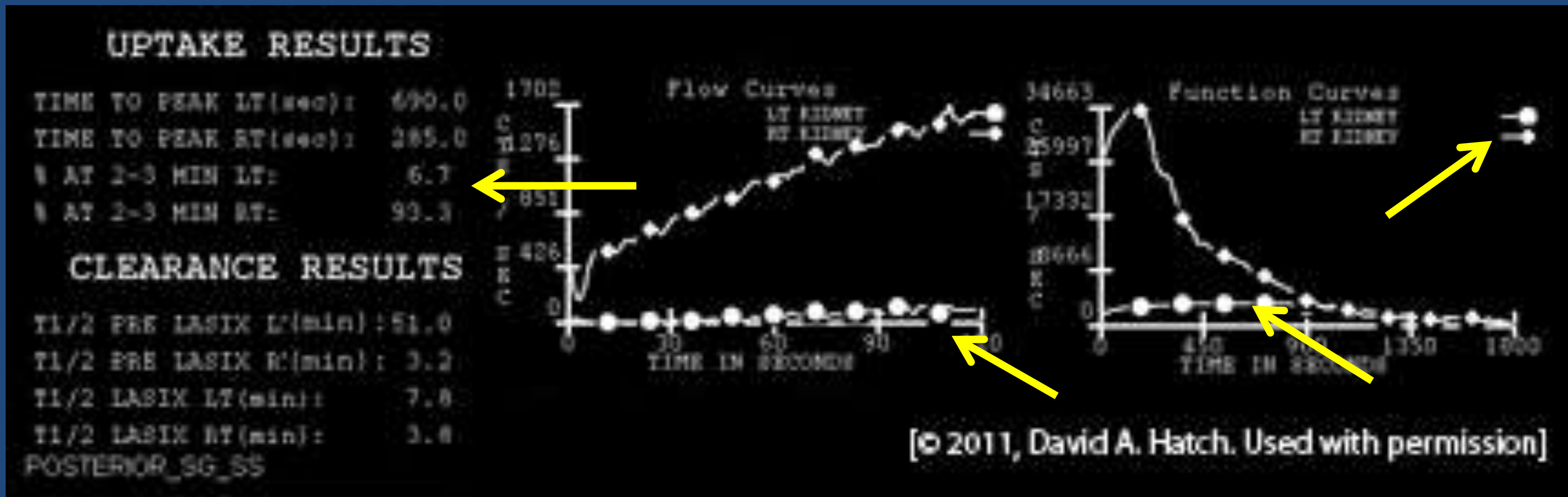


Look at some normal curves.

- Normally, the curves show rapid uptake (flow curve on left) and rapid drainage (function curve on right). Each kidney is plotted separately (see labels) on each graph.



Compare those results to these.



- Look at the labels to see which curve represents each kidney. In this scan the left kidney is represented by the line with circles, the right by the line with diamonds.
- There is almost no perfusion to the left kidney.
- Similarly, there is no significant function in the left kidney.
- The table shows that the left kidney uptake is only 6.7% of the total. Let’s look at the table more closely.

Table

- This table gives a numeric representation of the scan including:
  - Differential function, the relative contribution of each kidney to total renal perfusion/uptake.
  - T ½ - the time at which half of the radionuclide has drained (ignore T ½ pre-lasix for now).

UPTAKE RESULTS

TIME TO PEAK LT(sec):	300.0
TIME TO PEAK RT(sec):	210.0
% AT 2-3 MIN LT:	47.6
% AT 2-3 MIN RT:	52.4

CLEARANCE RESULTS

T1/2 PRE LASIX LT(min):	9.0
T1/2 PRE LASIX RT(min):	5.2
T1/2 LASIX LT(min):	4.0
T1/2 LASIX RT(min):	8.0

LASIX 2_SG2_SS

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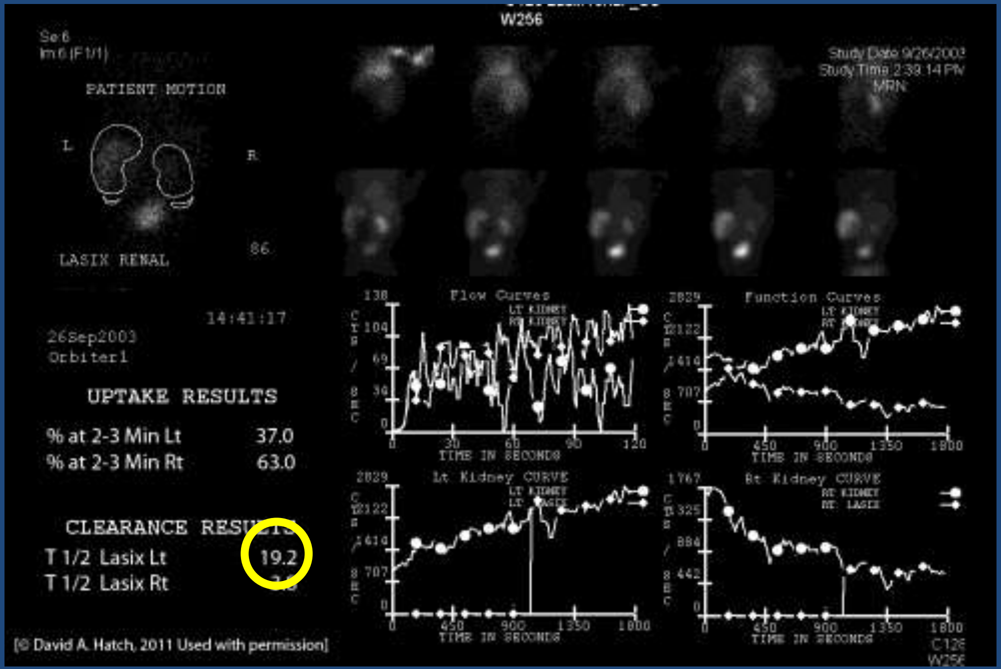
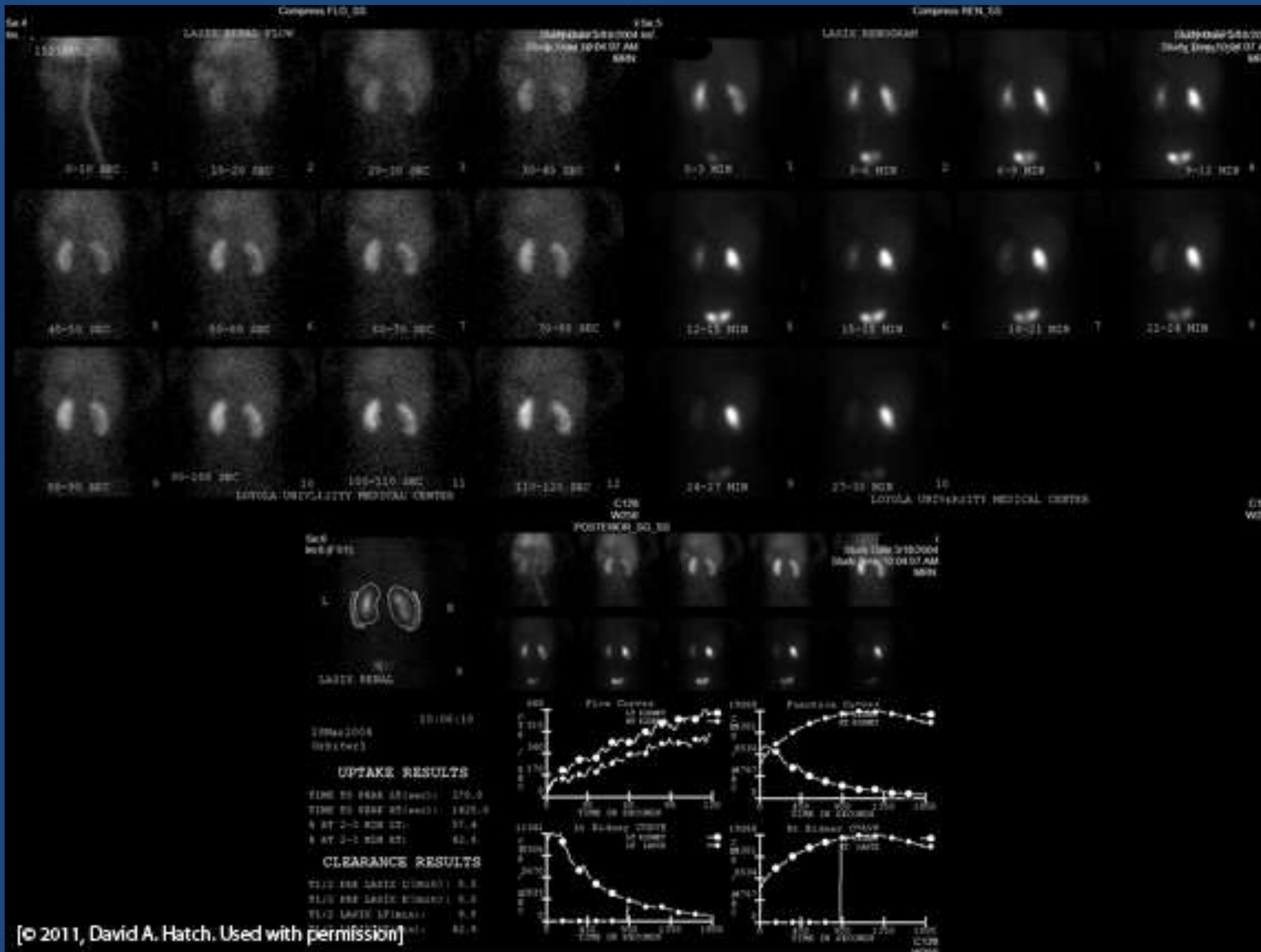
Lasix Renogram

- Normal T ½ is < 12 min. If the kidney doesn't reach T ½ by 20 min. the kidney is considered to be obstructed.
- T ½ from 12 min. to 20 min. is considered to be indeterminate.



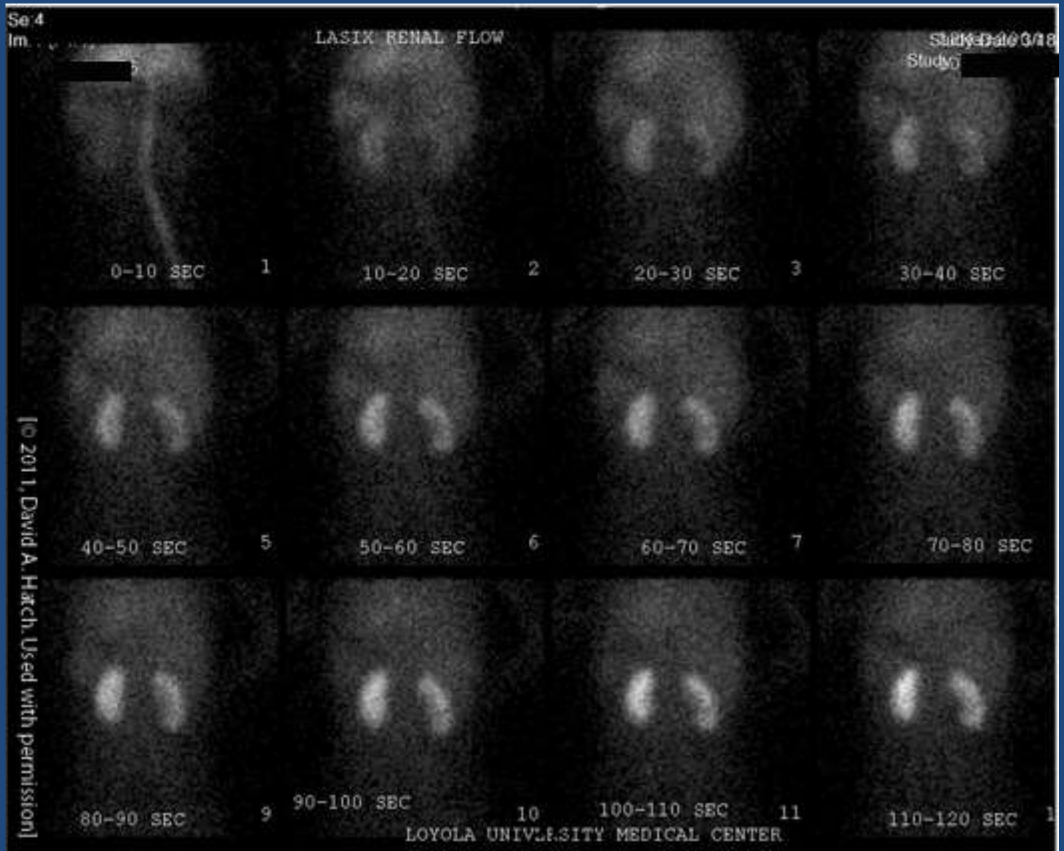
- This lasix renal scan shows that the T ½ of the left kidney is 19.2 minutes, in the indeterminate range.

The laisx renogram on that boy with right hydronephrosis is probably finished. Let’s take a look.



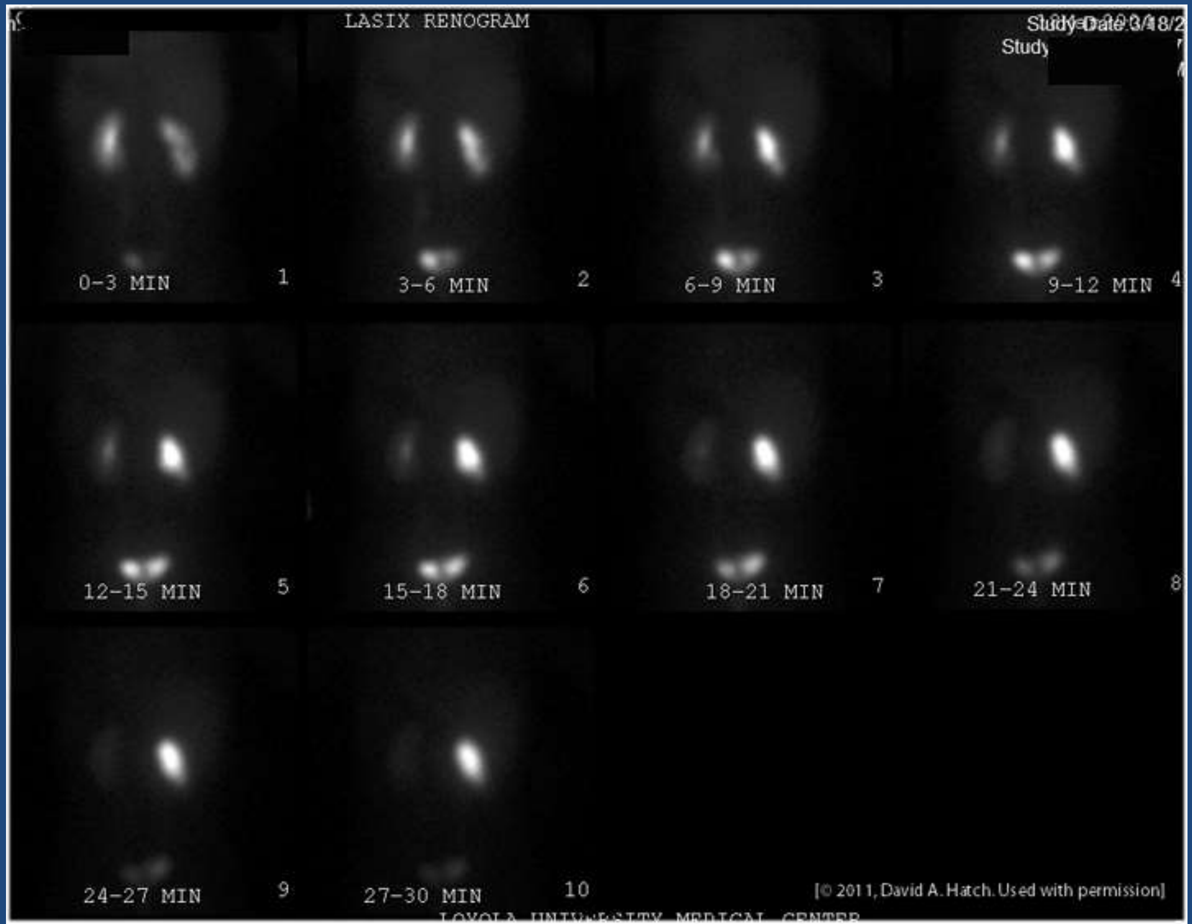
How did you do?

- This is the perfusion panel. Notice that the time intervals are in seconds. Both kidneys show prompt uptake, but the right kidney doesn't get quite as bright.



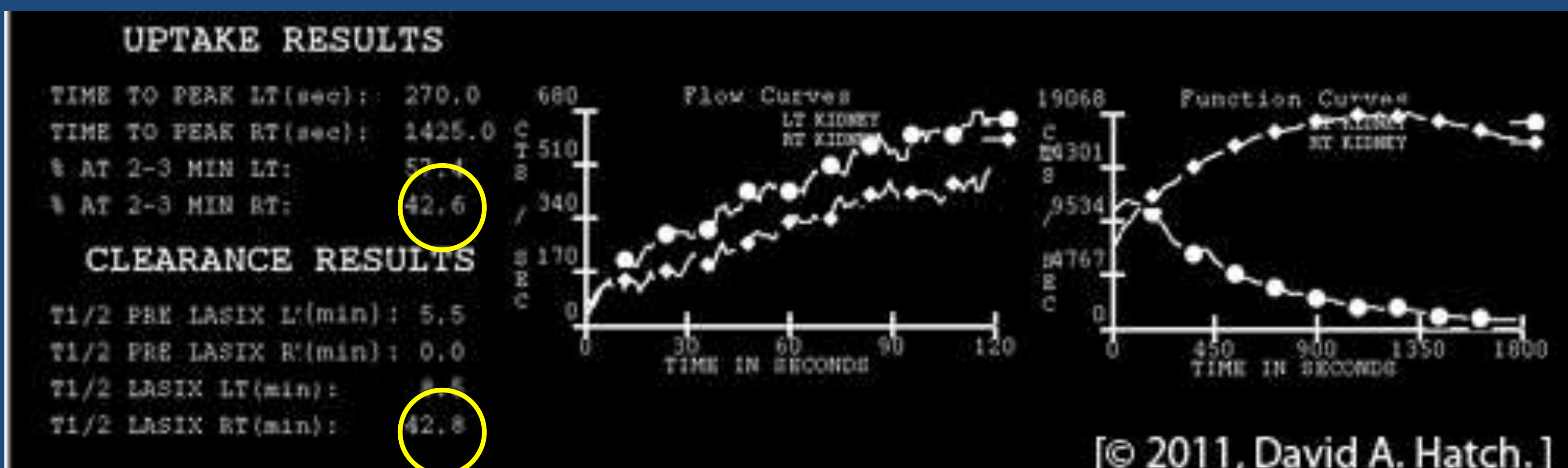
Drainage Panel

- The left kidney shows prompt drainage, but the right kidney retains the radionuclide even in the last image.



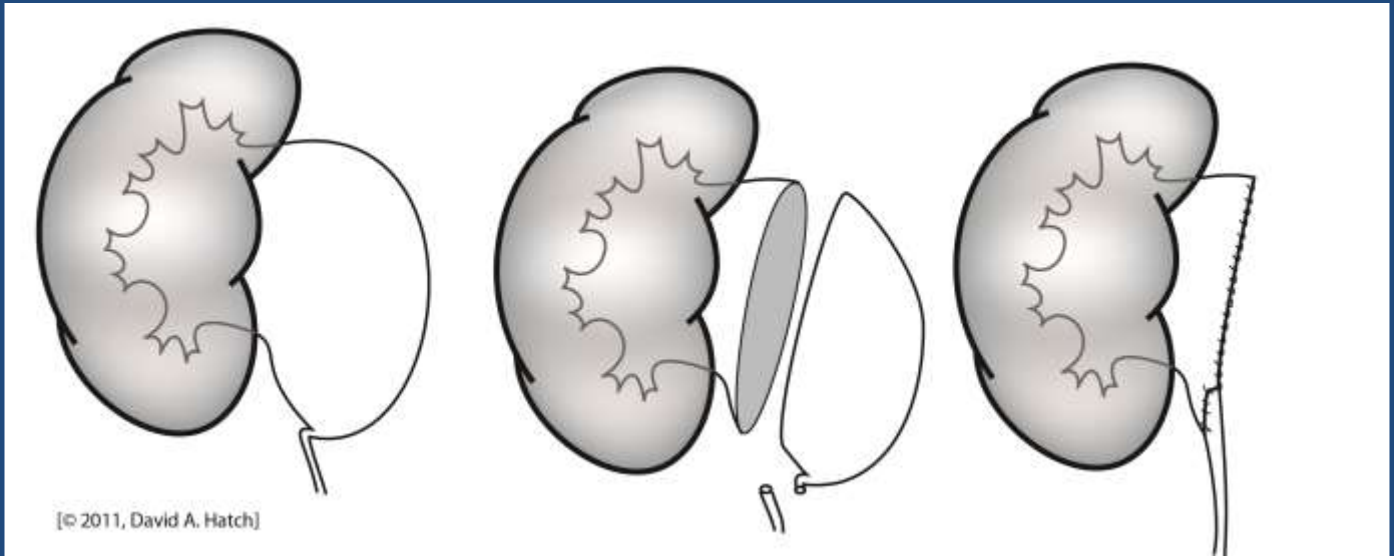
Curves / Analysis

- The right kidney contributes 42.6% of total renal function.
- The right kidney has a prolonged T ½ (42.8 min).



Case Summary

- The right kidney shows slightly less perfusion and significantly slower drainage than the left.
- This boy has a significant obstruction of his right kidney. The most common cause of hydronephrosis in a child is a ureteropelvic junction obstruction.
- You perform a dismembered pyeloplasty, relieving the obstruction. His parents are so grateful that they establish a research foundation in your name.



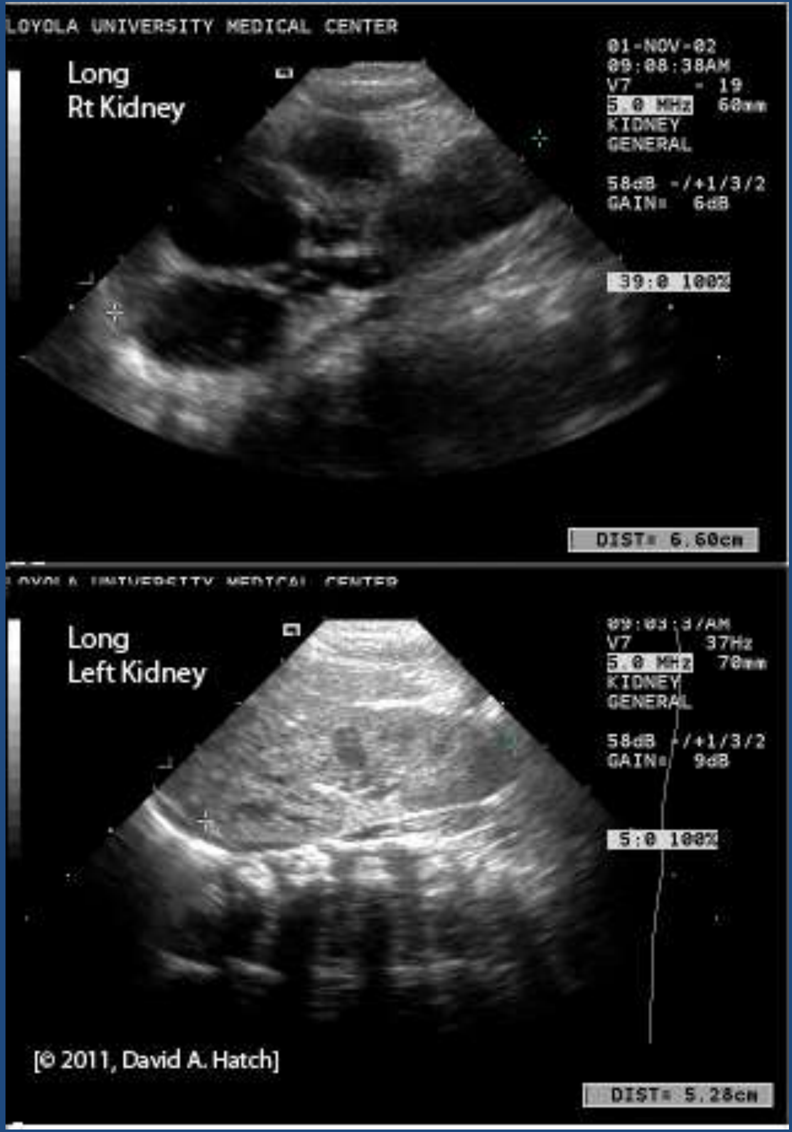
Case History

- You are called to see a newborn male. Prenatal ultrasounds have shown an abnormality of the right kidney. Unfortunately, neither the ultrasound images nor the report is available.
- The baby was born at 40 weeks gestational age with APGARs of 9/9/9. Exam is completely normal. His pediatrician orders an ultrasound. Remember how to read an ultrasound?

Ultrasound Interpretation

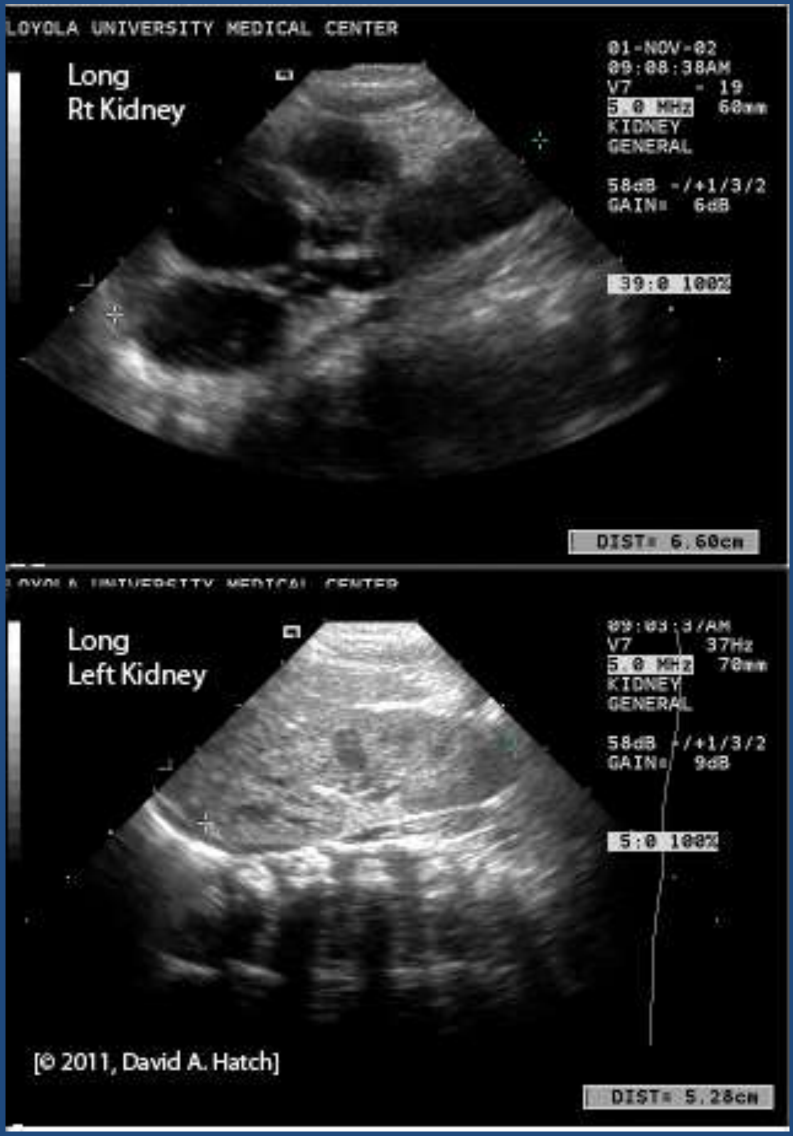
- Size
  - Right: 6.6 cm. Why is this kidney so large? (Nl = 4 cm)
  - Left: 5.2 cm. Why is this kidney so large?
- Shape
  - Right: Reniform
  - Left: Reniform

- You can learn more about reading ultrasounds by taking the AUA's Uroradiology Tutorial 1 and 2.



Ultrasound Interpretation

- Parenchyma?
  - Right: What parenchyma?
  - Left: Normal
- Hydronephrosis?
  - Right: What do you think?
    - Multiple round cystic areas in the left kidney don't appear to communicate
  - Left: None

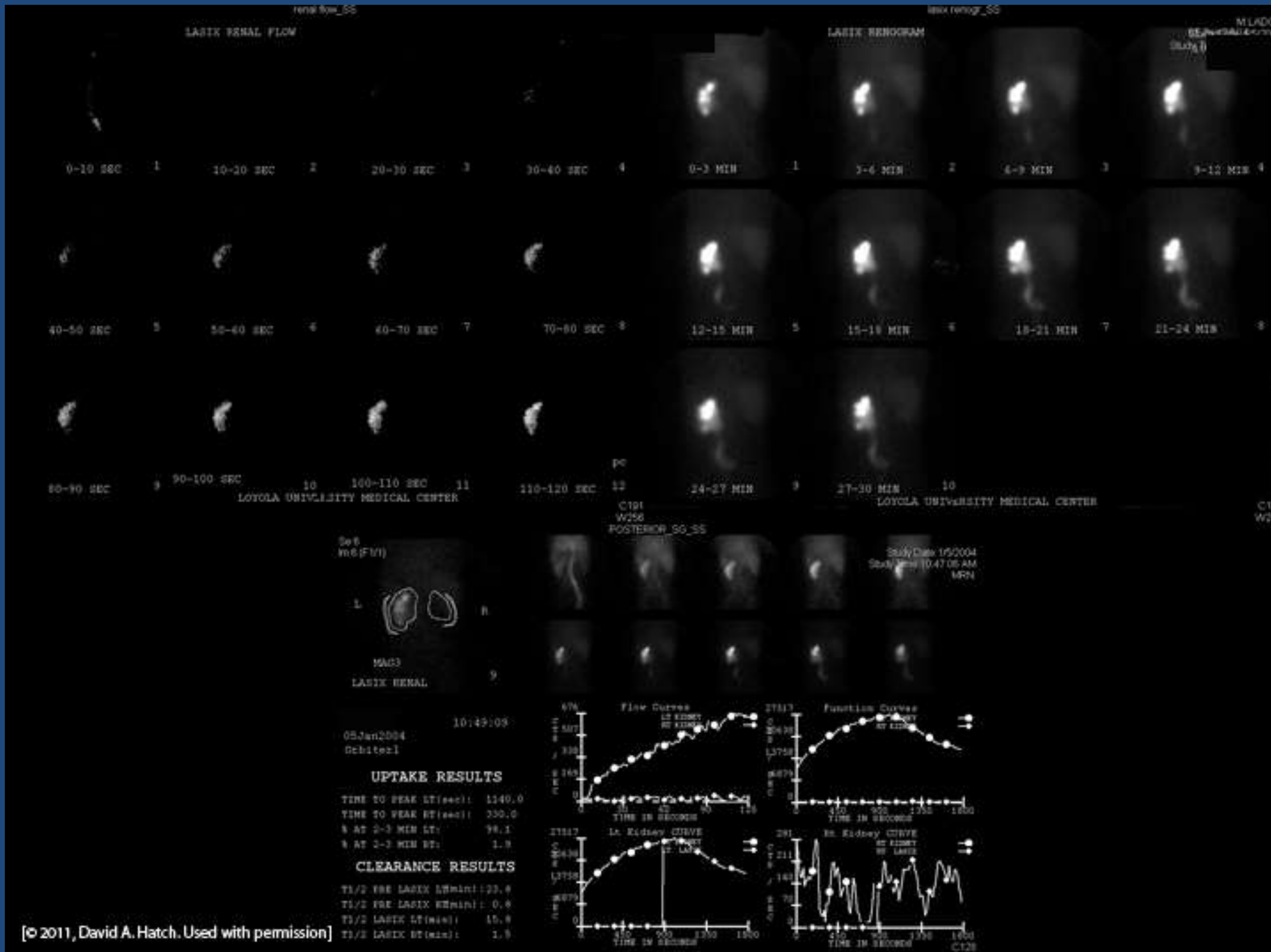


Renal Function?

- What type of nuclear scan would be appropriate to determine function and possible obstruction of the kidneys?

- Filtered agent
  - Demonstrates perfusion and obstruction
- Excreted agent
  - Function and perfusion (indirectly)
- Cortical agent
  - Renal mass

We ordered a DTPA Renal Scan (Filtered radionuclide)



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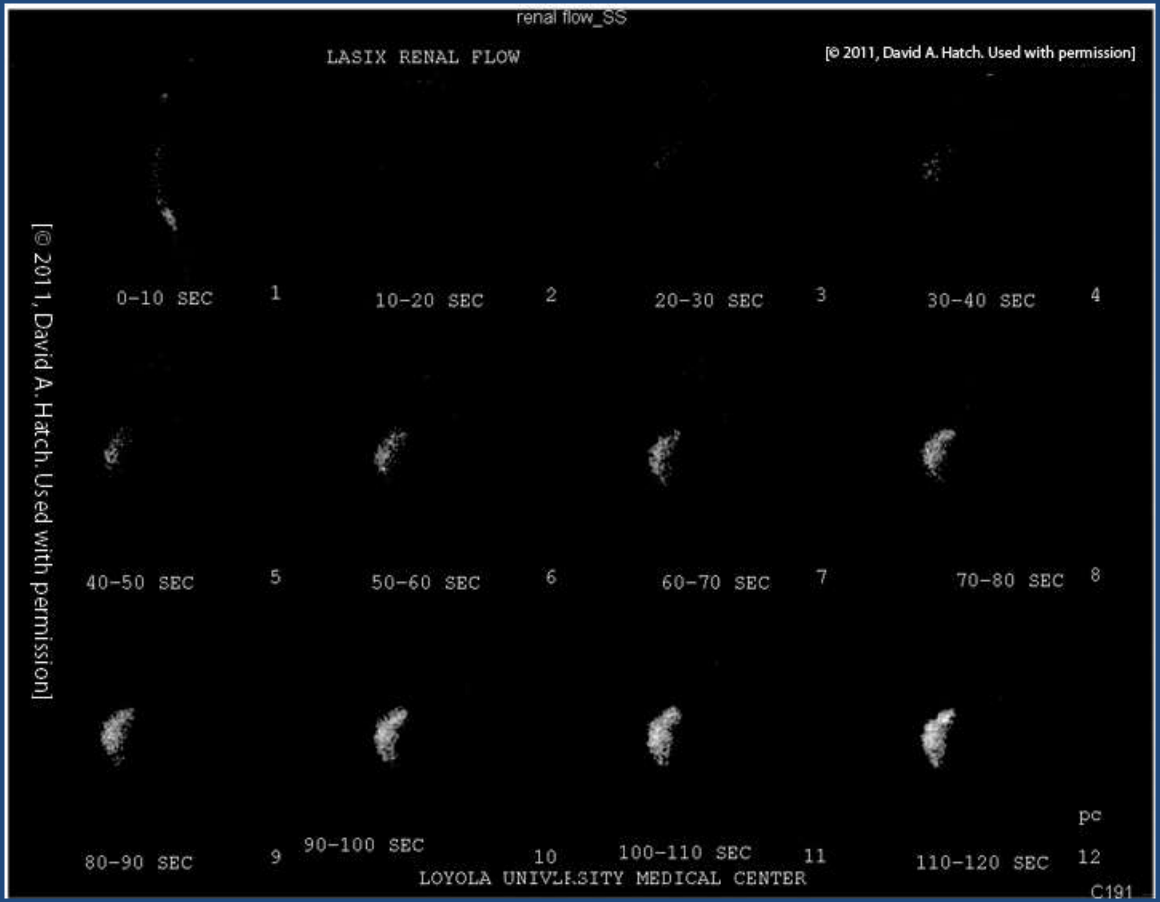
Your interpretation?

- Perfusion
  - Normal on left
  - None on right
  - We know from the ultrasound that there is a kidney on the right. Why doesn't it show up on the nuclear scan?

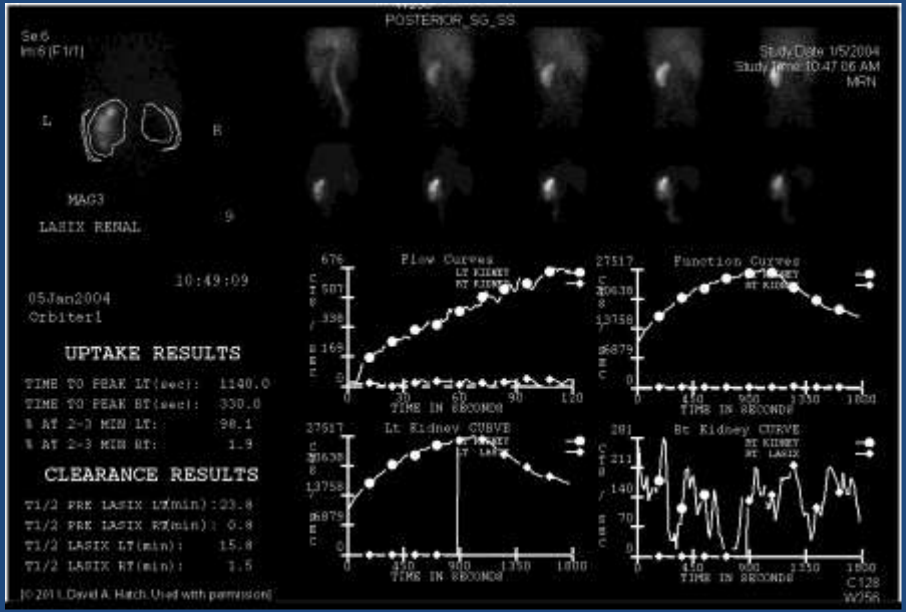


Your interpretation?

- Drainage
  - None on right
  - Delayed on left

Analysis/curves Panel

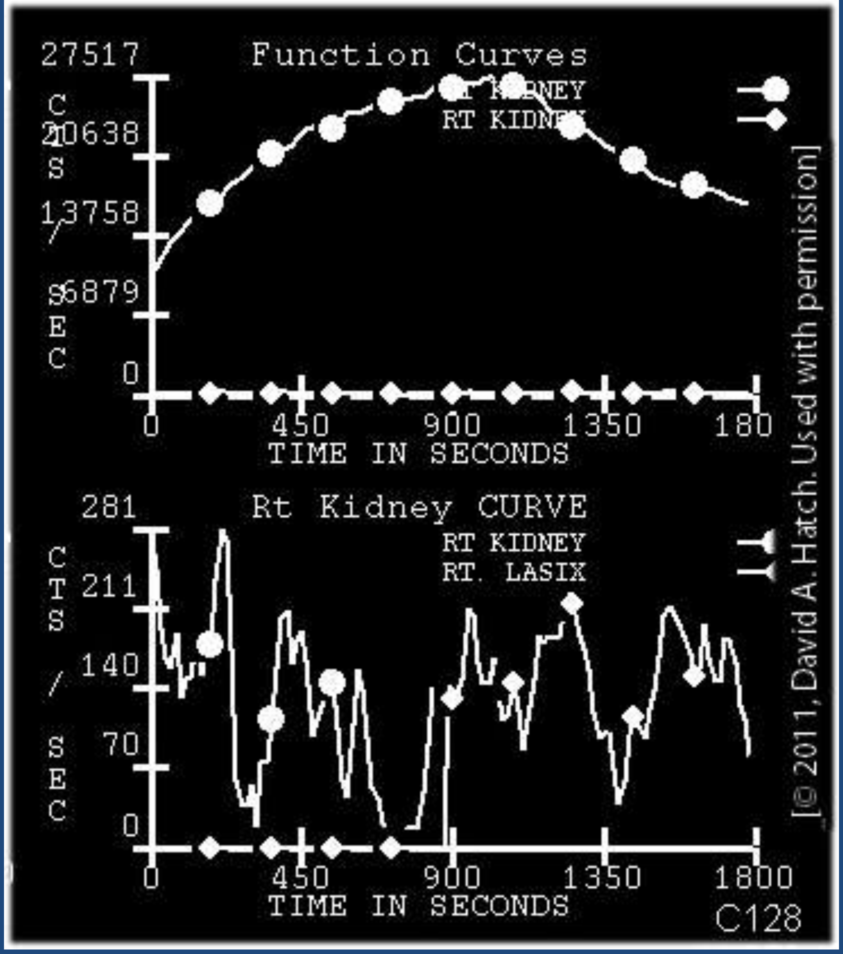
- The curves show no perfusion on the right, and there is delayed drainage on the left. This delay on the left is due to immaturity of the newborn kidney. Remember, we saw no left hydronephrosis on ultrasound.



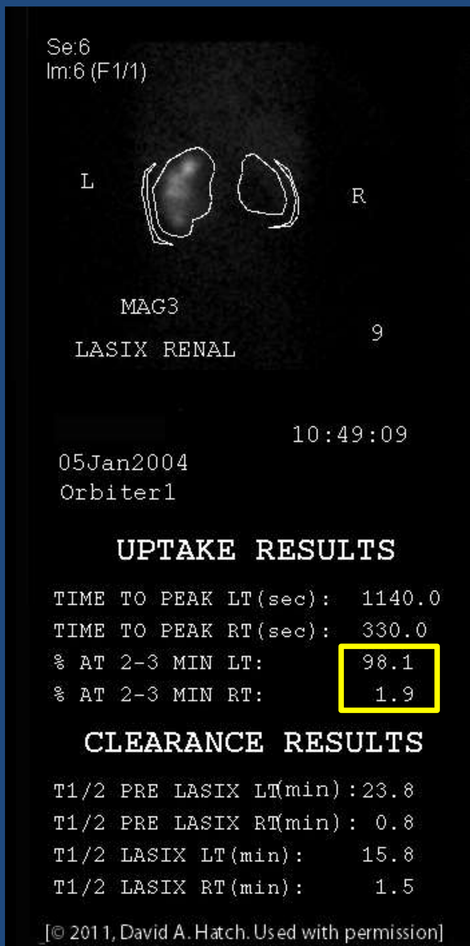
Look at the curve on the lower right. Why is it so irregular?

Why is this curve so irregular?

- Look at the Y axis. Notice the scale? The Y axis on the upper curve goes from 0 to 27,517. The lower curve axis ranges from 0 to 281. The lower curve is magnified. Motion can also cause this kind of irregular curve because the kidney may move partially out the area of interest the camera is “looking” at.



Analysis/ Curves Panel

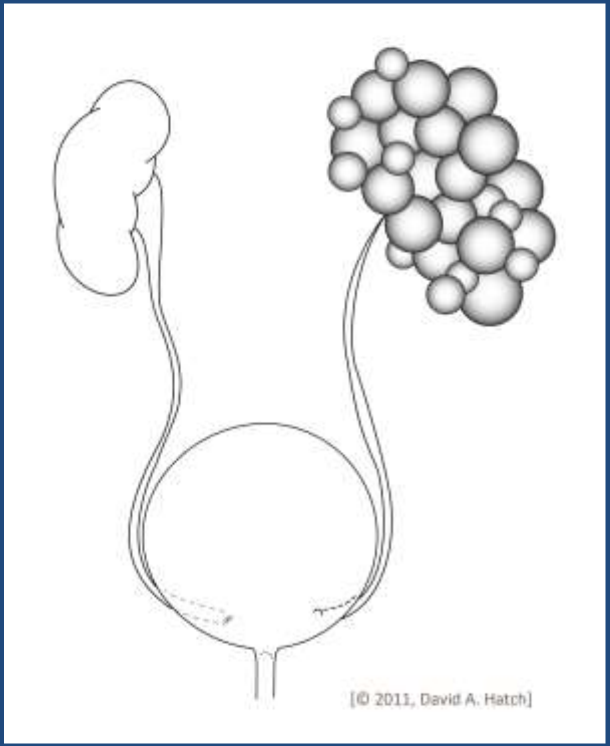


Take a look at the figures in the table. The differential function is 98.1% from the left and only 1.9% from the right. That right kidney isn't doing much. When the function of a kidney is that poor you can probably ignore any other data in the table such as T ½.

The T ½ of the left kidney is in the indeterminate range (15.8 min.). The ultrasound of the left kidney showed no hydronephrosis, so we can chalk that long T ½ to immaturity of this newborn's kidney. When we need accurate renal function data, we usually wait until a baby is at least two months old to perform a renogram.

Case Summary

This baby's right kidney is enlarged with multiple non-communicating cystic areas. It has no perfusion and no function. This is a typical **multicystic–dysplastic kidney**. The cause for this condition is thought to be a failure in the canalization and/or development of the proximal collecting system from the calyces to the renal pelvis. There is no communication between the collecting ducts and the ureter. You can learn more about multicystic-dysplastic kidneys in lesson 1 (Ultrasound).



Nuclear Renography Summary

- A nuclear renal scan is performed by intravenous injection of a radioisotope. A radiation detection device (nuclear medicine camera) is used to detect passage of the radioisotope through the urinary tract over time. Because the camera is placed posterior to the patient, the scan will show the right kidney on your right as you face the scan.

Nuclear Renography Summary

- Remember the 3 radionuclide classes
  - Filtered – Shows perfusion, drainage and function
  - Excreted – Shows tubular function
  - Cortical imaging – Shows scaring and renal mass
- 3 panels of a nuclear renogram
  - Perfusion
  - Drainage/function
  - Curves/analysis

Nuclear Renography Summary

- Ureteropelvic junction obstruction
  - An obstruction of urine flow from the kidney pelvis to the ureter. UPJ obstruction can cause pain, urine infection, gross hematuria and it can increase the risk of kidney stones.
- Multicystic-dysplastic kidney
  - A congenital condition caused by failure of development of the most proximal collecting system that results in a non-functioning kidney composed of cysts of varying size.