

Uroradiology Tutorial For Medical Students

Lesson 1:

Ultrasound – Part 1

American Urological Association

Introduction

- In order to understand urologic conditions and treatment, you need to know something about the way we examine the internal organs of the genitourinary tract. We call this imaging. Urologic imaging includes several different technologies: ultrasound, radiographs, angiography, computerized axial tomography (CAT scan), nuclear imaging and magnetic resonance imaging (MRI). Each of these imaging technologies is useful for illuminating genitourinary anatomy and/or function in a unique way. To illustrate the different techniques we will consider several case presentations.
- For the tutorial, you will be a practicing urologist, seeing several patients and examining their urologic imaging. Best of luck. As you will see, being a urologist can be interesting and very rewarding.

Case History

- A 4-year-old boy is occasionally crabby, crying as he holds his left side. His parents are very worried about his pain. It is made worse by drinking, but not by movement. He has had no fevers or dysuria, but he gets nauseated and he occasionally has emesis with the pain. He has never had a documented urine infection or gross hematuria.

Exam

- On exam, you find a healthy appearing male child with a temperature of 37.1 (normal), pulse of 110 and BP of 128/85 (this is high for a 4-year-old). His abdomen is not tender, but there is a small palpable mass in the left upper quadrant. Otherwise, the exam is unremarkable. The urinalysis shows 5-10 RBCs, 0 WBCs and no bacteria or protein.

Which imaging technique is the best initial test to evaluate this child's abdominal mass?

- Intravenous pyelogram (IVP)
- Ultrasound
- CAT scan
- Voiding cystourethrogram (VCUG)
- Nuclear renogram
- MRI

Best Answer: Ultrasound

- The most common causes of an abdominal mass in a child are urinary tract conditions and, of those, the most common is hydronephrosis. Ultrasound is the most effective initial imaging technique in a child with an abdominal mass. Ultrasound is relatively inexpensive, painless, gives no radiation exposure, and it requires no venous access. It is an excellent medium to differentiate between solid and cystic masses.

Ultrasound – Basic Principles

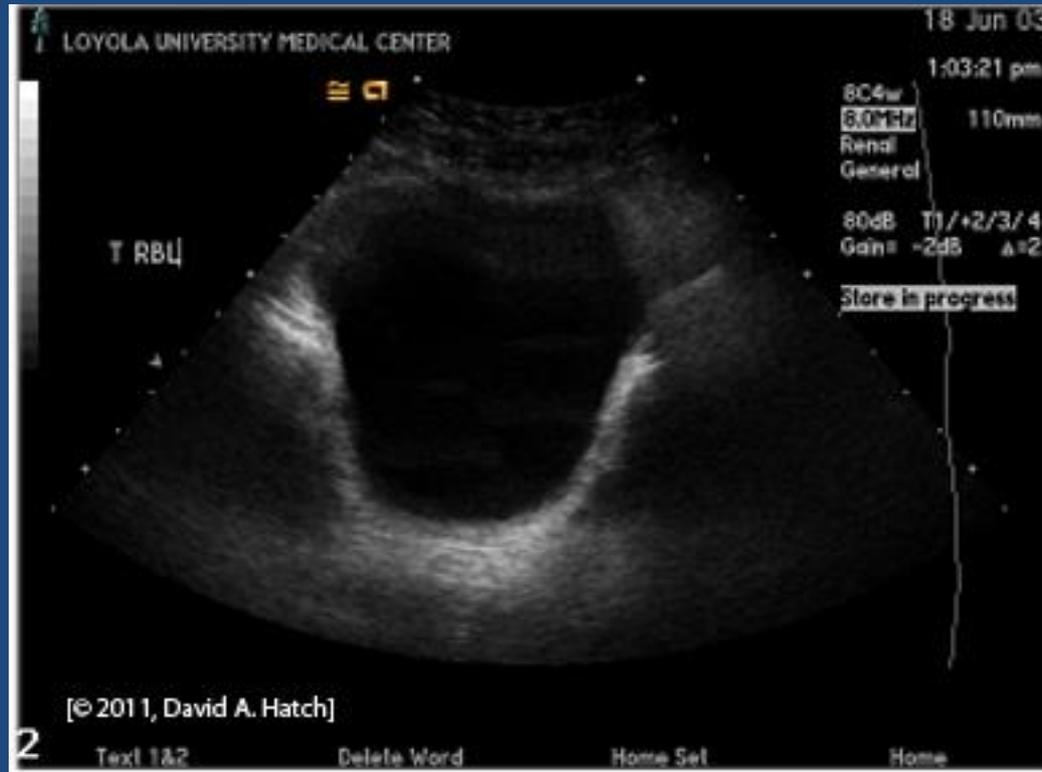
Ultrasound imaging is performed by directing high frequency sound waves (typically 5 – 14 MHz) from a transducer (essentially a speaker that generates sound waves coupled with a microphone to detect sound waves), through a coupling agent (gel applied to the skin) and into the body. The sound waves either travel through the tissues of the body or they are reflected back to the transducer. The sound waves reflected back to the transducer (echos) are analyzed by a computer and displayed on a monitor. If a tissue or structure generates a greater degree of reflection (more echos), it is termed **sonodense**. It is represented on the monitor as an area of white or light gray.

Sonolucent

A tissue or structure that generates little reflection of sound waves (lets the wave pass through unimpeded) is termed **sonolucent**. It is represented on the monitor as an area of black or dark gray. Liquids, such as water or urine, transmit sound waves readily.

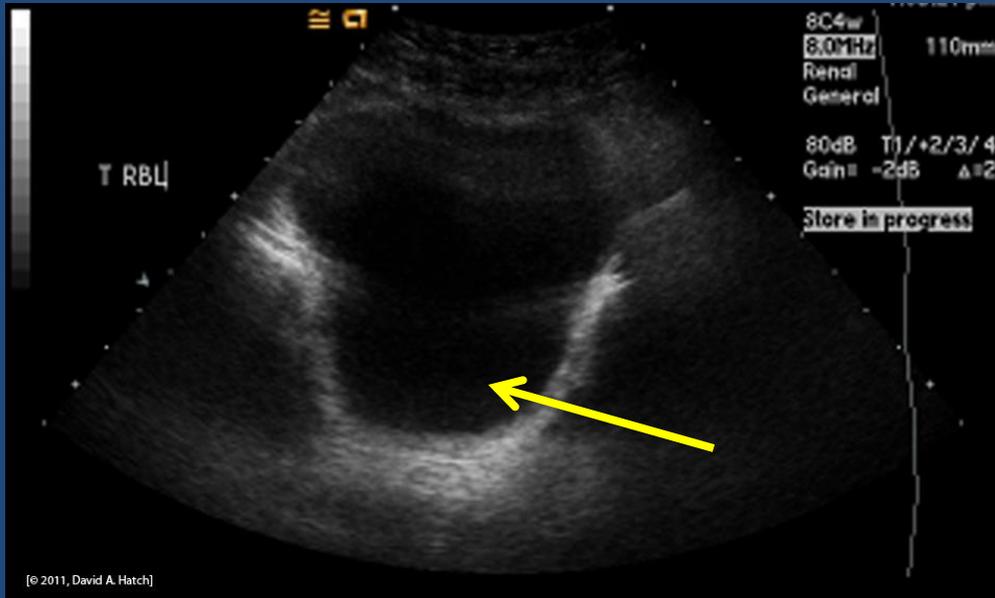
Therefore, a structure filled with urine or water appears black or dark gray on the ultrasound monitor.

Sonolucent



- This is an ultrasound image of a bladder. The urine inside the bladder generates no echos and, therefore, appears black. What color would a full bladder appear on a CAT scan?

Urine on Ultrasound & CT Scan

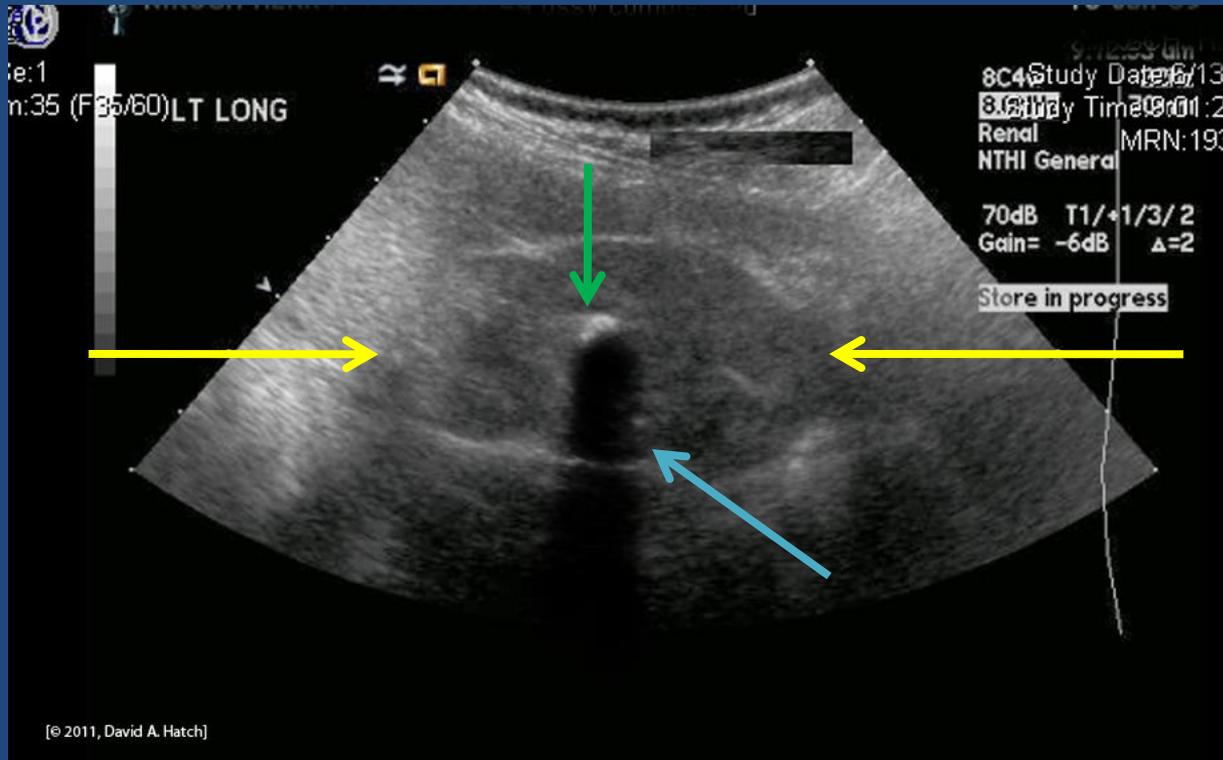


- Fluid (in this case, urine) appears black on ultrasound (left) because it allows sound waves to travel through without generating echos.
- Fluid appears dark gray on CT scan (right). The urine absorbs some of the x-rays. It is lower density than muscle, but more dense than air or fat (black).

Sonodense

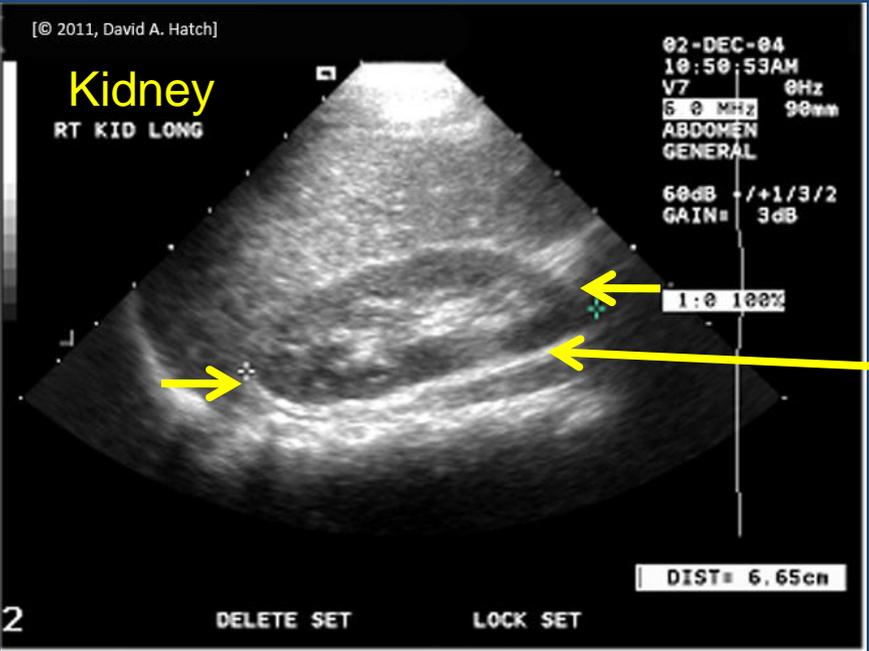
In contrast, sound waves directed at bone are reflected rather than being transmitted through the bone. Hence, bone appears very white or bright on the ultrasound monitor. In addition, because the sound waves are reflected rather than being transmitted through the bone, areas behind the bone have no exposure to the sound waves and are, therefore, represented on the ultrasound monitor as black. This area devoid of sound waves appears as a ray on the opposite side of the bone from the transducer. It is referred to as a **shadow**.

Sonodense



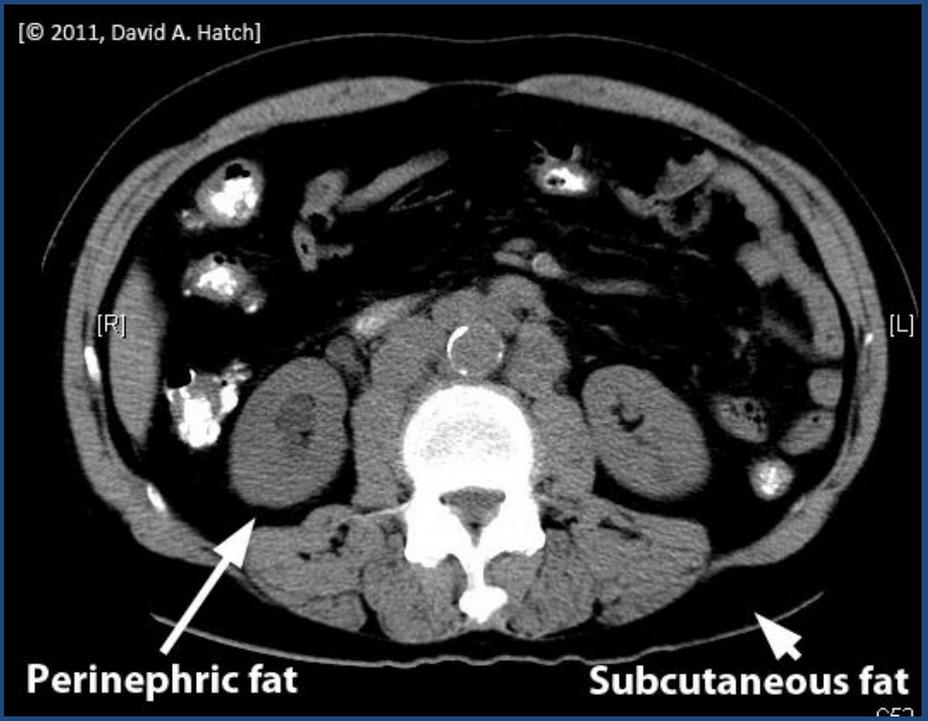
This is an ultrasound of a kidney [between yellow arrows] with a stone. The stone [green arrow] shows up as a sonodense [white or very light] object with many echos at the surface of the stone and shadowing [blue arrow] behind it.

It is important to remember that the terms sonodensity and sonolucency indicate a reaction to sound waves directed at an object, not the actual density of the object. Tissues that appear as low density on an x-ray may be very sonodense on ultrasound. For example, perinephric fat is represented as a very low density (black) area on CT scan. However, ultrasound images of perinephric fat appear very bright (white).



Fat Is Sonodense
[ultrasound]

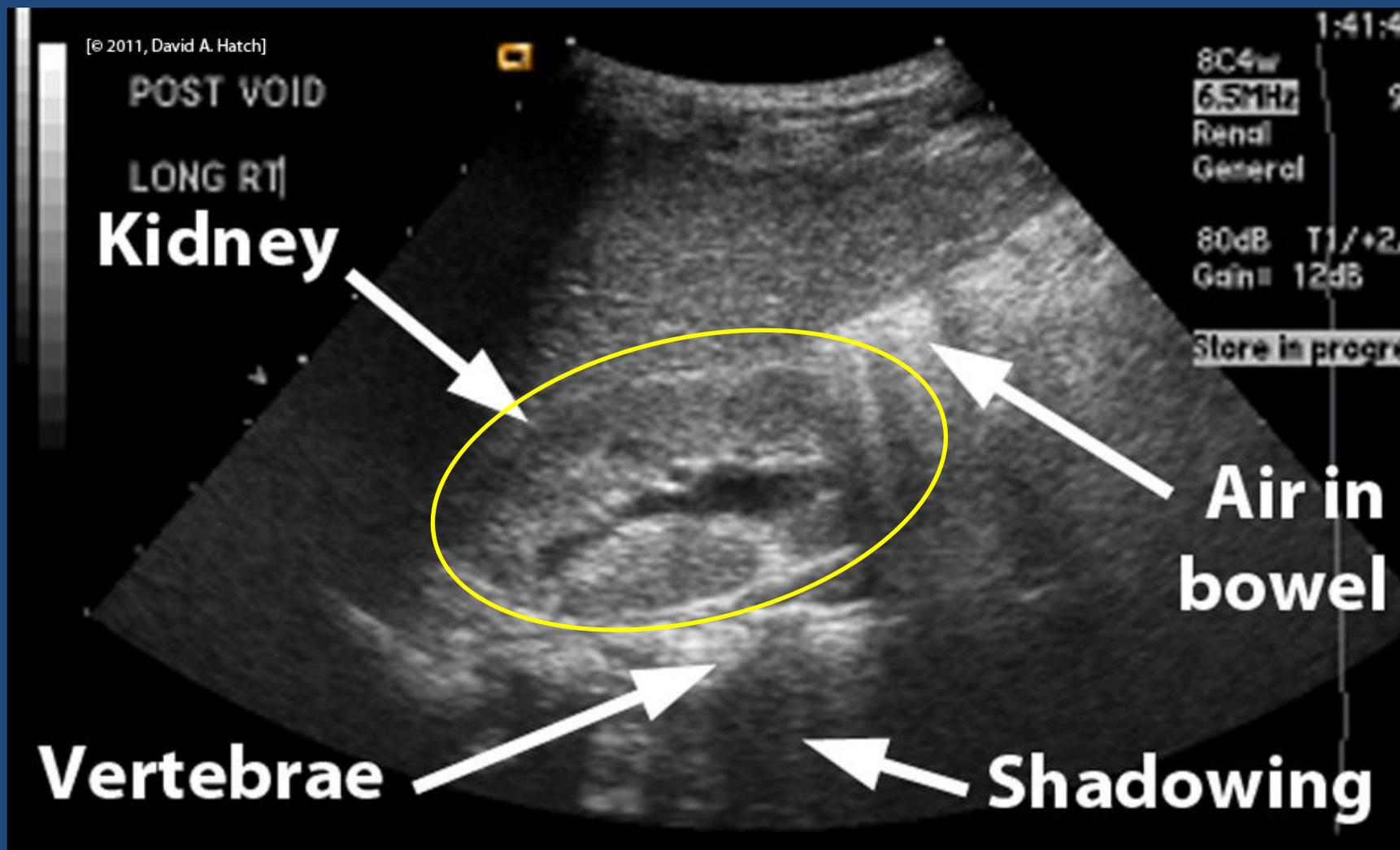
Fat is radiolucent
[CT or x-ray]



Tissue Density v. Sonodensity

- Fat is sonodense because adipose tissue contains many interfaces (fibrous tissues surrounding lobules of fat, small blood vessels, nerves and lymphatics) that reflect sound waves.
- Similarly, air within the body is represented on a CT scan as a very low density (black) area. Because there is poor transmission of sound waves from body tissues through air (they are reflected back to the transducer), bowel filled with air appears on ultrasound as a bright (white) area.

Ultrasound Showing Bone & Air



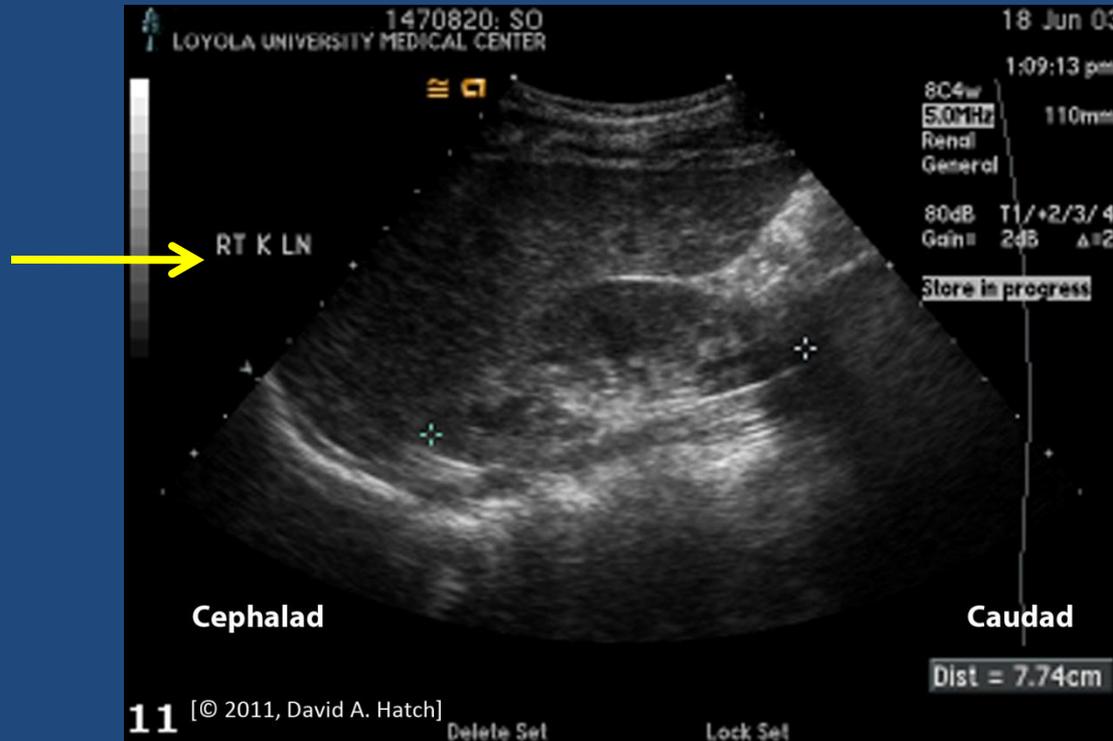
Synonyms

- Sonodense
 - Hyperechoic
 - Echogenic
- Sonolucent
 - Hypoechoic
- Sonodensity and radiodensity are **not** related

Ultrasound Interpretation Basics

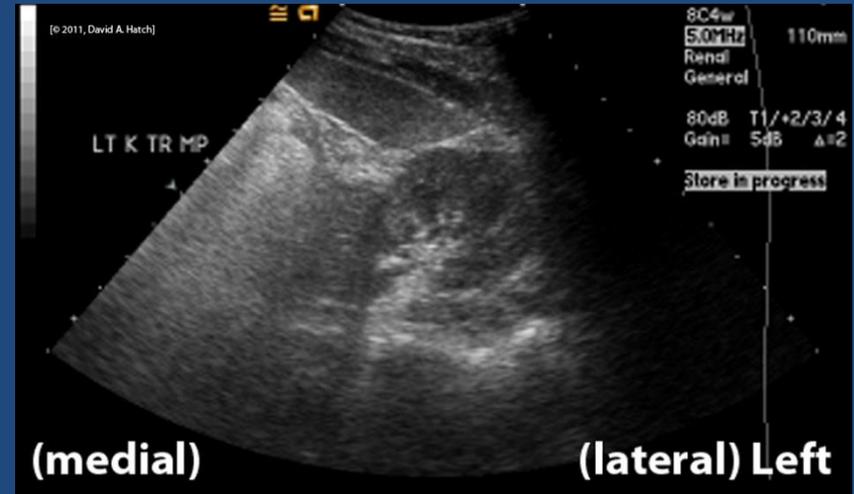
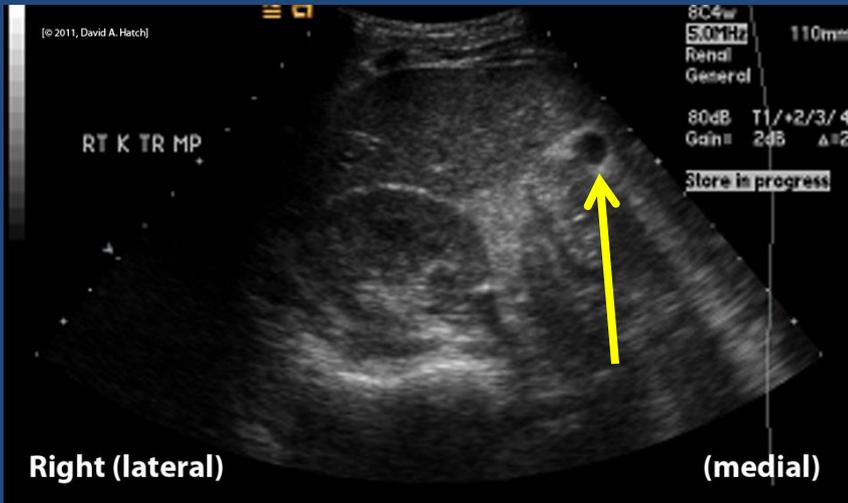
Let's look at some ultrasounds of the urinary tract. First, you'll need to learn some conventions. The ultrasound transducer can be held in a longitudinal (vertical) orientation or in a transverse (horizontal) orientation. On a longitudinal ultrasound image, cephalad is shown on the left and caudad is shown on the right side. Look at the labels on the image to know the orientation.

Conventions – Longitudinal Scan



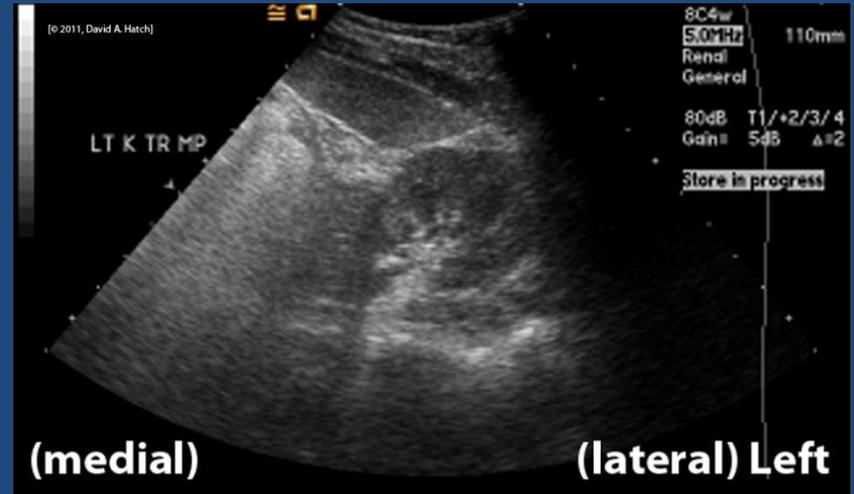
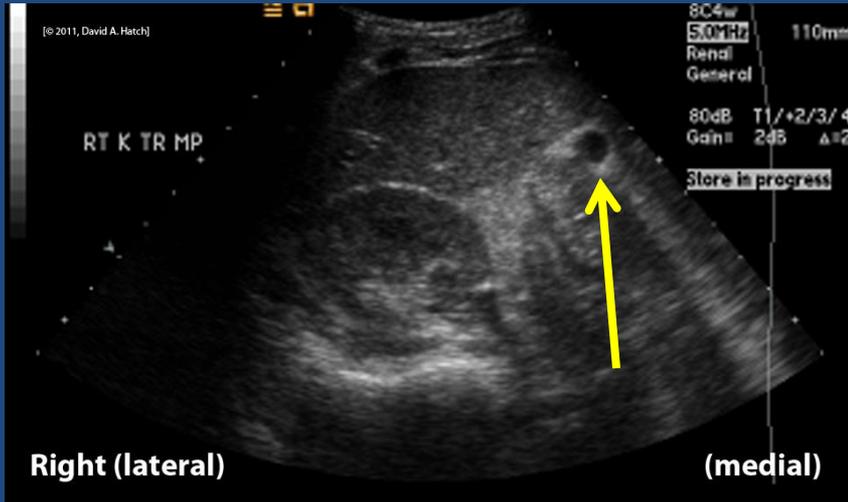
Right! This is a right kidney, examined longitudinally. Remember, cephalad or superior is shown on the left side of the image. Caudad or inferior is shown on the right. What does "RT K LN" mean? Click the mouse.

Conventions – Transverse Scan



- On transverse images, the right side of the body appears on the left side of the monitor just like a CT scan. The lateral side of the right kidney is on the left side of the image.
- The converse is seen on the left side; lateral is on the right and medial is on the left.
- What is the sonolucent structure medial to the right kidney (arrow)? Click the mouse.

Defining an Unknown Object



When you see something you're not sure about, systematically describe it. Shape? Echo pattern (sonodense or sonolucent)? Location? What is that structure? Click the mouse.

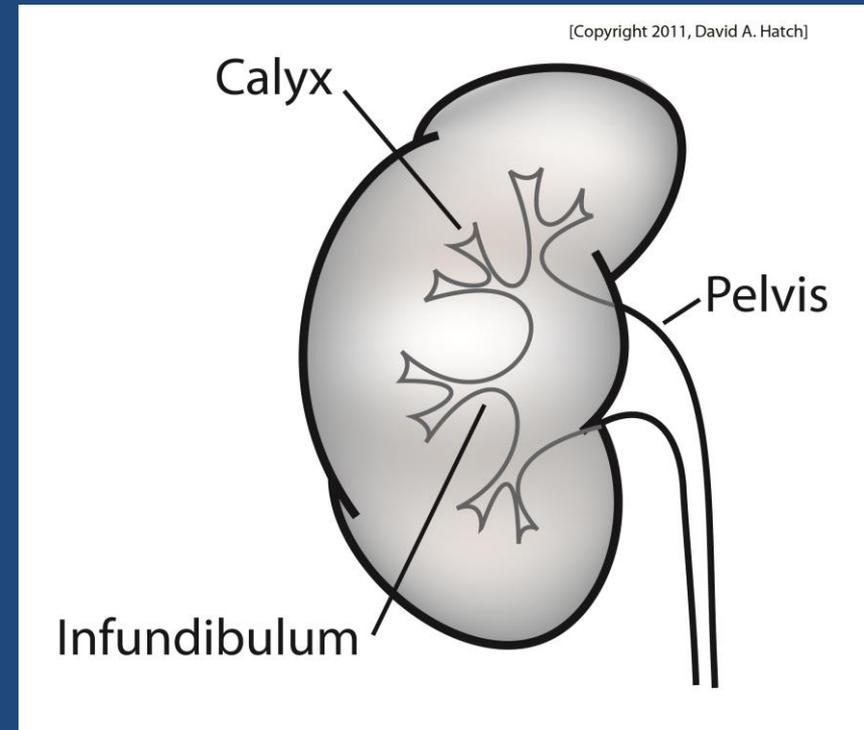
It is round, sonolucent, and medial to the kidney, deep to the liver.

Urinary Tract Ultrasound Interpretation

Reading and interpreting an ultrasound for the first time can be anxiety provoking. You may find yourself panicking to identify the pathology hidden on the image. “There must be something I’m missing, otherwise, why would they show me this ultrasound?” Don’t panic, you’ll do just fine.

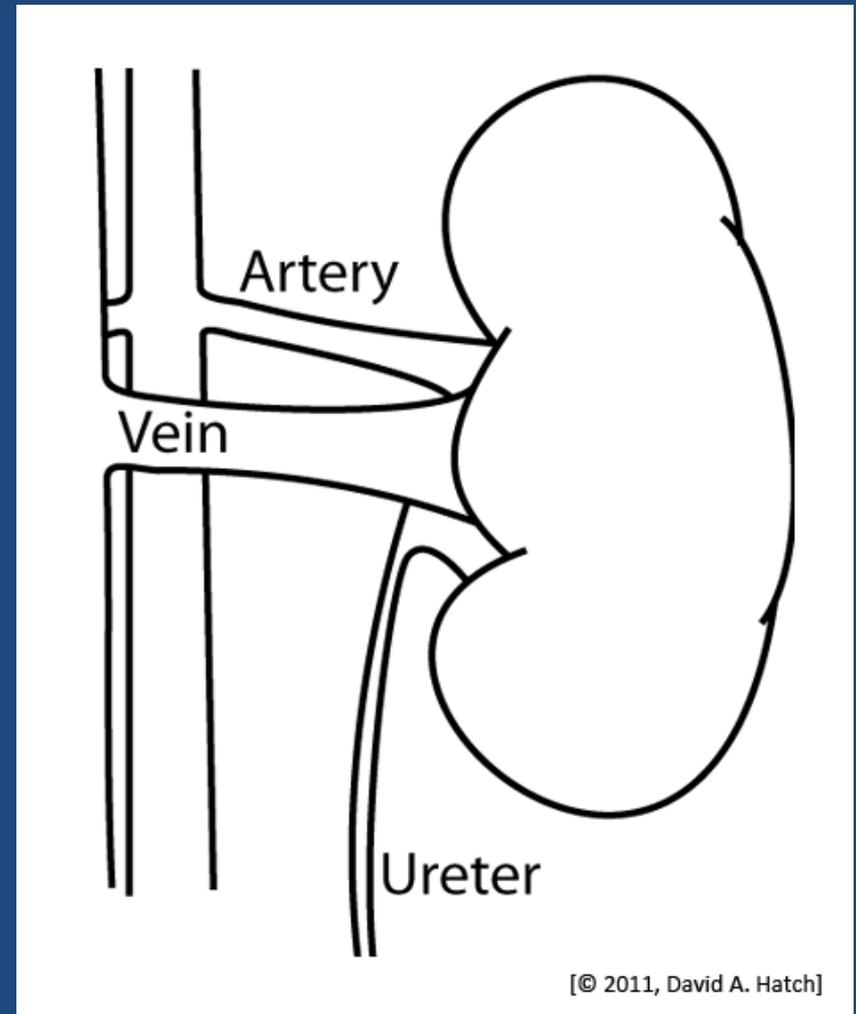
First, let's review some renal anatomy and terminology.

- The kidney is made up of many lobules. A lobule is a collection of many nephrons that drain into a **calyx**. Each calyx drains into a tube called an **infundibulum** that connects to the renal pelvis.
- **Parenchyma** refers to the solid tissue of the kidney, both the cortex and medulla.



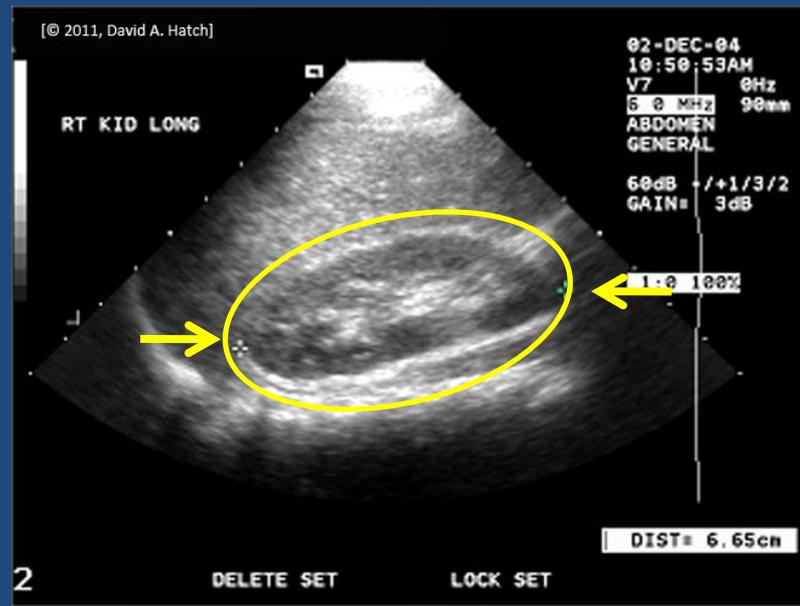
Renal Hilum

- **Renal hilum** refers to the area on the medial side of the kidney containing the renal vessels, the pelvis, lymphatics and nerves. This is also called the **central sinus**.



Where is the kidney?

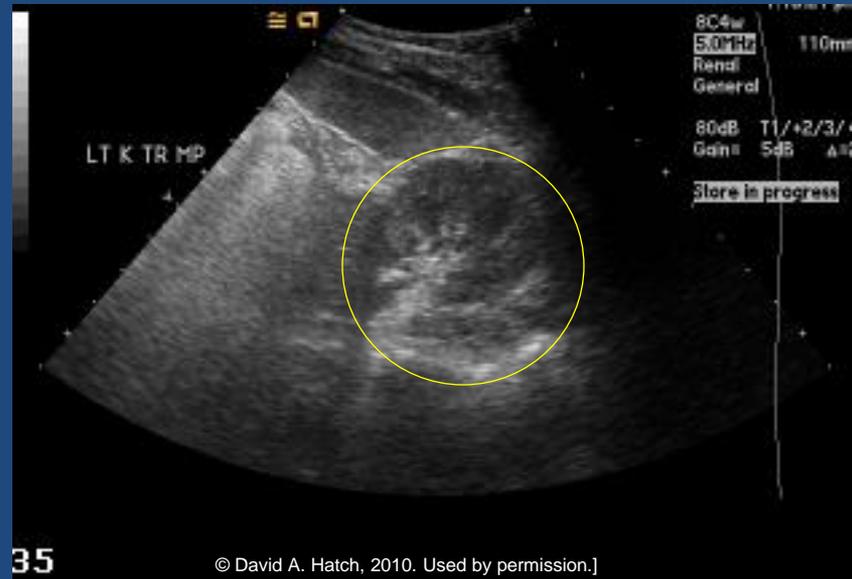
- First let's find the kidney on the images. Look for the cross hairs used in measuring size.



- Now the kidney is obvious. You can find similar structures on images without cross hairs.

Find the Kidney-Transverse Image

- On a transverse image the kidney is round.



- Once you've located the kidney, it is helpful to break down ultrasound interpretation into four true-false questions.

Four Questions

- #1 Size: Is the size normal?
- #2 Shape: Is the shape normal? (Does the kidney appear to be reniform, bean-shaped?)
- #3 Parenchyma: Is the parenchyma normal? (Does the kidney show abnormal sonodensity?)
- #4 Hydronephrosis: Is hydronephrosis present?

#1 Size

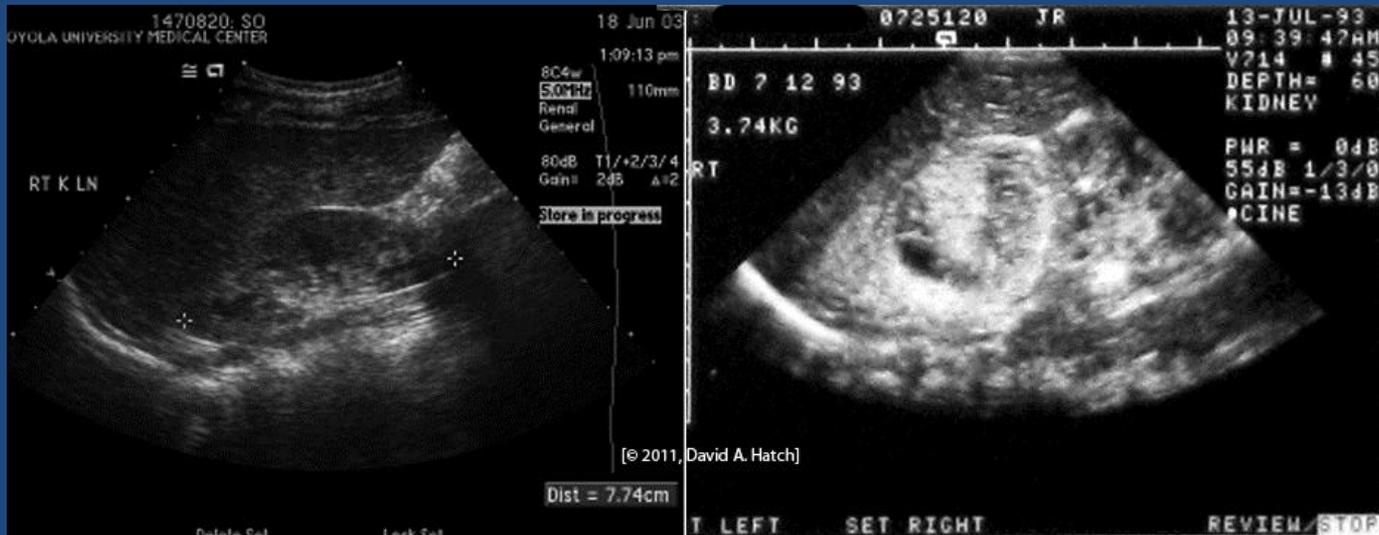
- Is the size normal? This can be determined by age-based tables or by this formula:
- $\text{Length} = \text{age (years)} \times 0.6 \text{ cm} + 1 \text{ mm/week of gestational age (4 cm at full-term)}$
- A 4-year-old's kidneys should be $(4 \times .6) + 4 \text{ cm}$ or 6.4 cm
- Of course this formula doesn't apply to older teenagers or adults, but it's a useful guide up to age 12 years.

Renal Size

- What could cause a kidney to be larger than normal?
- What could cause a kidney to be smaller than normal?

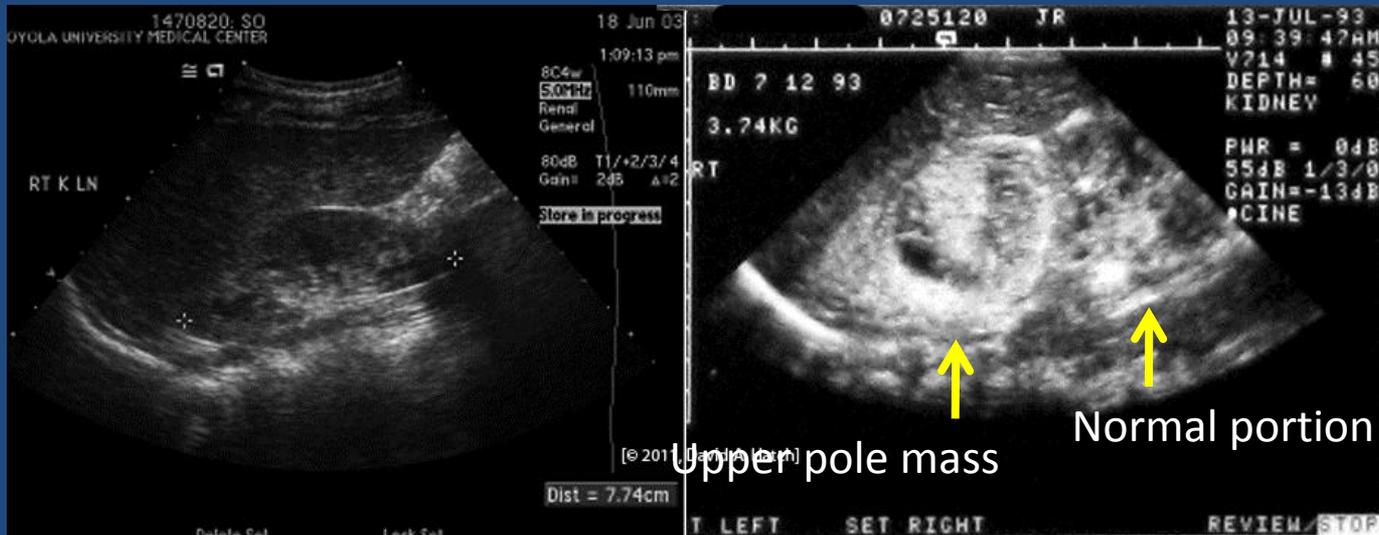
#2 Shape

- Is the kidney normal shape (bean shape), or is it irregular?
 - Is there a mass causing bulging in part of the kidney?
 - Is there a segment of kidney missing?



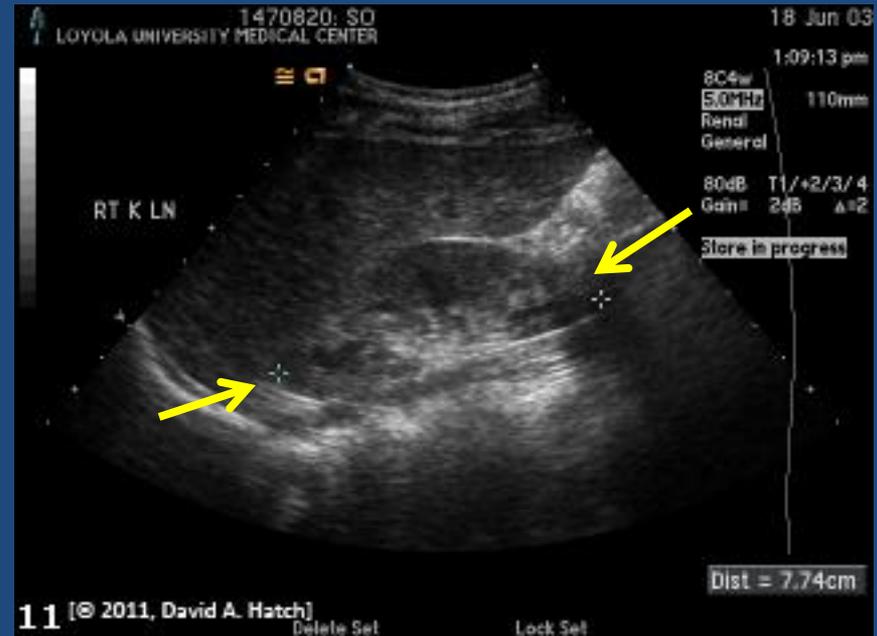
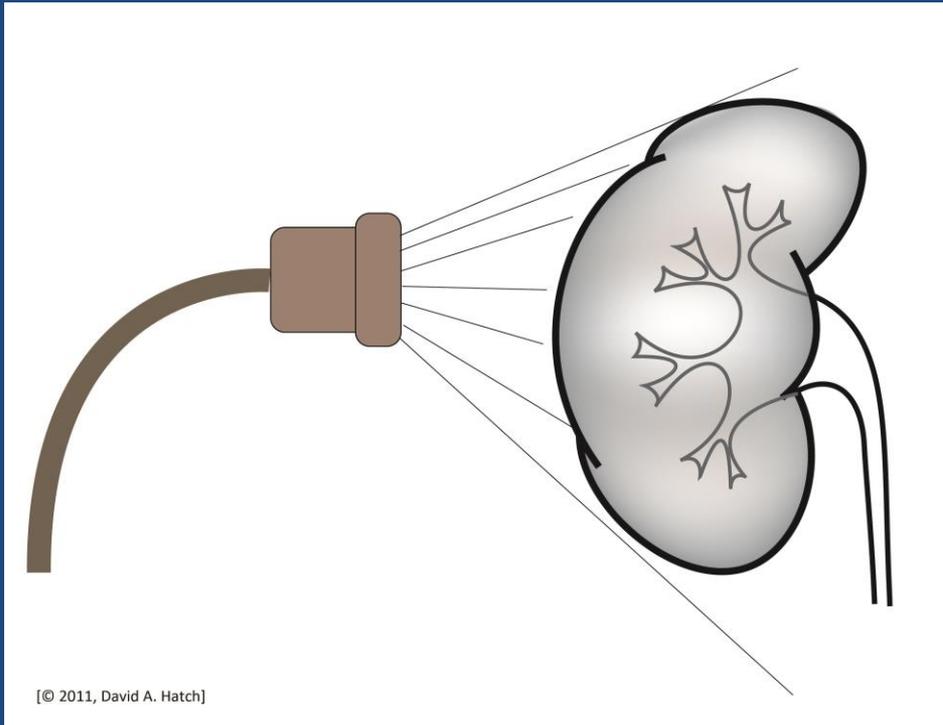
#2 Shape

- Notice that the image on the left shows a bean-shaped kidney. The image on the right shows a large, hyperechoic mass in the upper pole of the kidney.



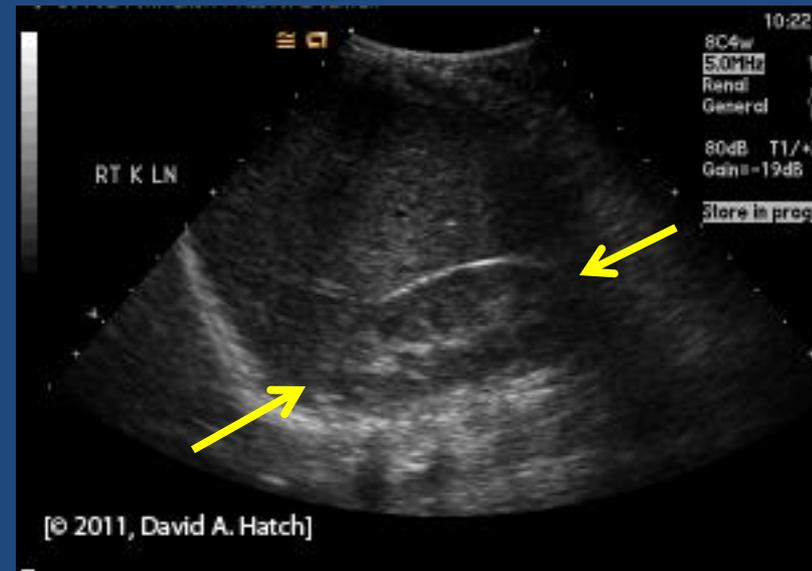
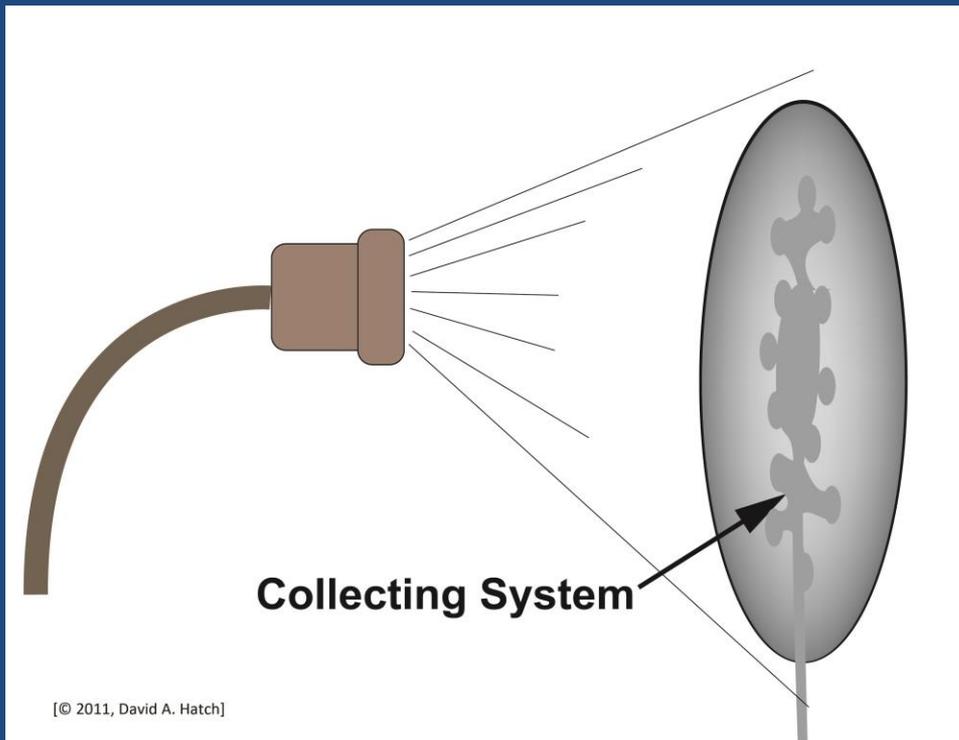
Shape

- On a longitudinal image, the shape depends on the orientation of the transducer. If the transducer is held in the coronal plane, the kidney appears bean-shaped with the medial side rather flat.



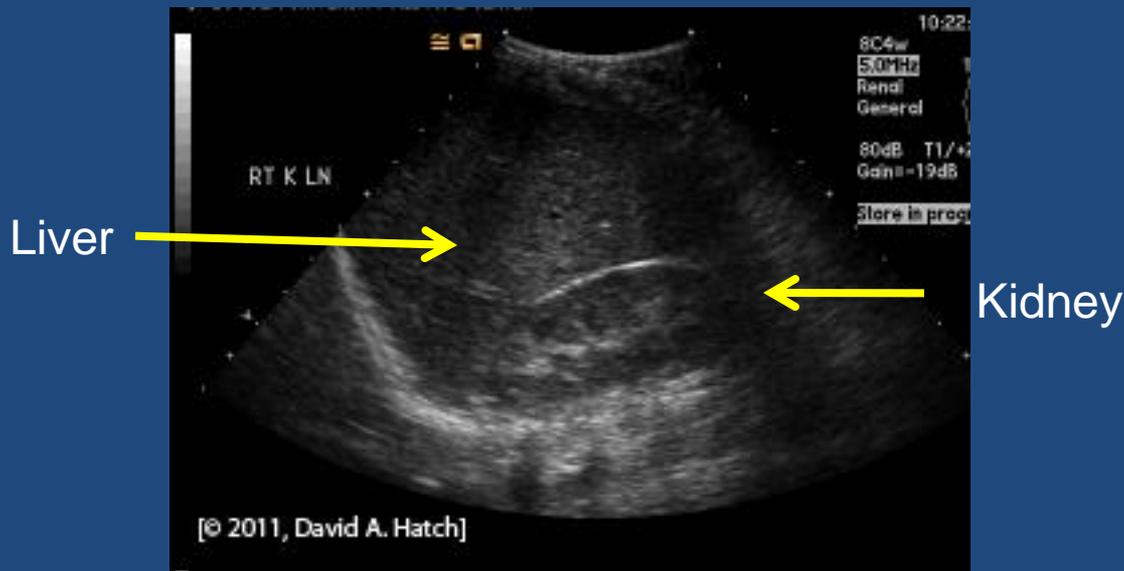
Shape

- If the transducer is held in the sagittal plane, the kidney appears more oval.



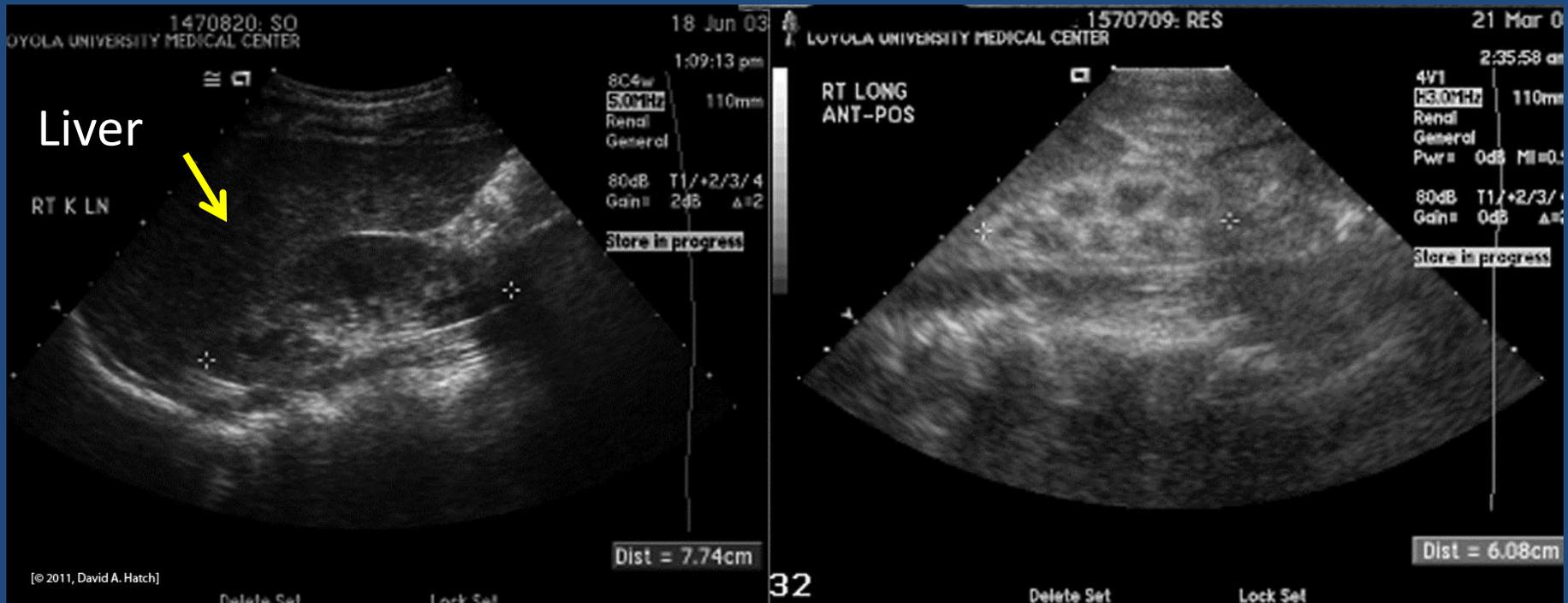
#3 Parenchyma

- This is probably the most difficult parameter to master. One might say that the parenchyma (solid tissue including the cortex and medulla) of a normal kidney is regularly irregular. A kidney does not have a homogenous echo pattern.
- Kidneys are generally less echogenic (darker) than adjacent liver (see the image of a right kidney below) or spleen.



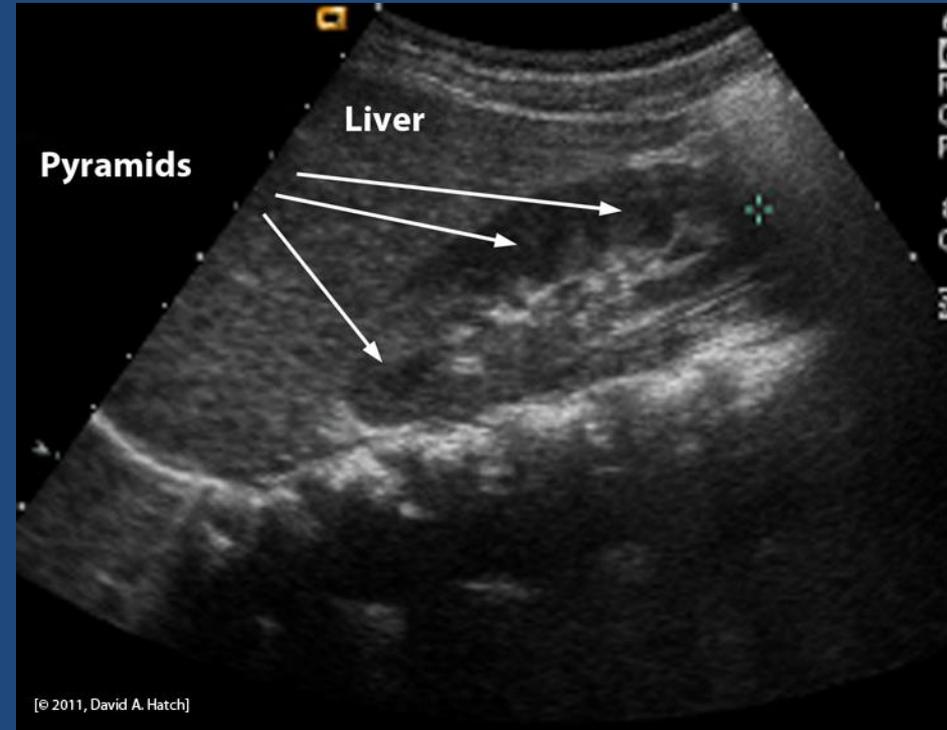
Parenchyma

- The image on the left shows a normal kidney that is somewhat darker (less echogenic) than the liver cephalad to it (left side of image). The right image shows an echogenic (hyperechoic) kidney. The abnormal kidney on the right has minimal function (makes little urine) due to glomerulonephritis.



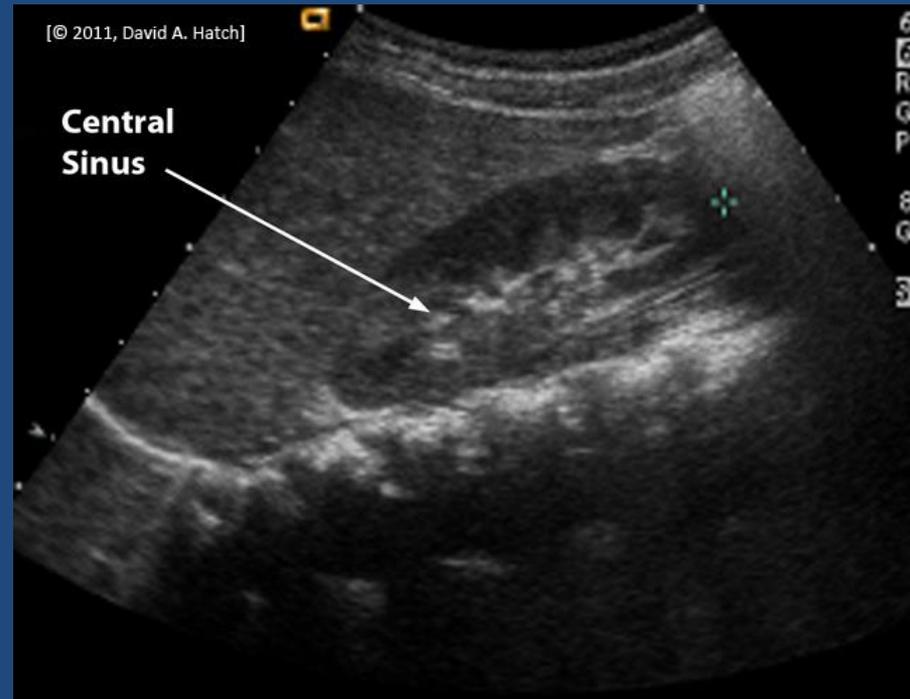
Pyramids

- Kidneys are made up of several lobules, each one centered by a pyramid under which a calyx lies. The pyramid is typically hypoechoic (darker) and the surrounding parenchyma is more echogenic (lighter).
- You should see pyramids spaced regularly around the cortex.



Central Sinus

- The hilum of the kidney (also called the central sinus) is made up of renal parenchyma, the collecting system, vessels, lymphatics, nerves and fat. The interfaces of these structures cause reflection of sound waves, so the hilum appears as a sonodense stripe on ultrasound.

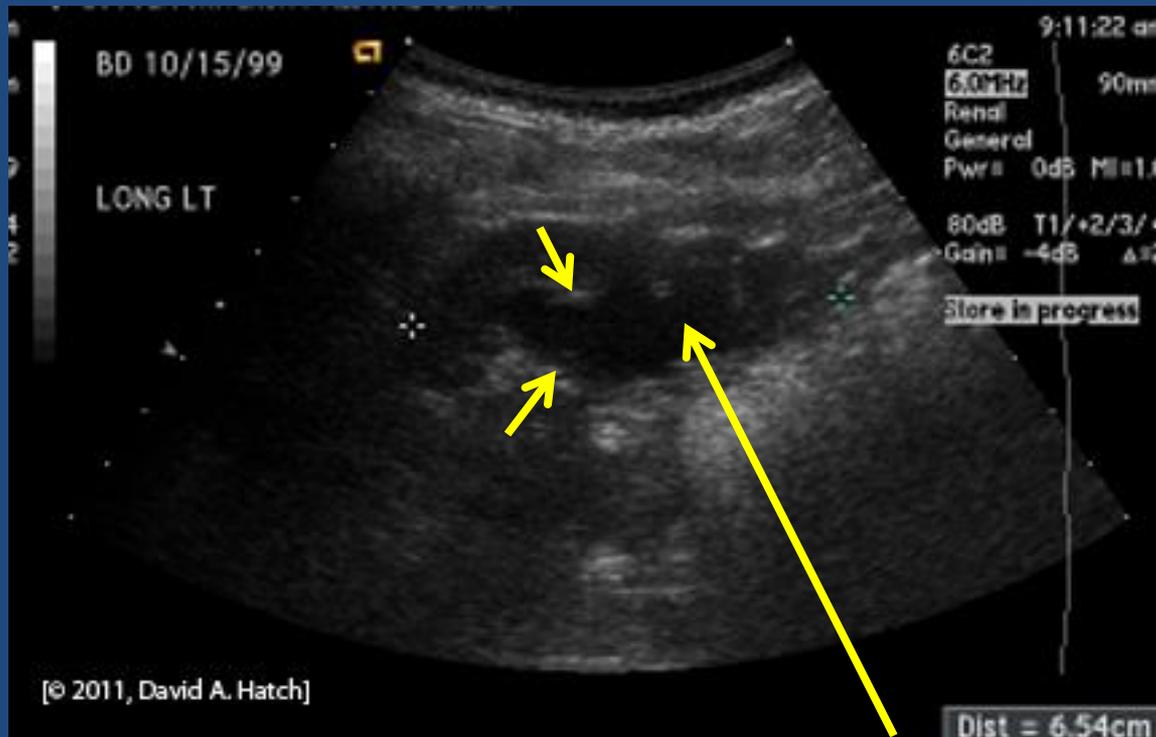


#4 Hydronephrosis

Accumulation of urine in the renal collecting system (pelvis and/or calyces) shows up as an anechoic structure, typically in the middle of the hilum. Radiologists frequently describe this as **splitting of the central sinus**. This simply means that the hyperechoic region in the center of the kidney is split by the enlarged renal pelvis. This is hydronephrosis.

Splitting of the Central Sinus

Central sinus (hyperechoic region in the center of the kidney)



split by a hypoechoic region (hydronephrosis)

Grading of Hydronephrosis

Grade I: mild / minimal splitting of the central sinus echos.



LONG RT KID

Grade II: hydronephrosis extends to mildly dilated major calyces



LONG LT

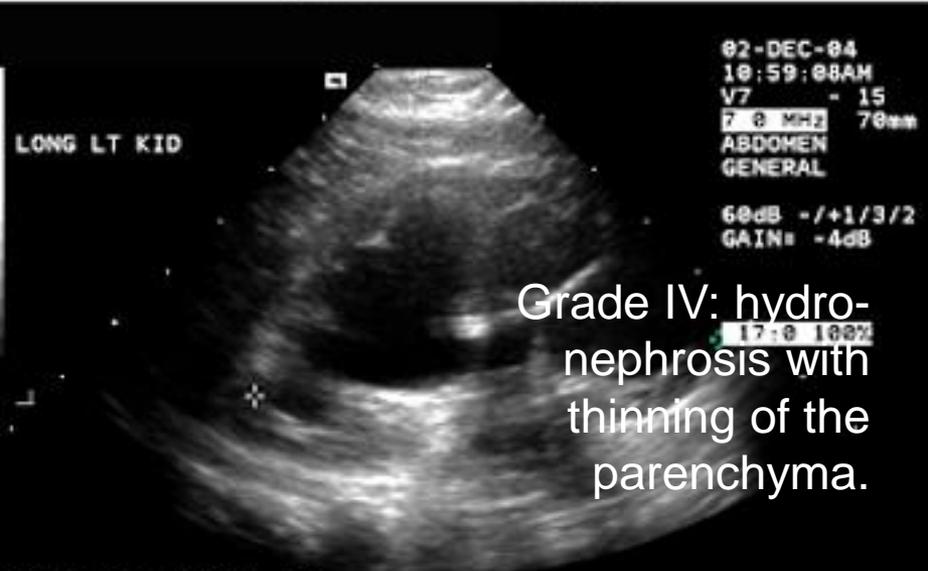
Dist = 8.02cm

Grade III: hydronephrosis extends into dilated calyces



LT LONG

Grade IV: hydronephrosis with thinning of the parenchyma.



LONG LT KID

Bladder Ultrasound

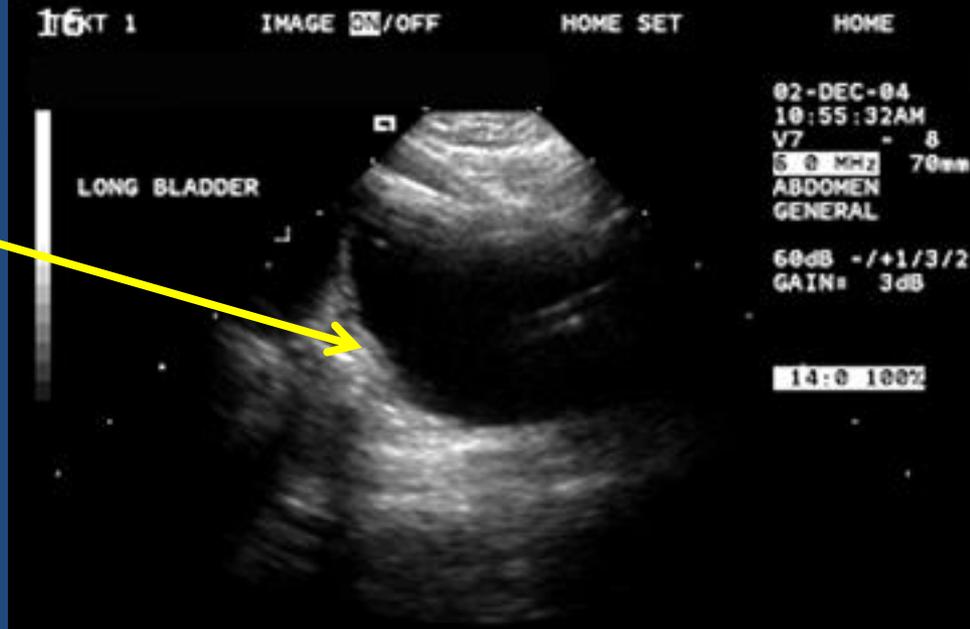
- Is there anything in the bladder besides urine (mass, foreign body, etc.)?
- Is the bladder wall thickened (> 4 mm)?

Bladder Ultrasound

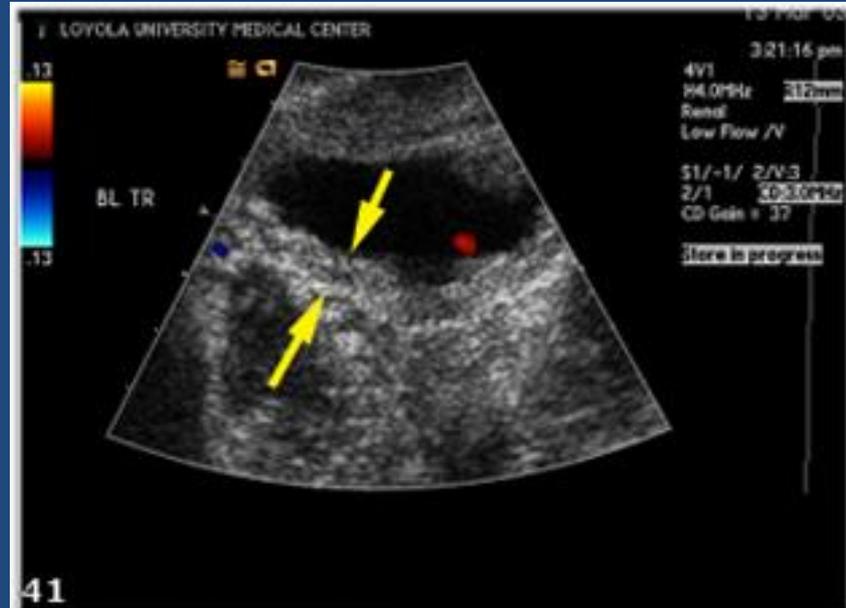
Anything in the bladder that shouldn't be there?



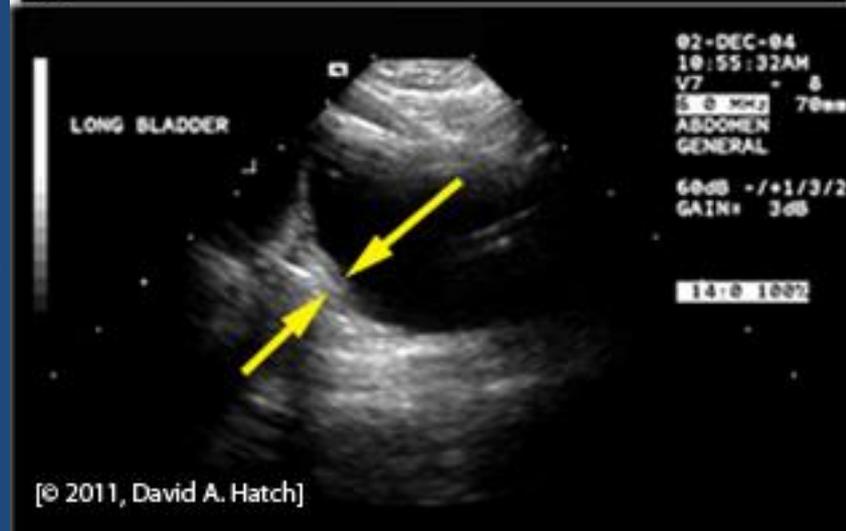
Is the bladder wall thickened (> 4 mm)?



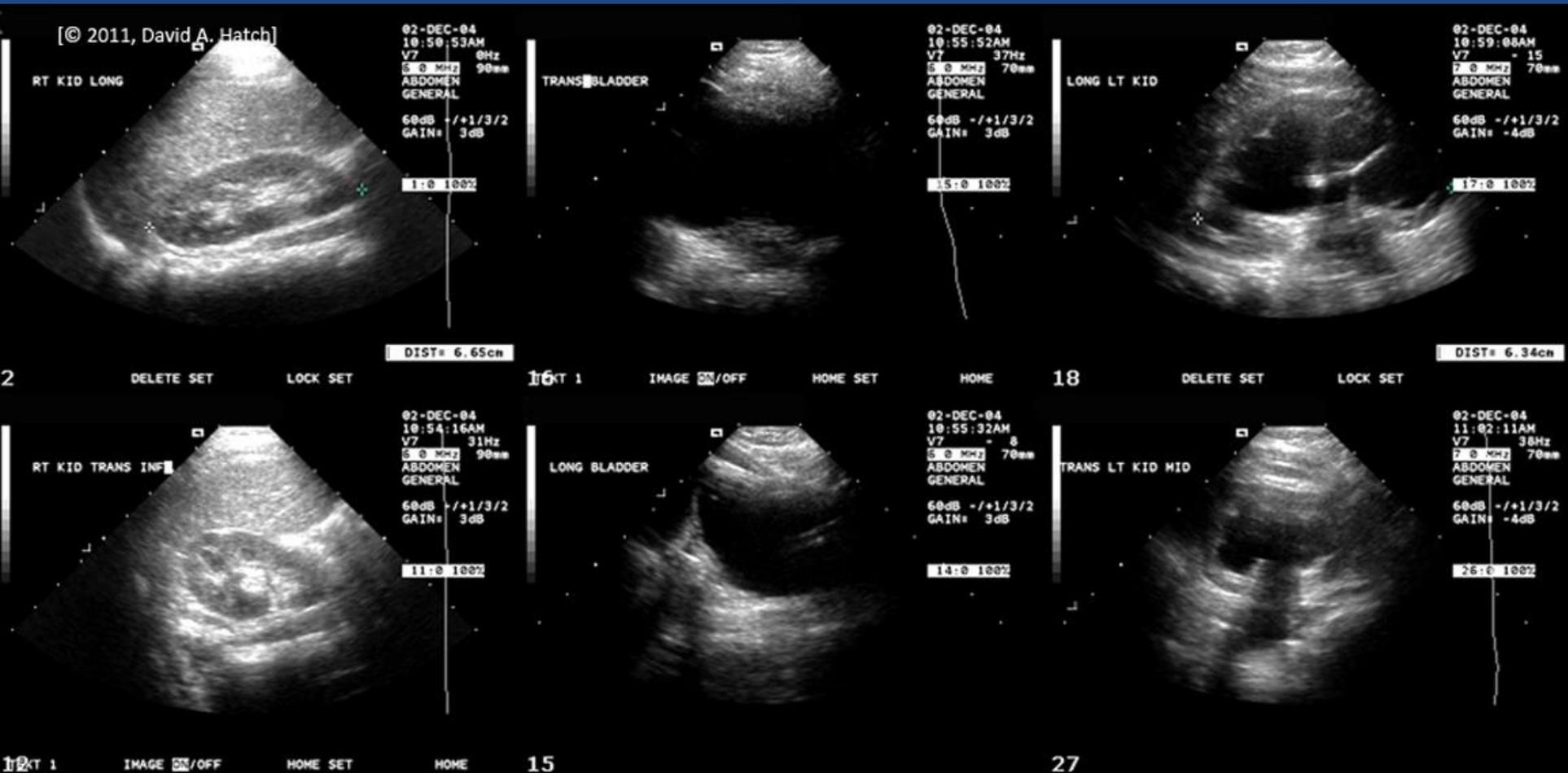
The bladder wall thickness is best measured at the base (inferior). Look for two parallel white lines. These should be < 4 mm apart.



Bladder wall thickness is somewhat analogous to the peel of an orange. Is the bladder wall more like a Valencia (juice) orange, or like a Naval orange (thick)?



- That 4-year-old boy has probably had his ultrasound by now. Let's take a look.



Your Interpretation?

- Let's start with the right kidney
 - Size? (Look for the cross hairs)



- Expected for a 4-year-old? $4 \text{ cm} + 4 \times .6 \text{ cm} = 6.6 \text{ cm}$
- This is a normal size kidney.

Shape?

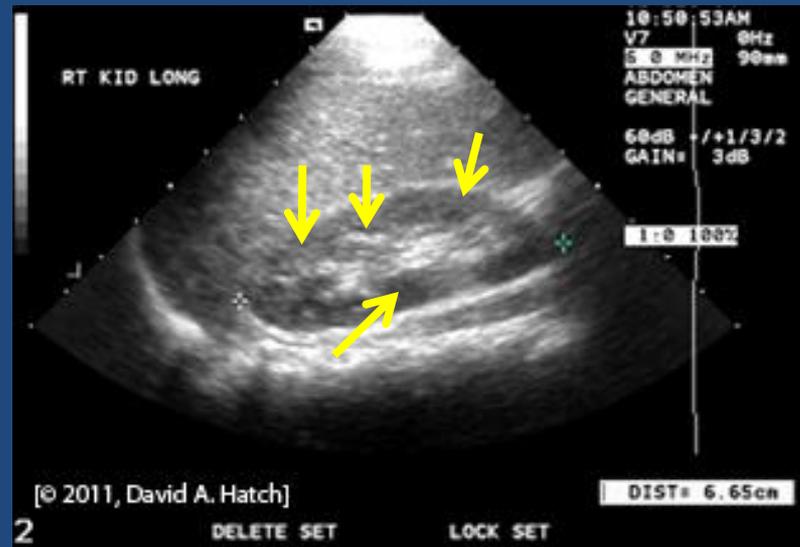
- Shape is normal



Parenchyma?

The parenchyma is generally darker (more echogenic) than the liver.

Pyramids



Pyramids are spaced fairly regularly.
The parenchyma is normal.

Hydronephrosis?

- Do you see any anechoic areas (sonolucent) in the hilum (splitting the central sinus)?

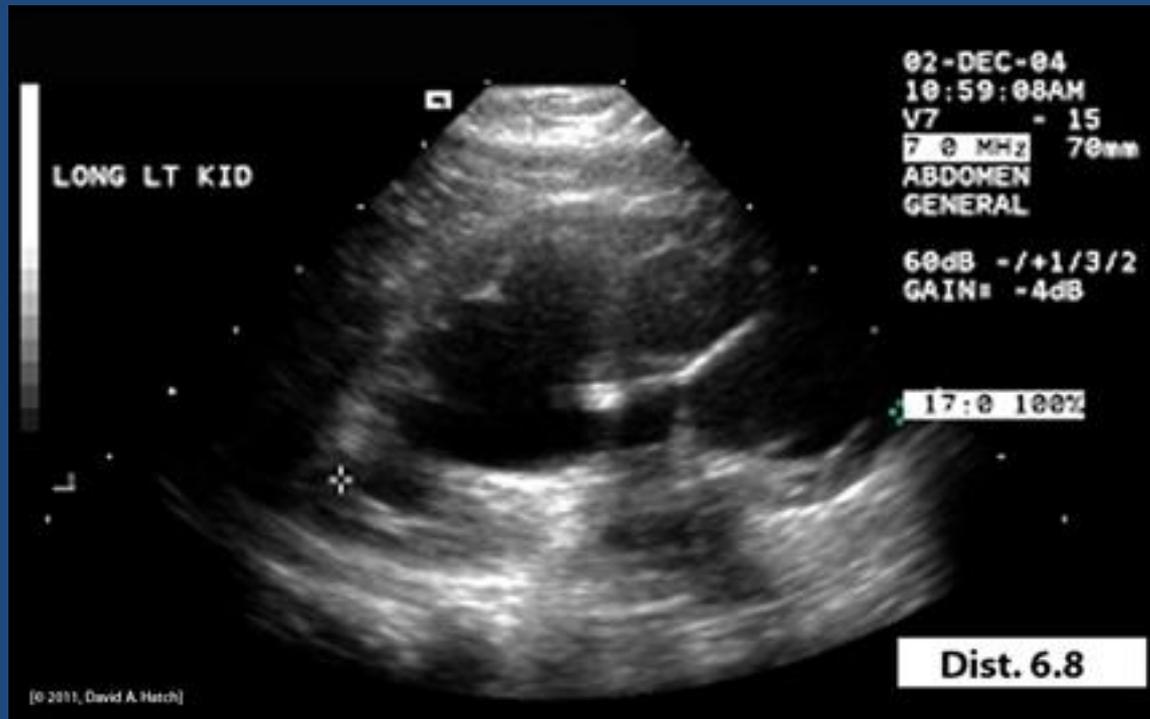


- This is a normal kidney

Look at the left kidney

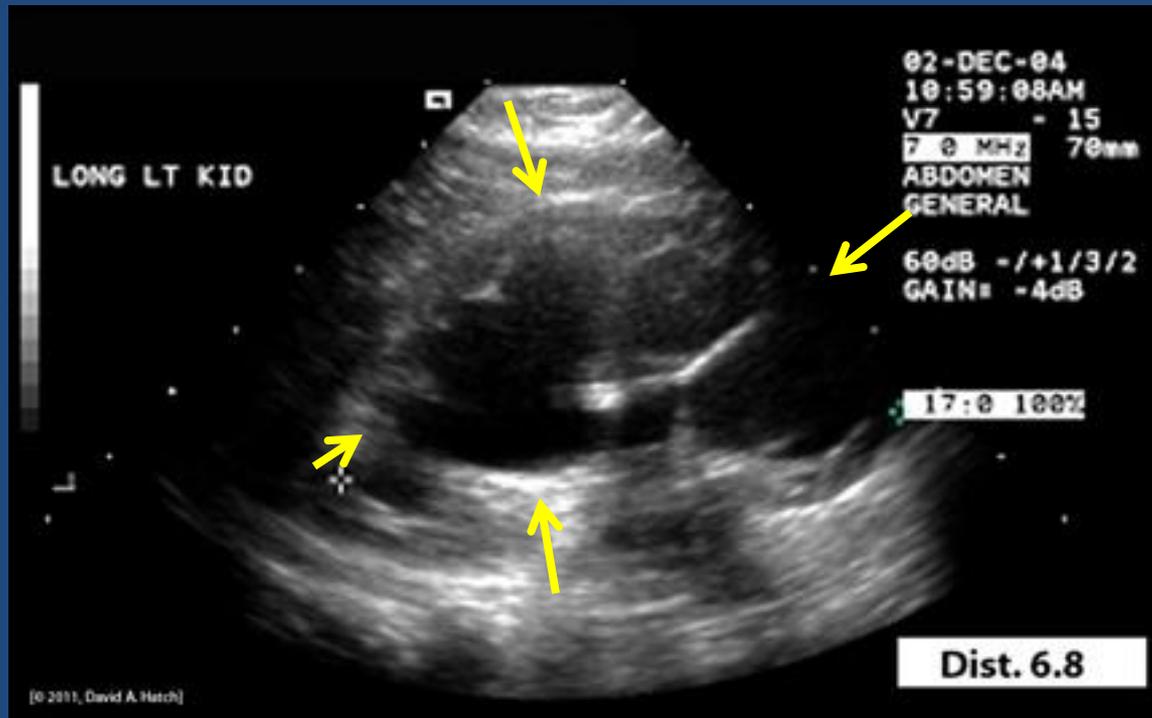
Size: It's a little longer than the right kidney, but that is common.

This size is normal.



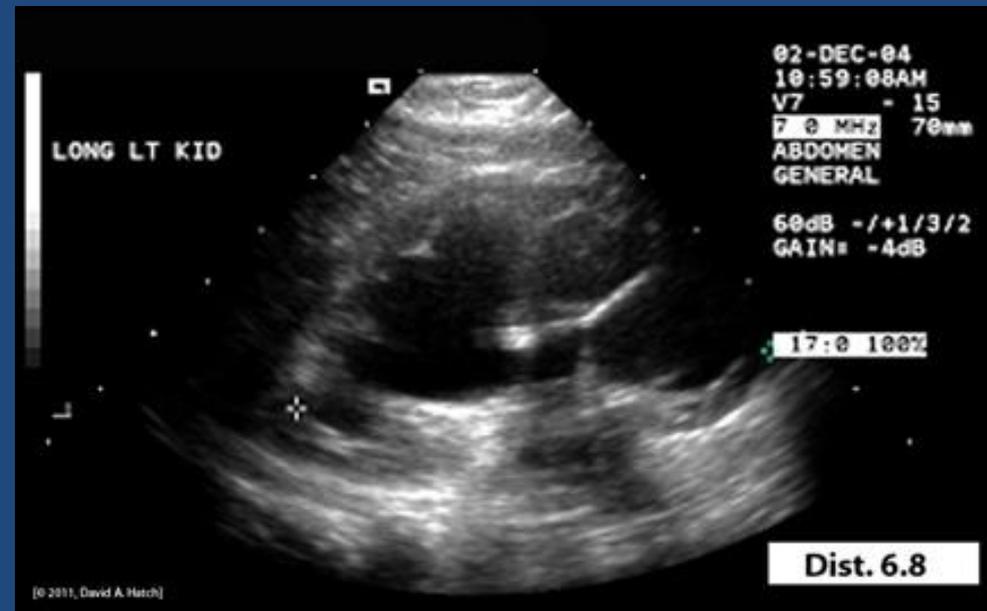
Shape?

Normal



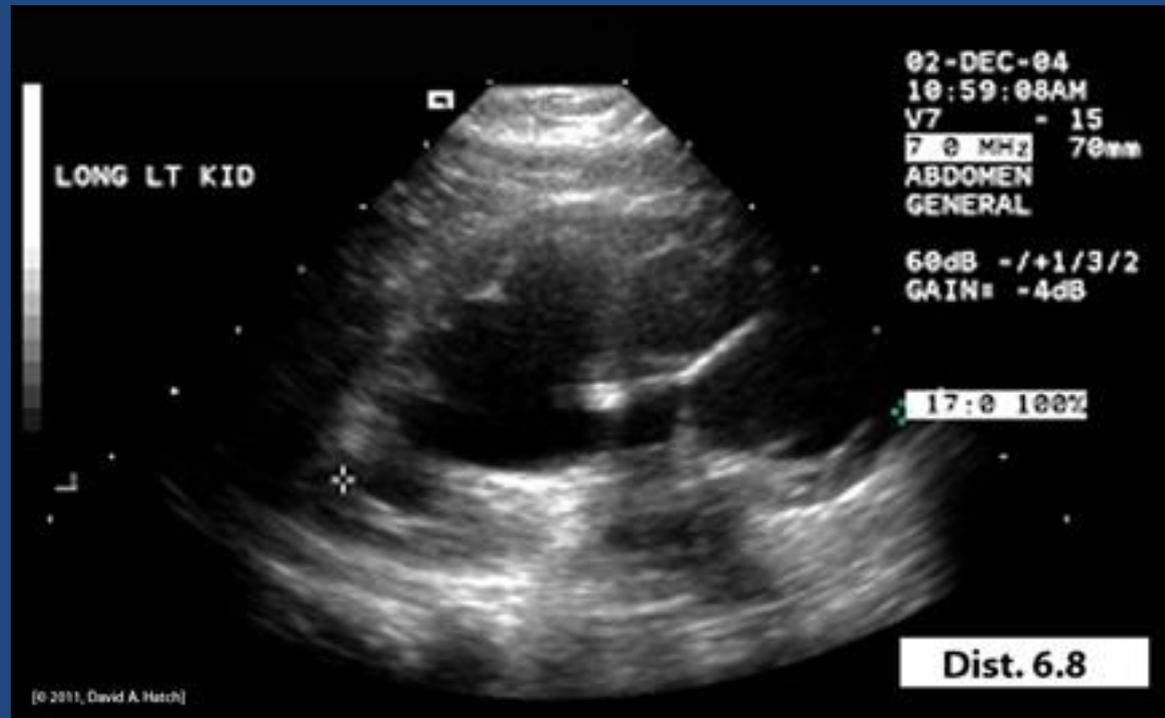
Parenchyma?

- This is a little bit tricky. There isn't as much parenchymal thickness on this side, but look at what is there.
- Regularly irregular
 - Varying echos.
- Relatively darker than the adjacent spleen



Hydronephrosis?

- Yes



- Grade?
 - Thin parenchyma
 - Grade IV

Bladder?

Bladder wall thickness?

Thin

Anything in the bladder?

No



Interpretation:

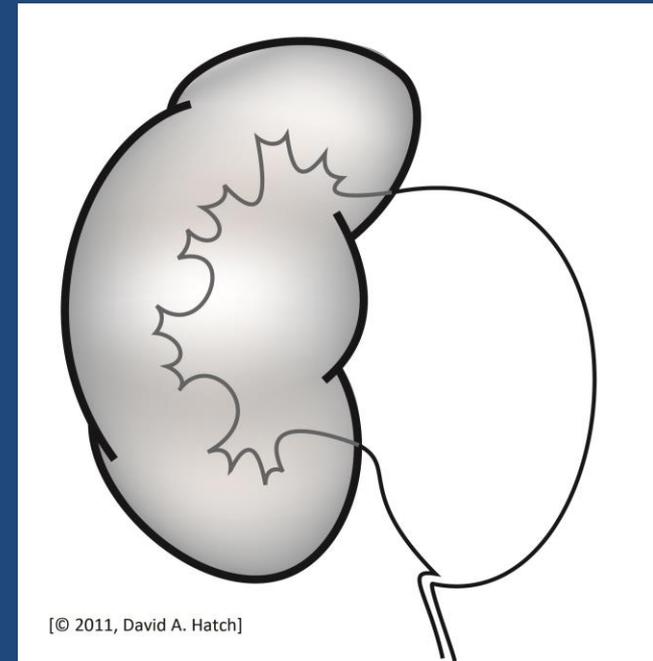
- Left hydronephrosis
– Grade IV

- What caused it?



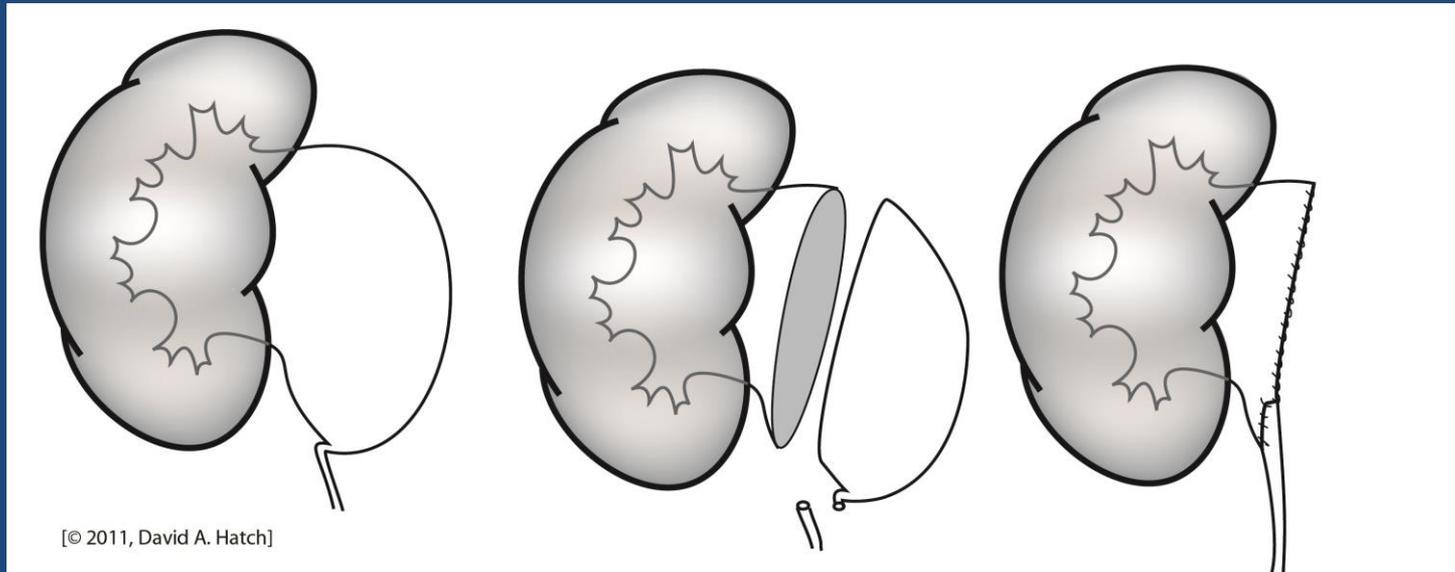
Hydronephrosis

- The most common cause of hydronephrosis in a young child is ureteropelvic junction obstruction, an incomplete blockage at the point where the ureter drains the pelvis.
- When your little patient drinks a lot of liquids, the increased urine output stretches the renal pelvis, causing pain. The obstruction can also cause elevated blood pressure as this boy had.



Ureteropelvic Junction Obstruction

- You perform a dismembered pyeloplasty, removing the obstructing segment and reconnecting the ureter to the pelvis with a wide anastomosis..



- The boy's parents are so grateful that they endow a chair at your medical school in your name. Before you get a big head, you get another page.

Case History

You are asked to see a full-term newborn who is referred because prenatal ultrasounds were “abnormal.” Unfortunately, all of the high risk OB docs are in Florida attending a conference, so no other information is available. The baby’s mother is beside herself with fear. “They told me that there’s something wrong with my baby’s kidneys. Is she going to need a kidney transplant?” APGARs were 8-9-9. What kidney conditions would affect APGAR score? There is no other significant medical history.

Physical Exam

- Healthy appearing female infant
 - T = 37, P = 125, BP = 72/58 (normal), Wt. 3.2 Kg
- Abdomen: The left kidney is palpable and enlarged, but non-tender.
- Genitalia normal.
- What is the best initial imaging technique?
 - Right, ultrasound



DIST= 5.26cm

6 DELETE SET LOCK SET
LOYOLA UNIVERSITY MEDICAL CENTER

52 T 1 IMAGE ON/OFF HOME SET HOME

36 LOYOLA UNIVERSITY MEDICAL CENTER

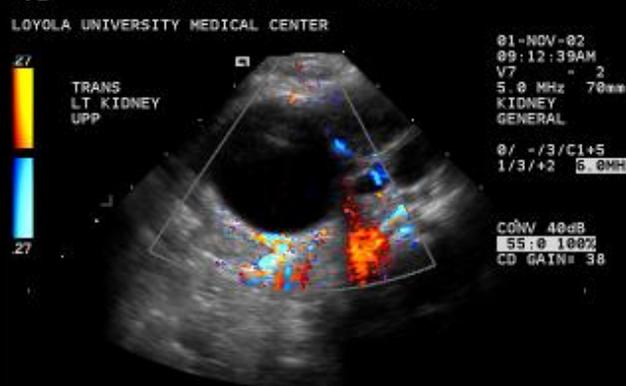


DIST= 6.60cm

20 T 1 IMAGE ON/OFF HOME SET HOME
LOYOLA UNIVERSITY MEDICAL CENTER

LOYOLA UNIVERSITY MEDICAL CENTER

40 DELETE SET LOCK SET
LOYOLA UNIVERSITY MEDICAL CENTER



Ultrasound Interpretation

- Right kidney
 - Size:
 - Shape:
 - Parenchyma:
 - Hydronephrosis:
- Left kidney
 - Size:
 - Shape:
 - Parenchyma:
 - Hydronephrosis:

How Did You Do?

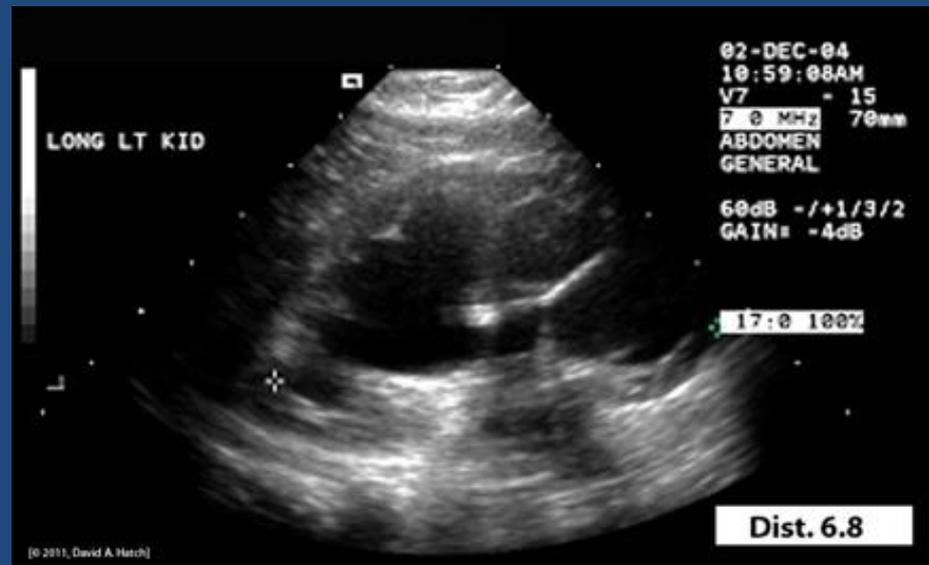
- Right kidney
 - Size: 5.28 cm is large for this baby's age (normal = 4 cm + 0.6 x age in years, or $4 + 0.6 \times 0 = 4$ cm). What could cause that?
 - Shape: Normal
 - Parenchyma: Normal
 - Hydronephrosis: None
- Left kidney
 - Size: Even larger!
 - Shape: Hard to determine
 - Parenchyma: What parenchyma?
 - Hydronephrosis: Be careful

Case Analysis

- We've got a few things to explain:
 - Right kidney is large, but otherwise normal
 - There is little or no parenchyma on the left
 - There are several round to oval cystic (hypoechoic) structures within the area of the left kidney. The ultrasound tech tells you that the hypoechoic areas do not interconnect. They are distinct fluid collections.
 - There is no dilated ureter

Compare With the Last Case

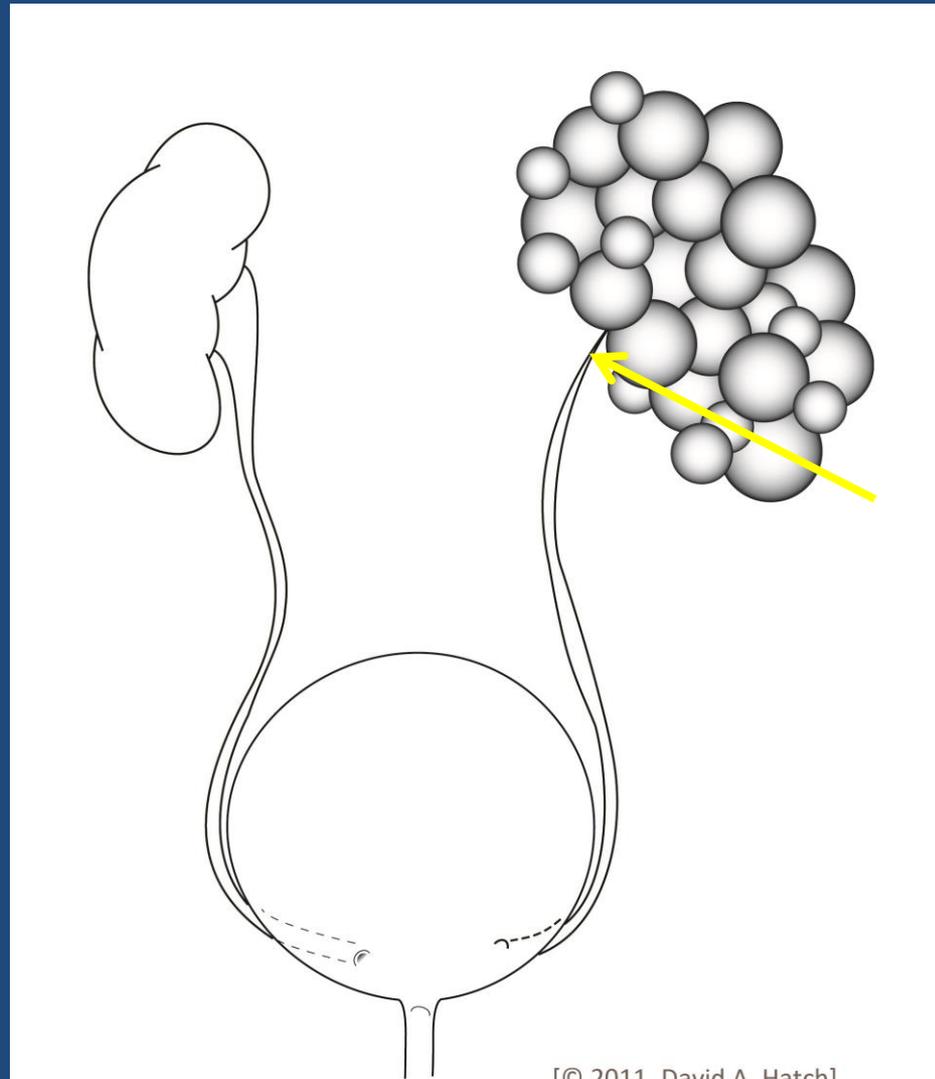
- Although both of these kidneys contain hypoechoic regions, they are very different. The kidney on the left has many separate cystic structures. The kidney on the right has a single large hypoechoic structure: the hydronephrotic kidney pelvis.



Case Analysis

- The right kidney is large due to compensatory hypertrophy. If one of paired organs is missing, the contralateral organ usually hypertrophies to compensate. This affects kidneys up to about age 40.
- On the left, we see a huge kidney with very little parenchyma and large hypoechoic areas that don't seem to communicate. These are the cysts of a **multicystic-dysplastic kidney**. These kidneys usually show no uptake on functional imaging (lasix renogram, CT scan [no concentration of contrast]).
- If we were to do a retrograde pyelogram (x-ray performed by putting a catheter up a ureter and then injecting liquid contrast into the kidney/ureter) we would see a blind ending ureter—no connection to the calyces.

Multicystic-dysplastic Kidney



Atretic ureter

Ultrasound – Review

- Ultrasound is the best initial imaging for a child with an abdominal mass.
- Excellent study for determining solid v. cystic
- Conventions: Longitudinal – cephalad (left side of image), Caudal – right; Transverse-like a CT scan (as though you were facing the patient)
- Kidney size for a normal child:
 - Age (years) x 0.6 + 4 cm (full term)

Ultrasound – Review

- Compensatory hypertrophy: if one of paired organs is missing, the contralateral organ will hypertrophy. If an apparently single kidney is normal size, look for an ectopic organ.
- See an unknown object?
 - Take a deep breath and then systematically describe it.
 - Location, size, shape, echo pattern

Congratulations!

- You've completed the first ultrasound tutorial.
- Need a break?
- When you're ready, open Ultrasound 2