Kidney and urinary system ultrasound

A presentation for the internist

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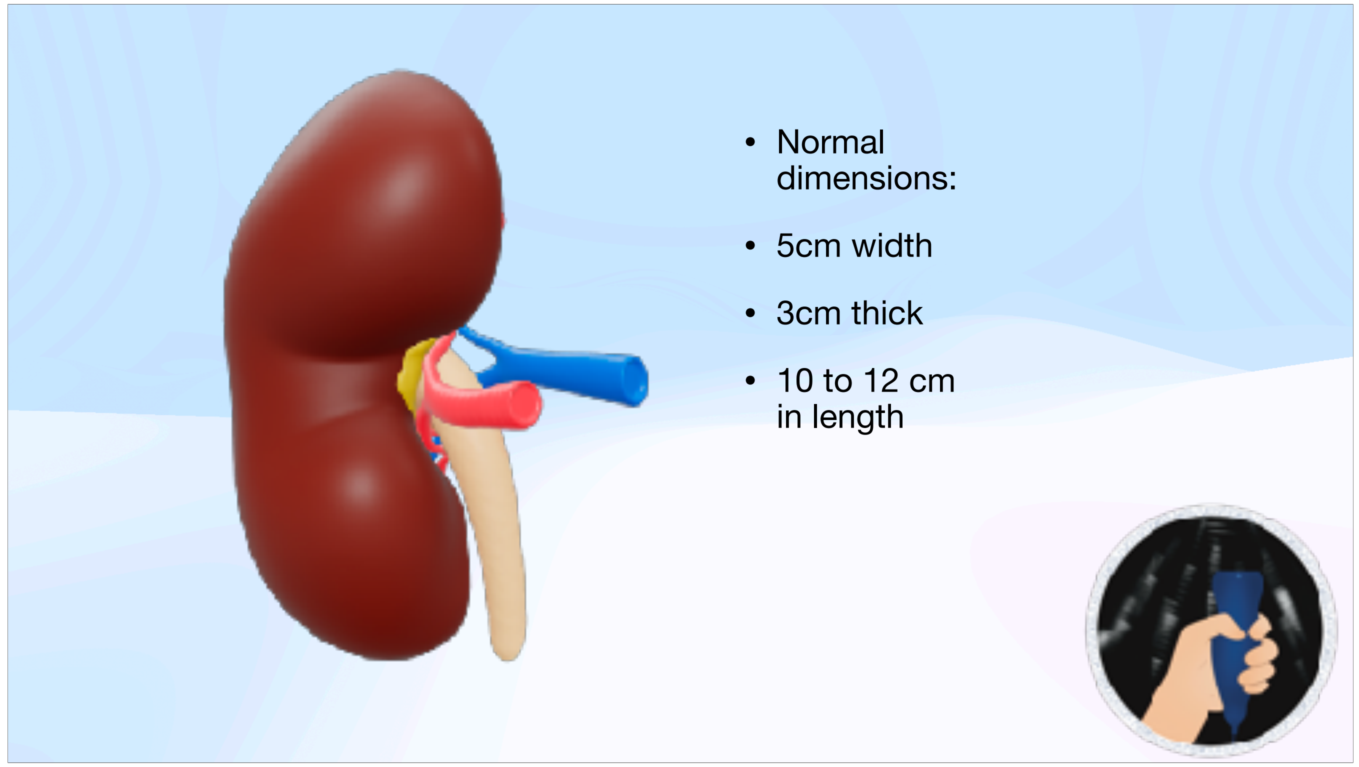
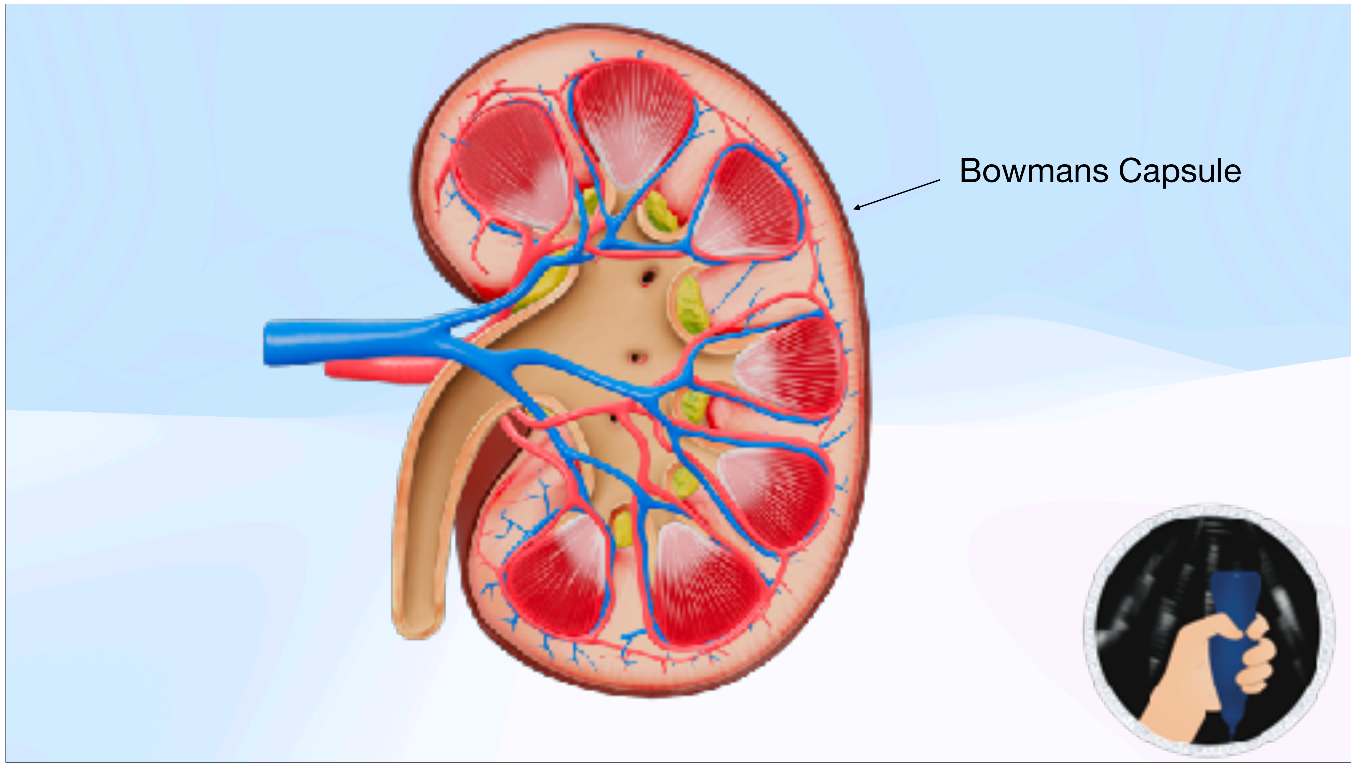
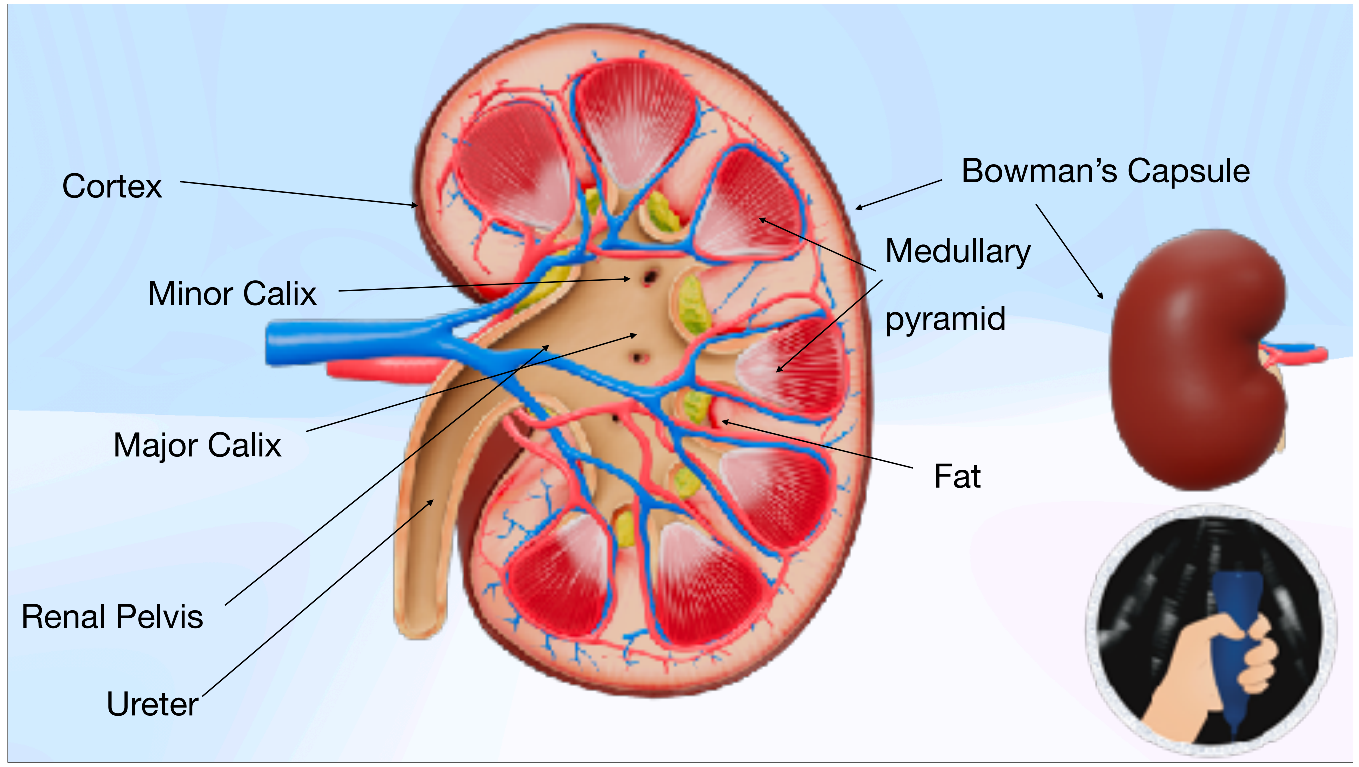
Kidney and Urinary Ultrasound for the Internist.
The kidney and the urinary tract are of special interest to the internist in the inpatient and outpatient settings.
Ultrasound is useful for anatomic and physiologic evaluation.
It is important for the internist to be familiar with the evaluation of the kidney.



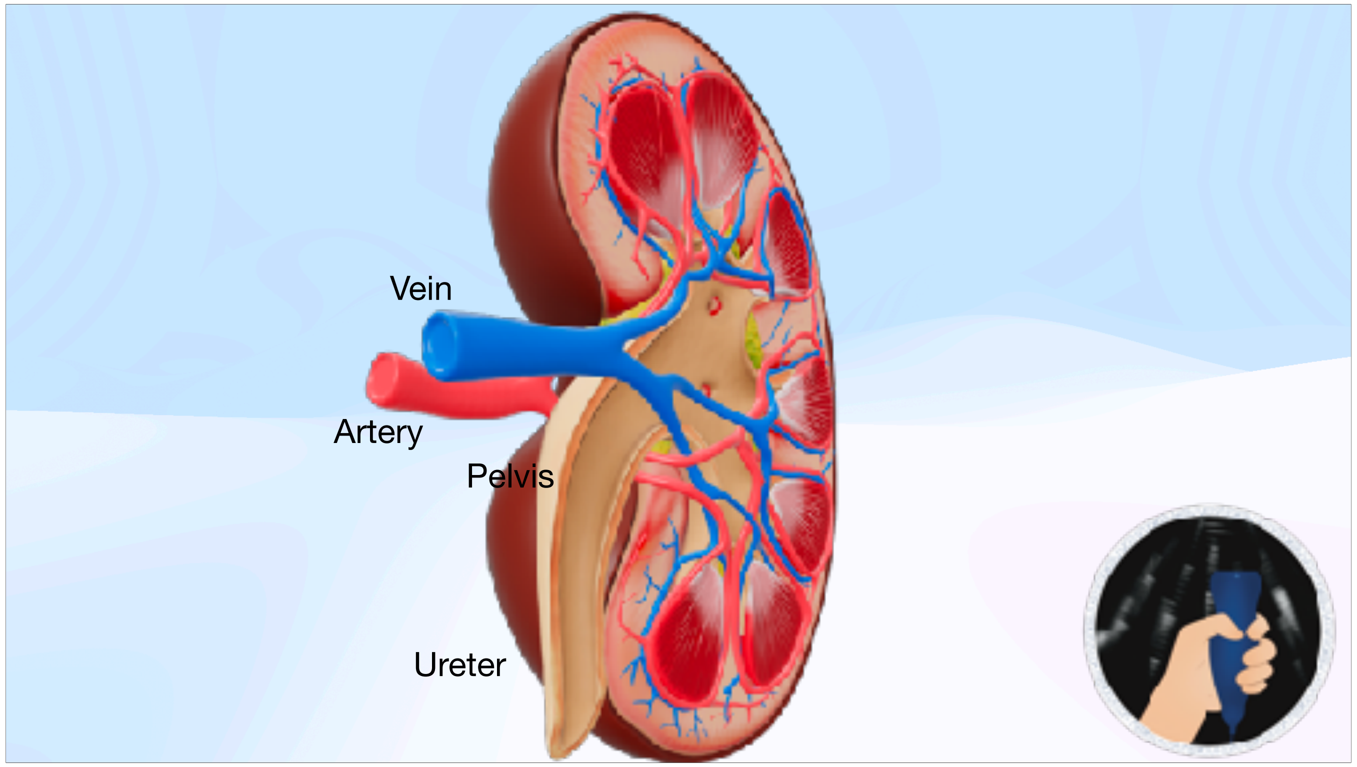
The kidneys are bean-shaped paired organs with dimensions usually 5 cm in width, 3 cm in thickness, and 10 to 12 cm in length.
The focused evaluation of the kidneys is different from the full anatomic evaluation of renal structures that the radiologist team will perform.
Evaluation of the kidney at the point of care can help us determine the cause of kidney failure, volume status, gross anatomic abnormalities, and the presence of hydronephrosis.
The evaluation of the rest of the urinary tract is important at the point of care, as it can provide a very good idea of a patient's anatomy and physiology.



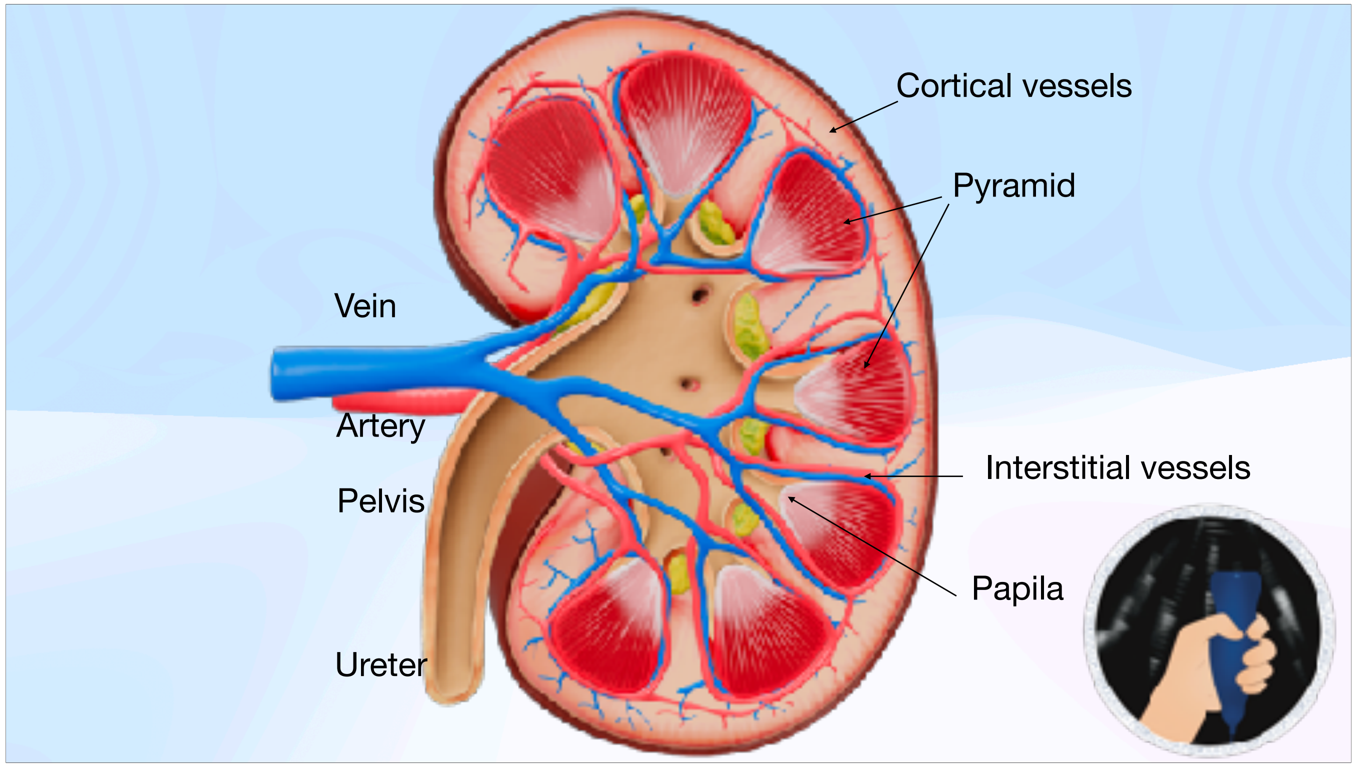
The kidney is enclosed by the Bowman's capsule, a fibrous tissue that appears hyper-echoic. Sometimes, in the presence of edema or infection, one can see straining or edema of the Bowman's capsule.
During this course we will revisit the kidney and urinary systems in our case section.



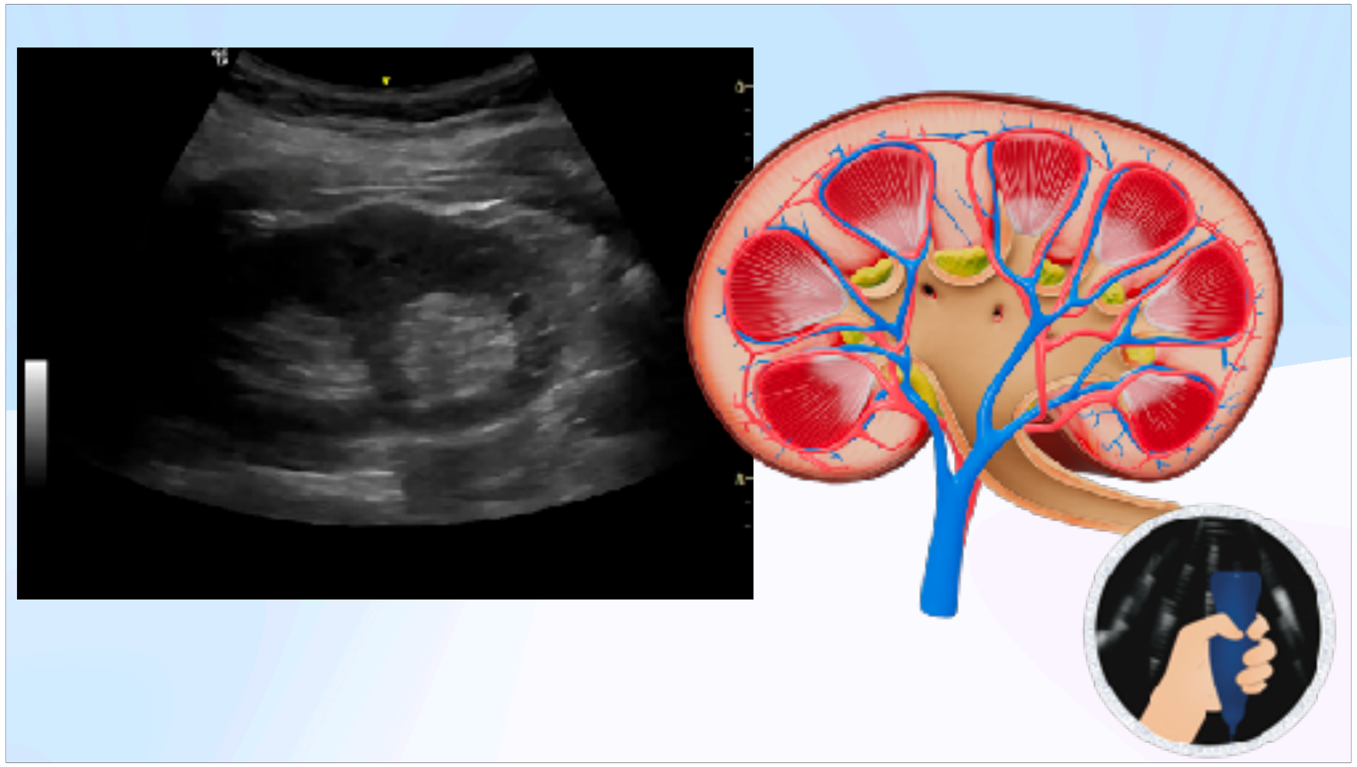
The Bowman's capsule surrounds the kidney. This is a fibrous tissue that will appear hyper-echoic when compared to the rest of the structures.
Immediately below the capsule is the kidney's cortex, where most of the glomeruli are located. This area appears hypo-echoic due to the large amount of glomeruli that lives there.
The circulation of the cortex comes from the cortical arteries that are supplied by the segmental and lobular arteries this arteries are of special interest when evaluating volume status.
The kidney pyramids are located in the medulla, here is where the loops of Henle and its vessels liveds. They also appear hypo-echoic.
One pyramid, its cortex papilla, and minor calyx is called a renal lobe; the kidney has 8 to 18 lobes.
Each kidney has about 800,000 nephrons, and both kidneys have about 1.5 million.
About a third of cardiac output passes through the kidneys every minute.
At the tip of the pyramids, we can see the papilla, which is connected to the minor calyces.
Then they will coalesce and form the major calyces and the the renal pelvis which finally will drain into the ureter.
Parts of the medulla re hyper-echoic due to the fact that are made from fat and connective tissue
In point-of-care ultrasound, we can visualize the minor and major calyces, lobular arteries, the main artery, and the vein; we usually do not see the ureters.



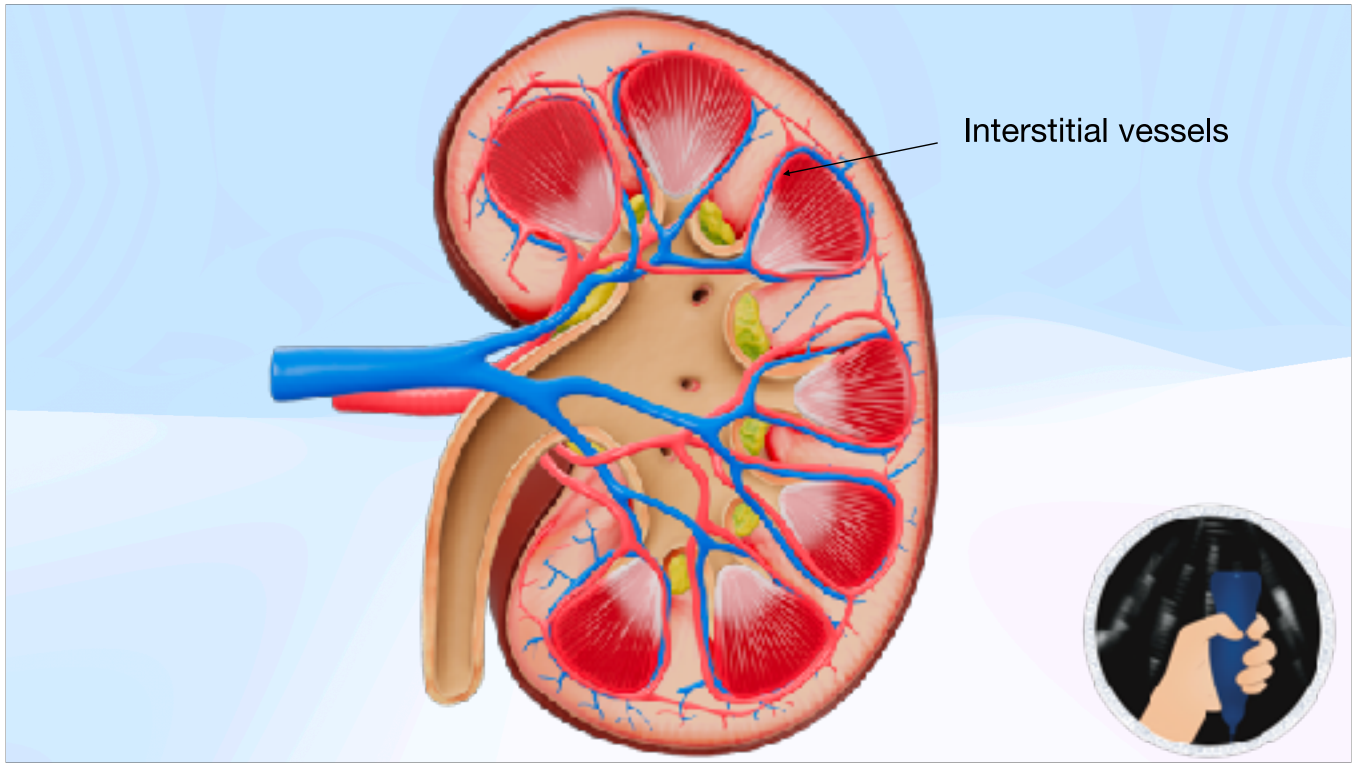
This is illustration demonstrates the kidney cut in half, in an angle to facilitate the understanding that the kidney is a 3-D structure that we are evaluating with a two dimensional tool.



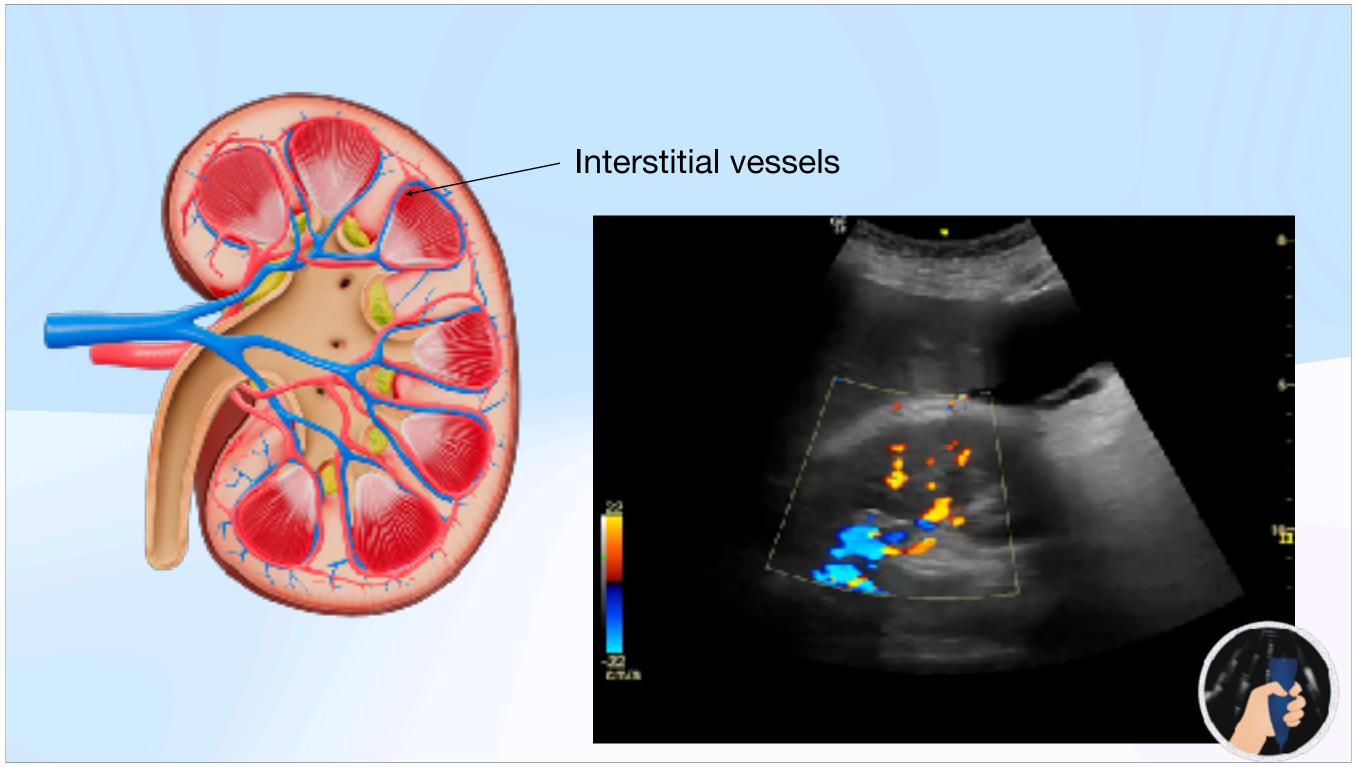
Please take a moment to see all the major structures of the kidney.



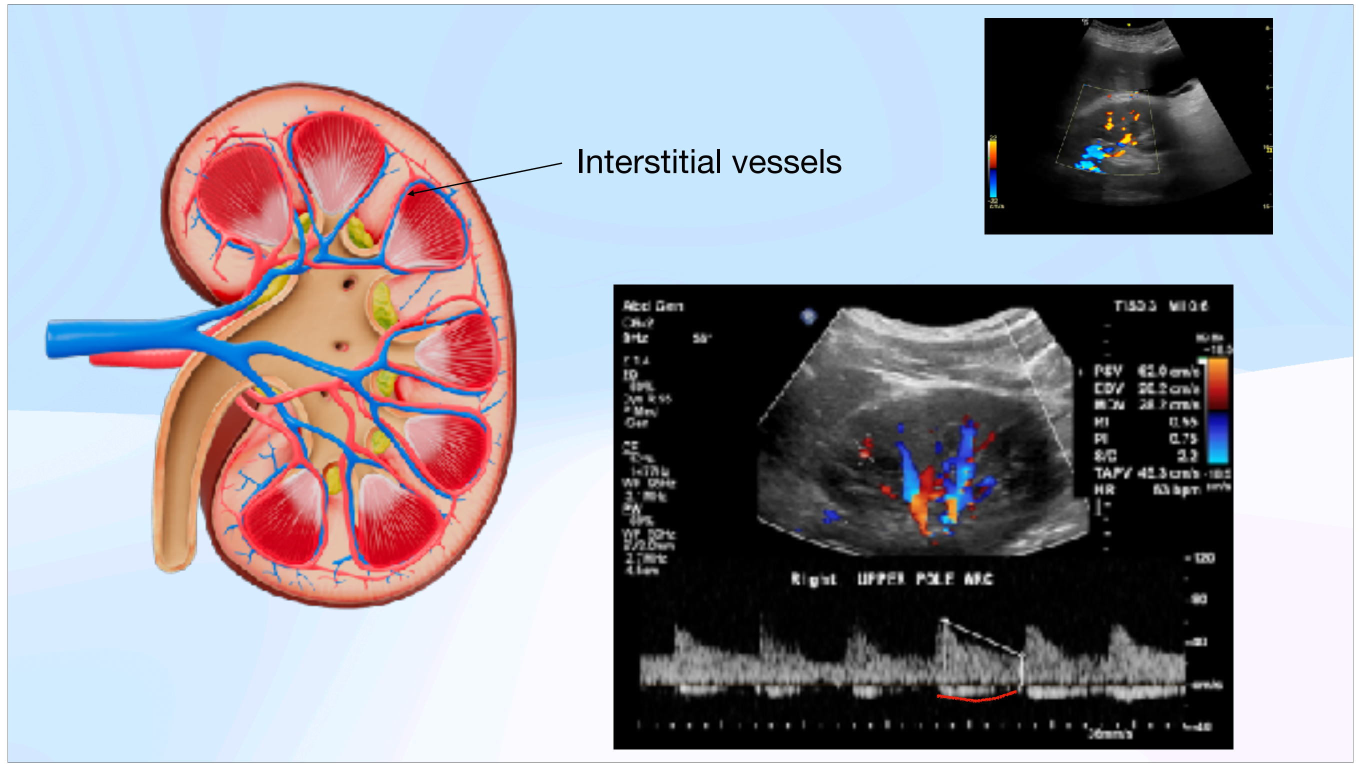
In this illustration, we have a video of a normal kidney you can see the correlation of the structures and the kidney illustration while it is in axis with the video of the ultrasound.
For us, the generalists, the long axis evaluation of the kidney is usually the most useful. Again, remember that this is an evaluation that is limited to make clinical decisions at the bedside of the patient, if you're objective is to rule out or in small anatomic abnormalities, the traditional radiology approach by the radiology team is usually better.



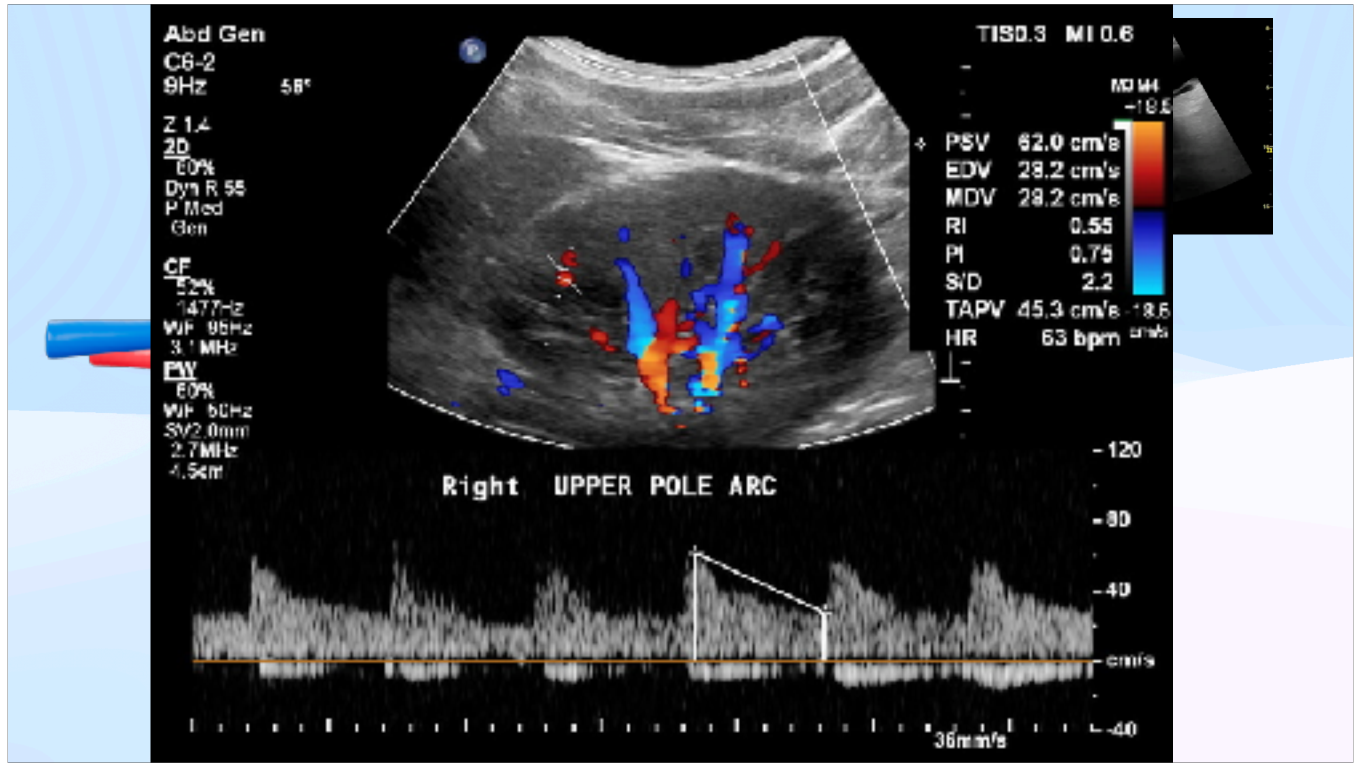
In this illustration we see the interstitial vessels. These vessels runs in pairs. One artery and one vein.
The study of the pulsed wave doppler of these vessels can help the generalist in evaluating the volume status. And I want to use a the next few slides to demonstrate the usefulness of this evaluation.



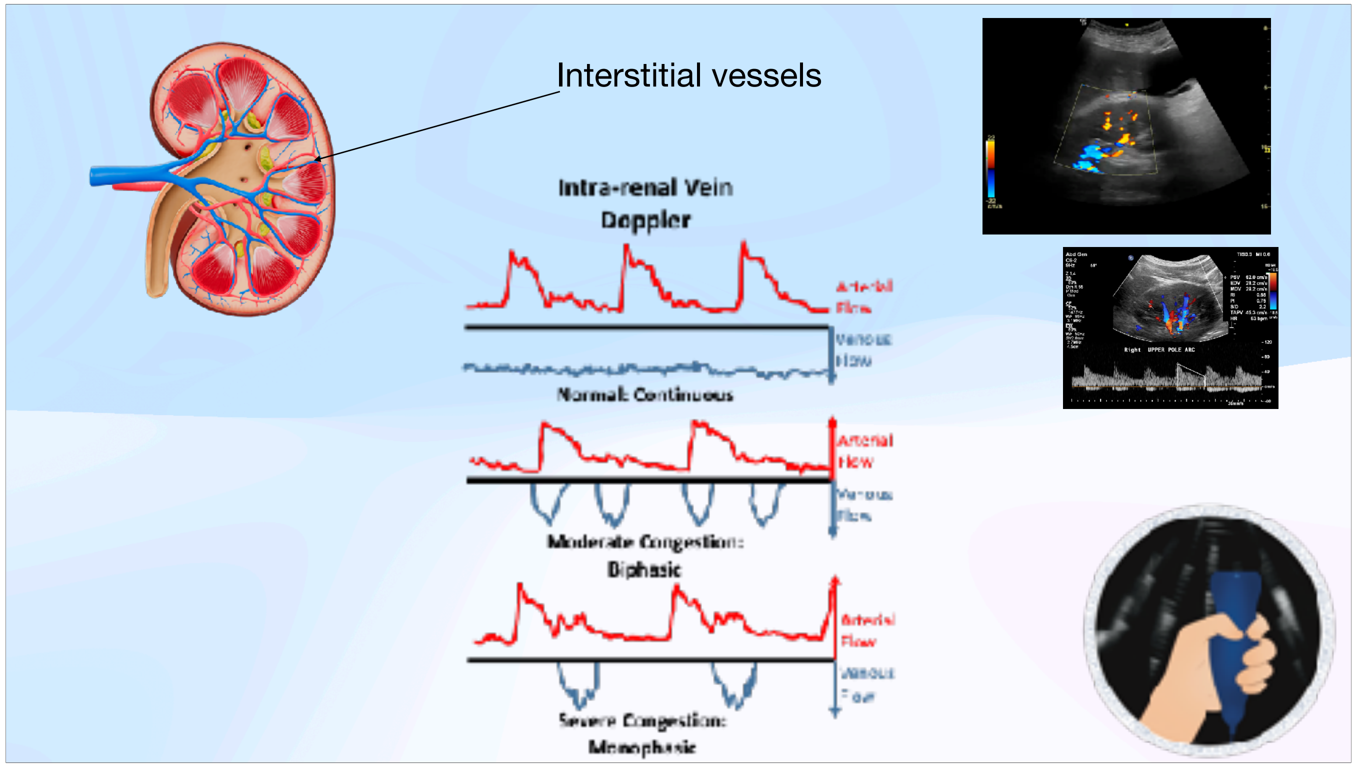
In this video, we see color Doppler of a normal kidney in abdominal settings. We can see some interstitial vessels, the study of the Doppler of these vessels can help us to determine hemodynamics of a patient. The probe being used is a curvilinear probe.



In this slide, we have now used Pulsed-Waved-Doppler (PWD) gate to sample interstitial vessel.
Usually interstitial vessels run in pairs, one artery and one vein. So when the gate of the Doppler is placed on the vessel, we will find an arterial phase, which is in this case the positive deflection of the spectrum, and a venous phase, in this case, the negative deflection of the spectrum.
When systole occurs there is an increase of the velocity of the positive spectrum. In the negative spectrum during systole we usually will find a constant or increased negative deflections which correlate with the venous flow of the interstitial vein.
In different states of congestion, this correlation is abnormal as we will see in next slide.

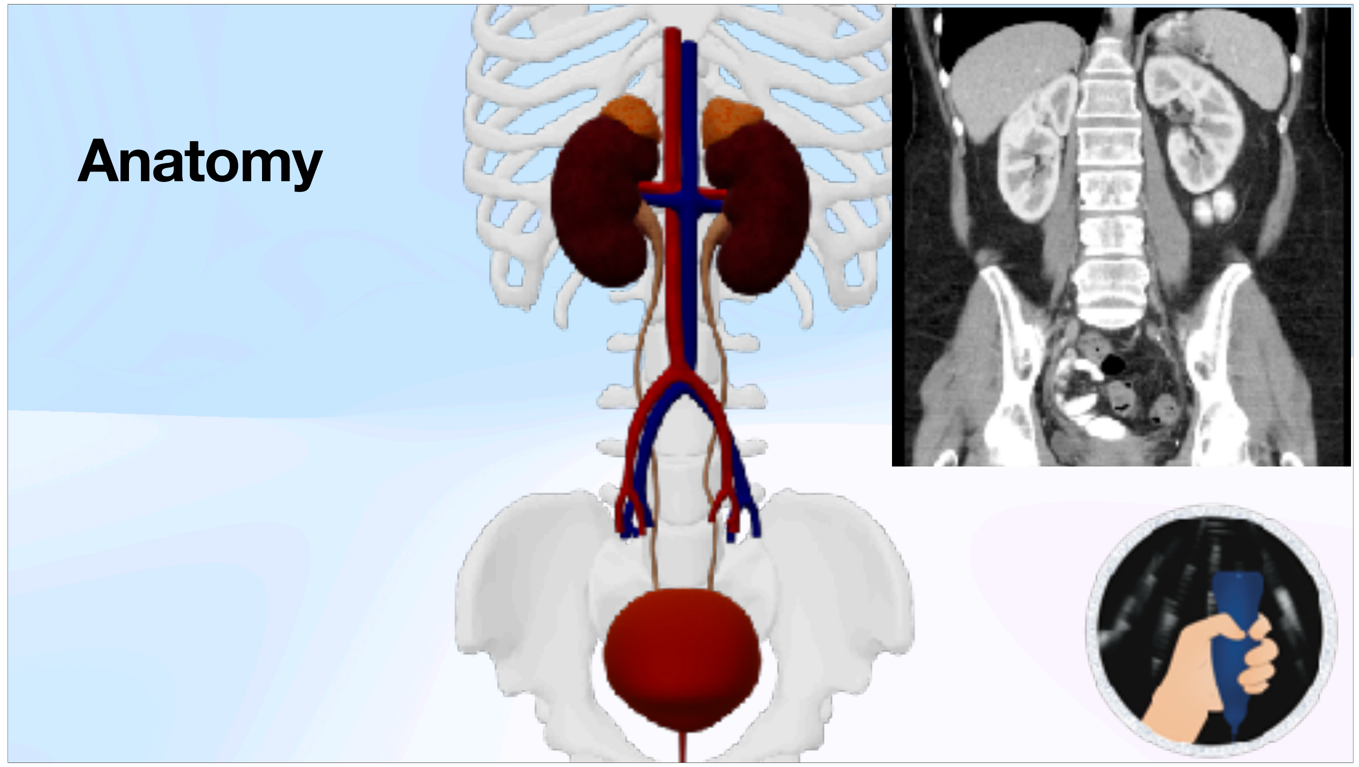


So when the gate of the Doppler is placed on the vessel, we will find an arterial phase, which is in this case the positive deflection of the spectrum, and a venous phase, in this case, the negative the flexion of the spectrum.
It is important to remember that the venous flow should not stop during systole.
Abnormalities of the venous return in the pulse wave Doppler are very useful to determine the volume status of a patient.

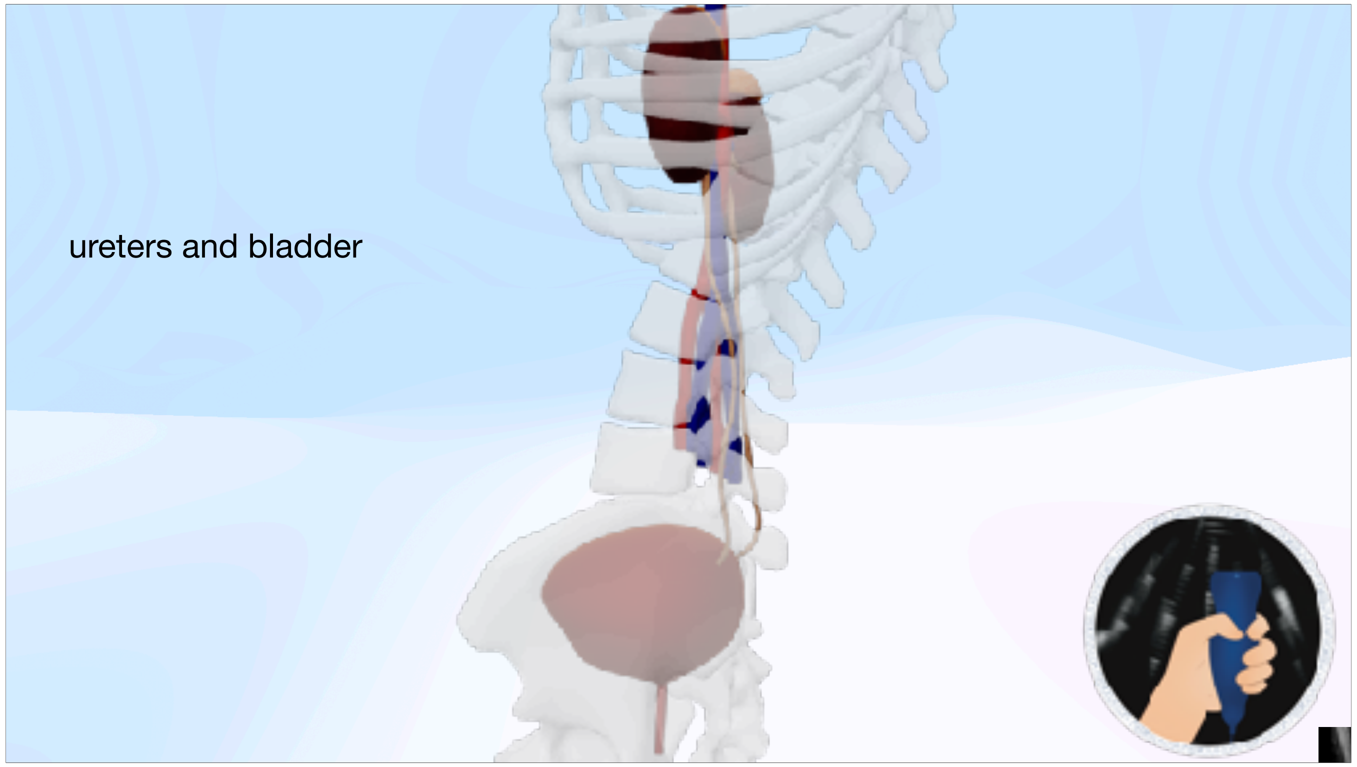


In here, I illustrate the expected Dopplers found in different types of congestion.
Note that these Dopplers are obtained from interstitial vessels.
On top, we see the normal flow of arteries and veins in the pair of vessels sampled with PWD. You can see that during systole and diastole, the venous flow is constant. *
Below, we have an illustration showing that the Venus flow is interrupted and biphasic. This is because of the congestion, as blood enters the renal parenchyma the venous flow is not as free to exit the kidney due to increased venous pressure and increased volume. In moderate congestion the venous return is interrupted in the middle of the uptake of systole creating this bifasic venous flow.
At the bottom, we can see a complete interruption of venous flow in severe congestion during the uptake in systole, having venous return after the arterial uptake.
This qualitative evaluation is part of what we call venous excess ultrasound. A multi-organ ultrasound using Doppler to further help the clinical evaluation of the volume status.

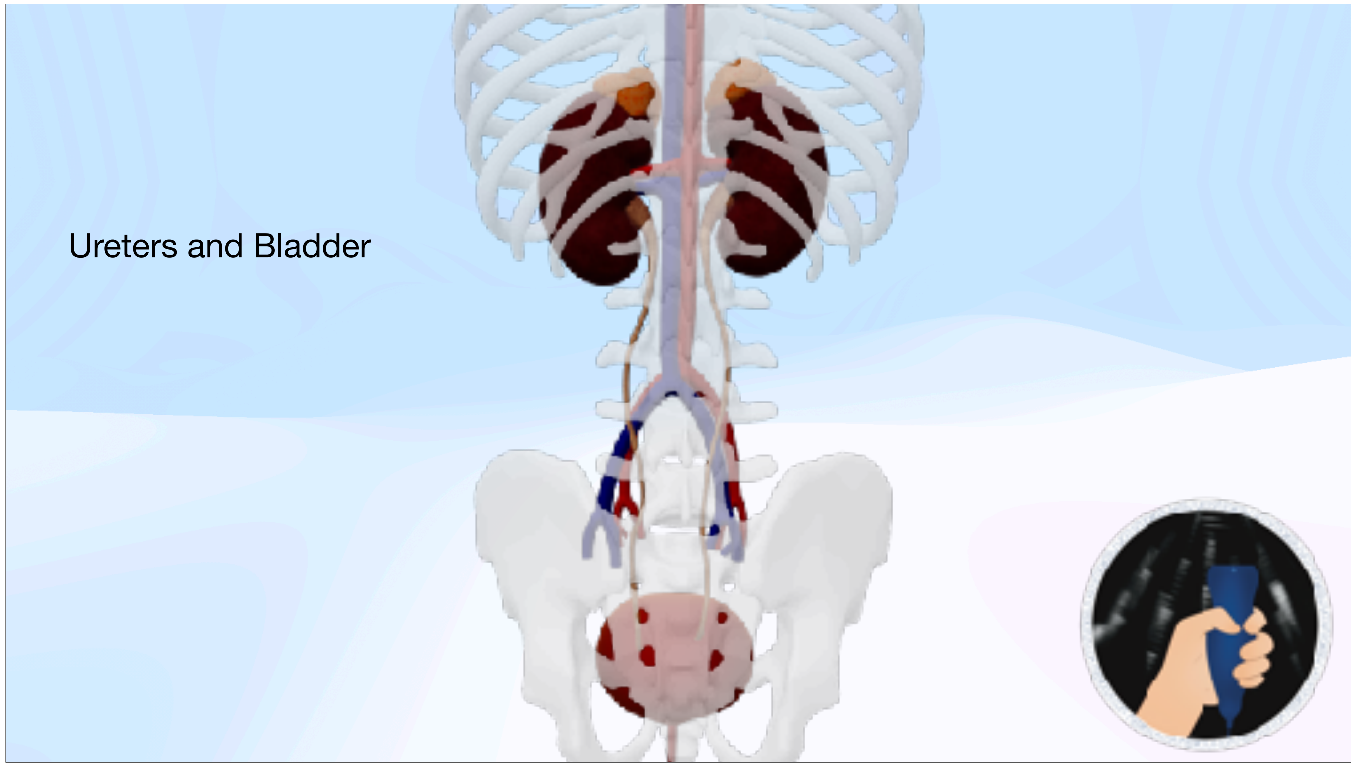
*Systole being represented by the positive deflection uptake in velocity in the PWD.



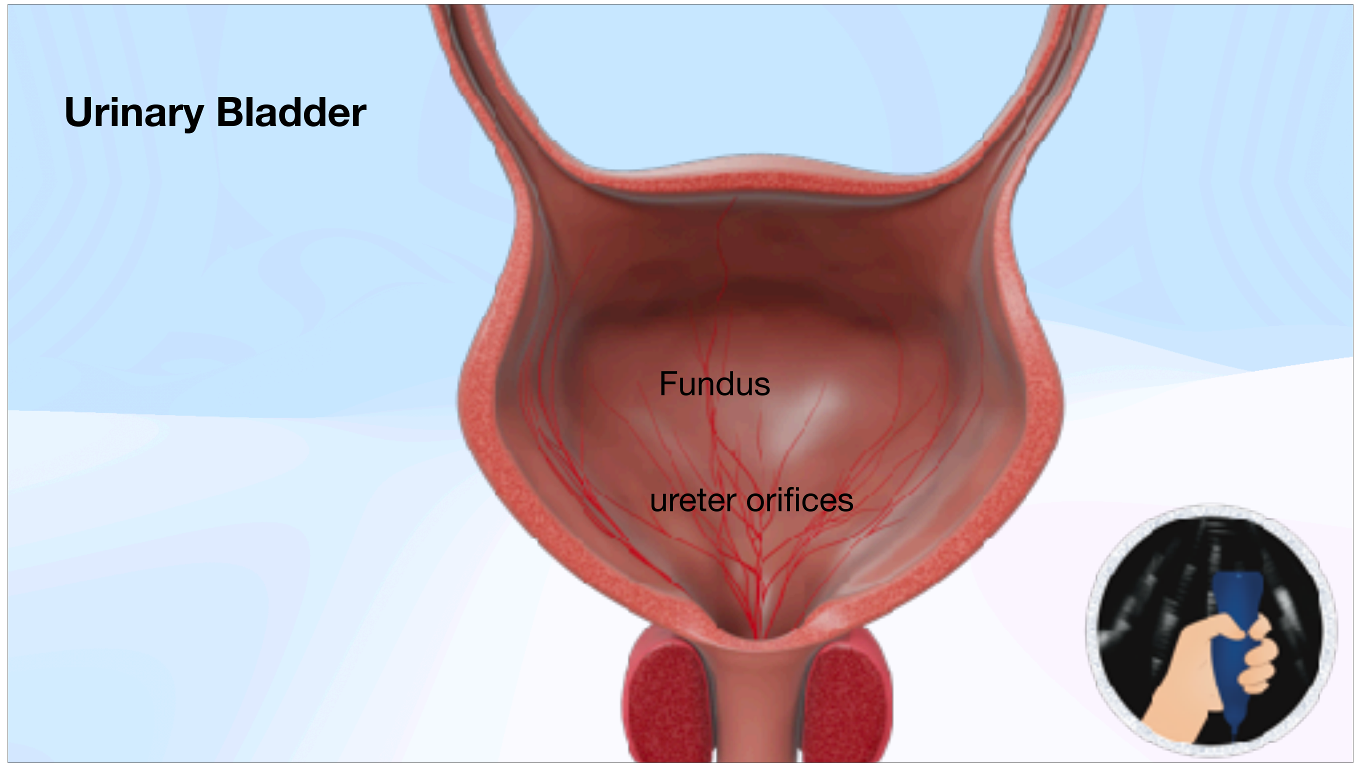
Kidneys are retroperitoneal. Lying on top of the para-spinal muscles. And posterior to the abdominal organs.
You’ll find the kidneys at the level of the 11th and 12th ribs, and they have a slightly tilted orientation with the upper pole more posterior than the lower pole.
The right kidney is slightly lower than the left kidney. This is because the liver is larger than the spleen.
The ureters run in the retroperitoneum.
The bladder lies just above the pelvic bones, anterior to organs such as the rectum and uterus.
In this illustration, a CT scan shows the right kidney below the left kidney. Right at the center of both kidneys, you can see the Psoas muscle.
Also, in this illustration, you can see the relationship between the kidneys, ureters, and major vessels.



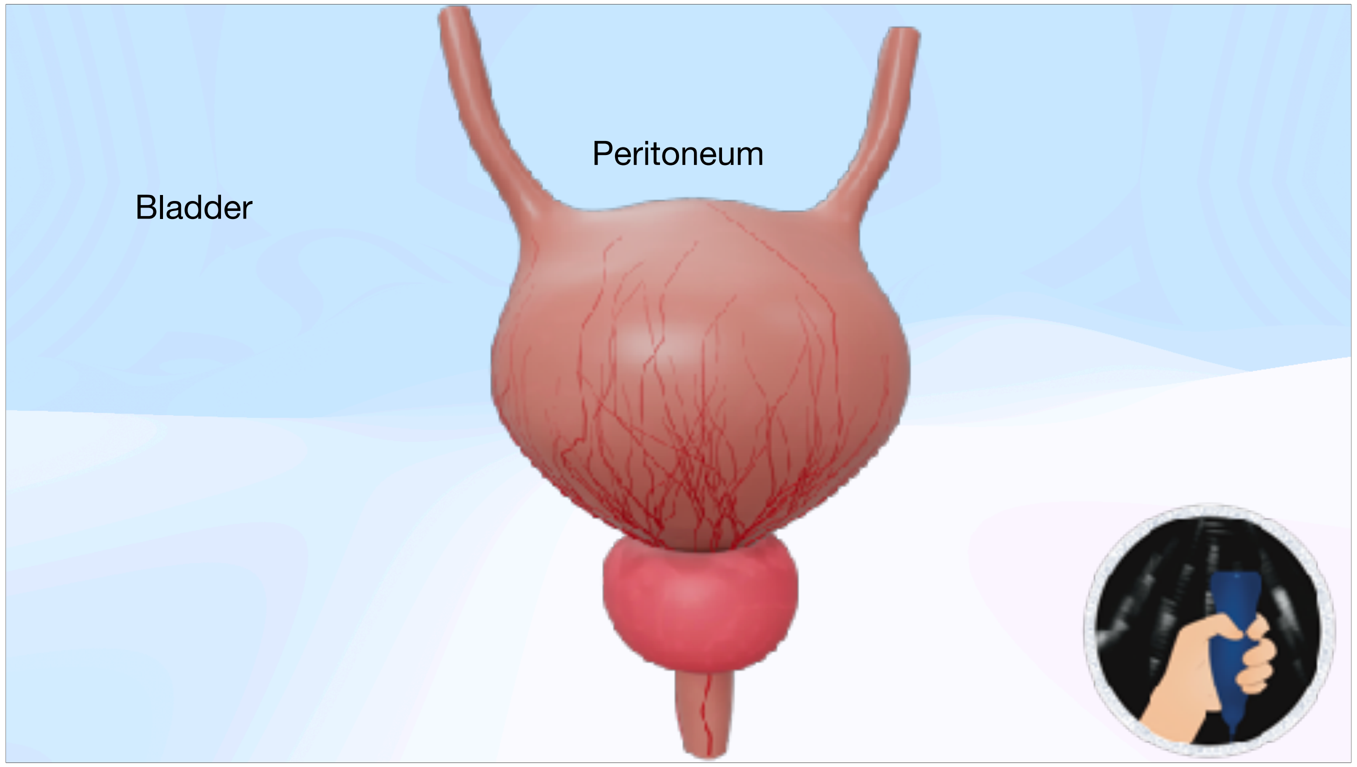
In this lateral view, you can see the kidneys right around the 11th and 12 ribs.
Also, you can see the kidneys being posterior to the urinary bladder which sits in the pelvis.



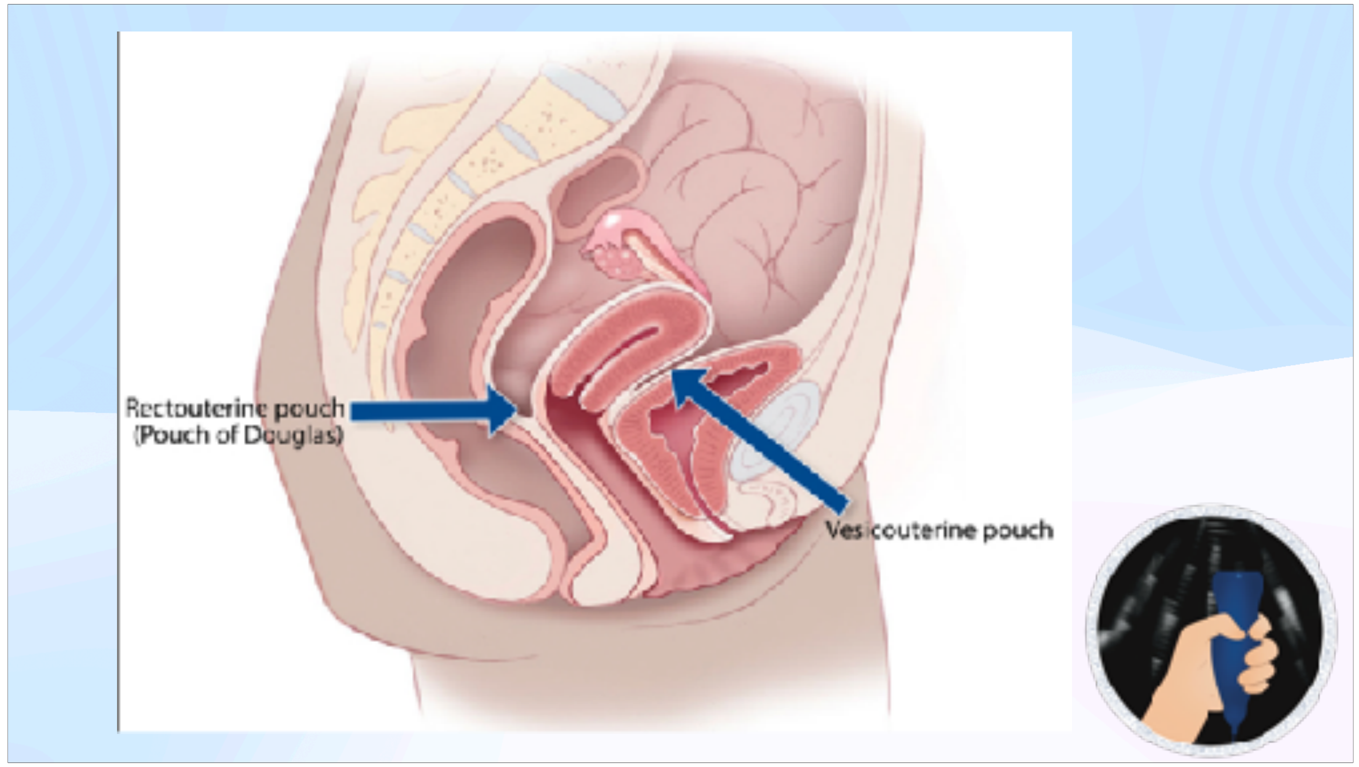
This is a poster view, please pay attention to the different structures.



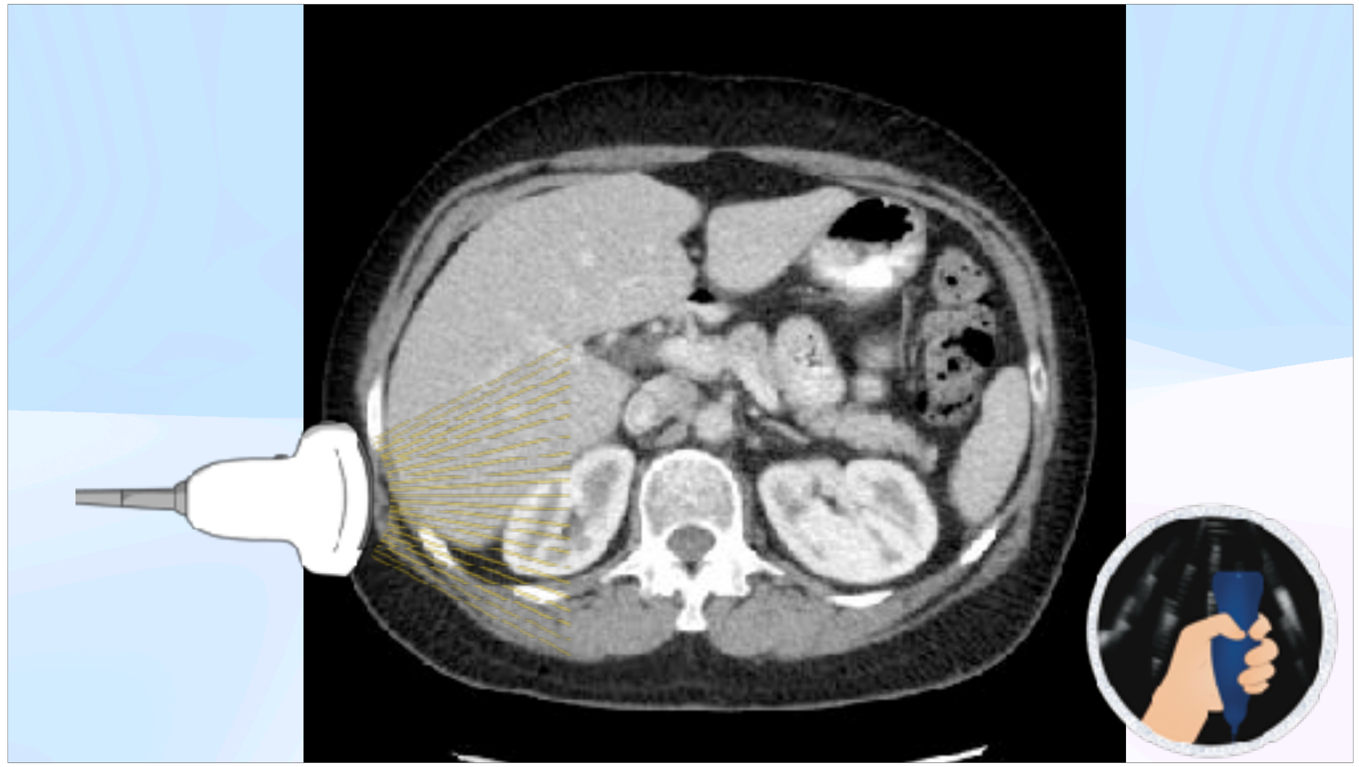
This is a cut of the anterior half of the urinary bladder, showing its interior. The ureter inlet is not shown as they enter the bladder posteriorly. The bladder has a fundus, the ureter, and the urethra.
This is a male bladder; you can see that because of the presence of the prostate.



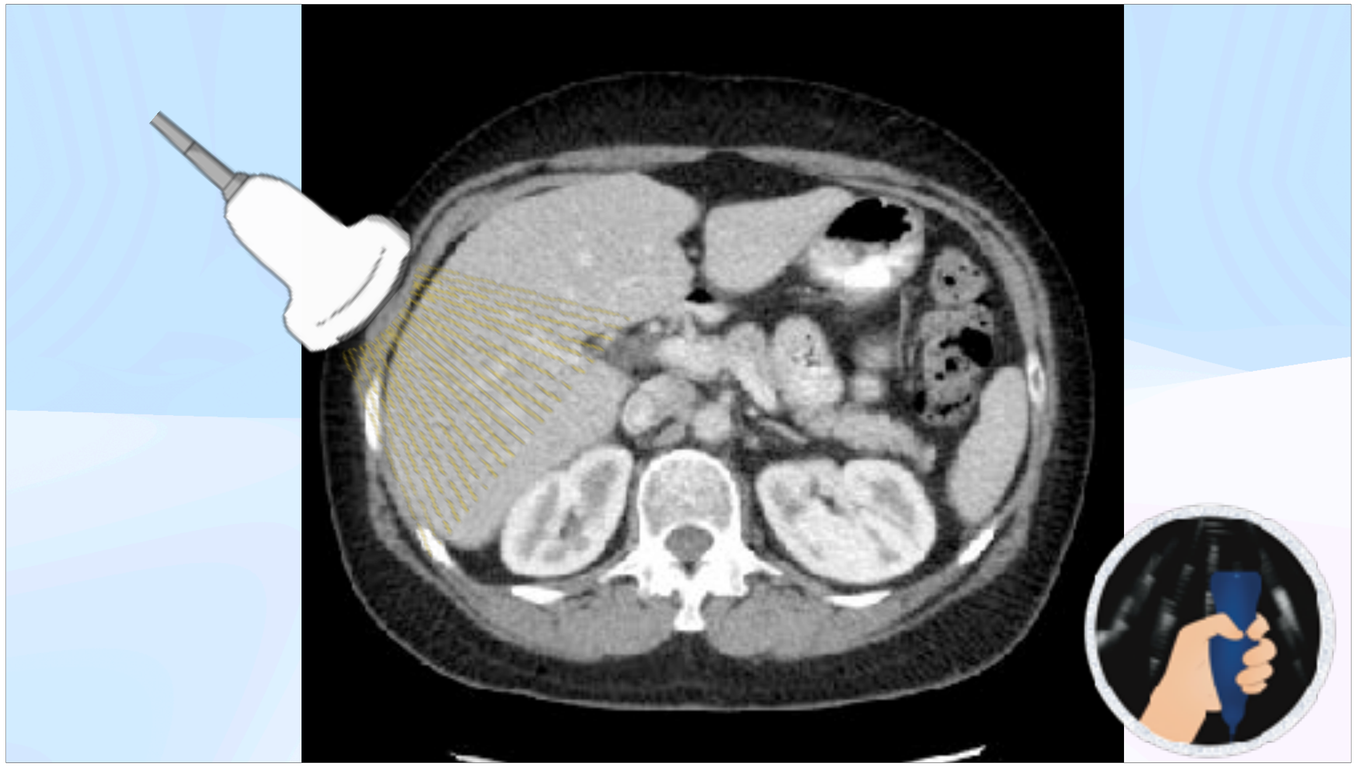
This is the anterior view of the bladder.



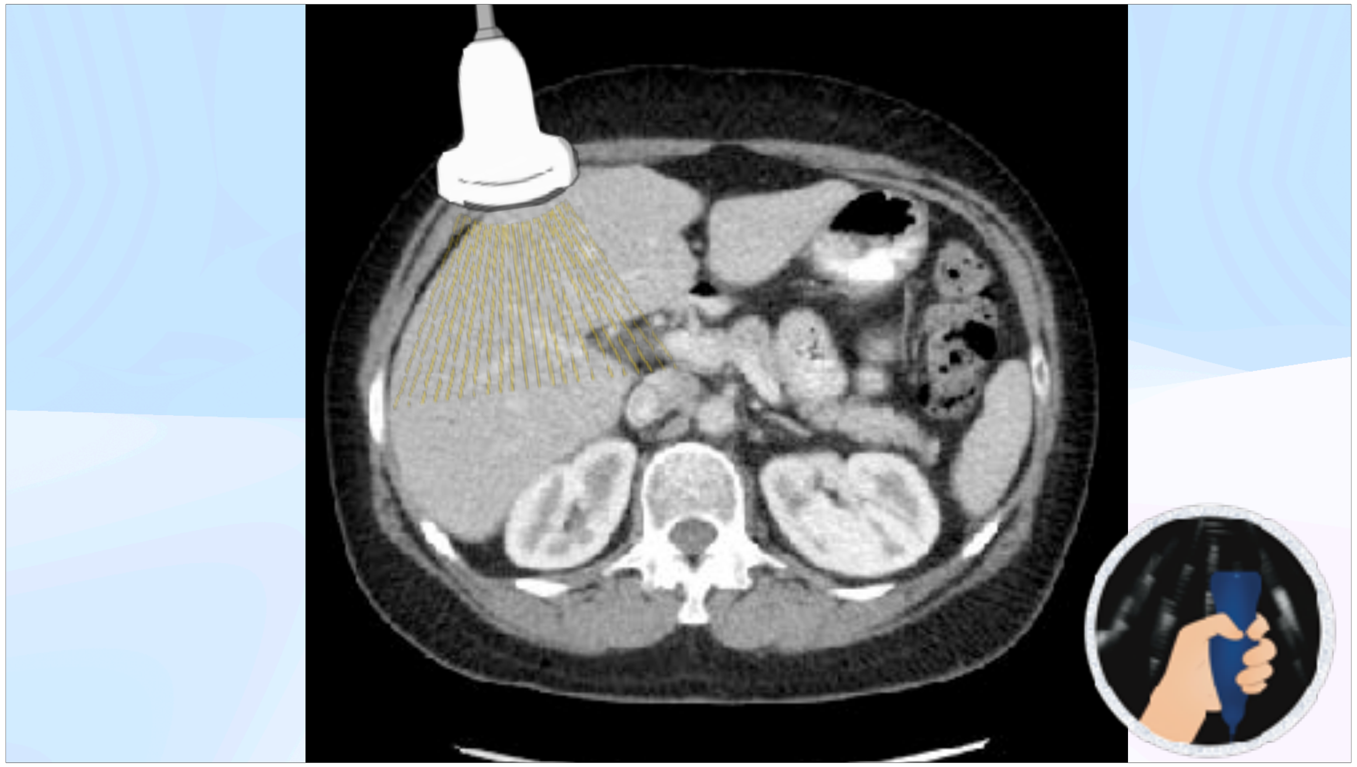
The female urinary bladder is slightly different from that of the male; it sits anterior to the uterus and the rectum. It has two virtual spaces that can be filled with fluid. The Pouch of Douglas and the Vesico-uterine pouch.



The right kidney, as you see in this CT scan, has more opportunities to be scanned thanks to the liver, which we use as an acoustic window. Here is a more posterior approach that will give you a good image.

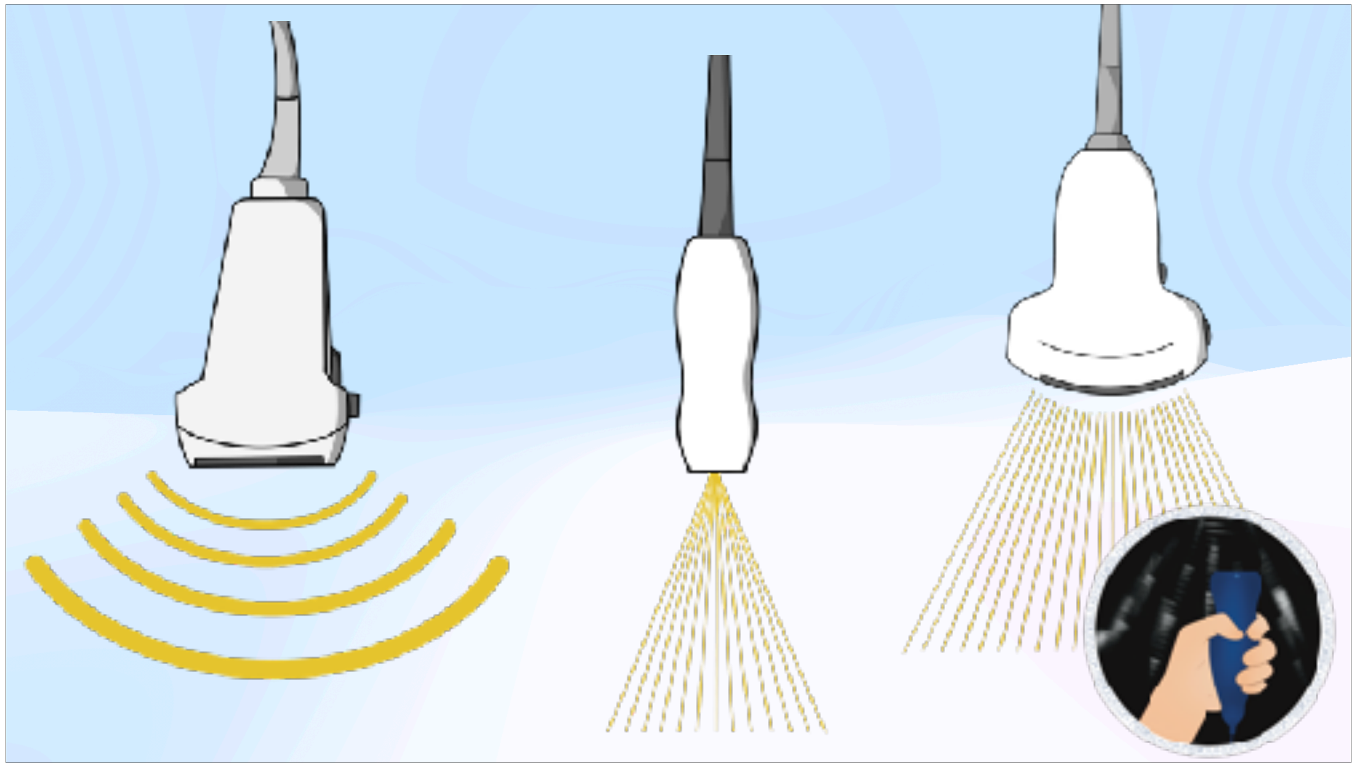


You can see that you can also use some more anterior approach as we will see in the next slide

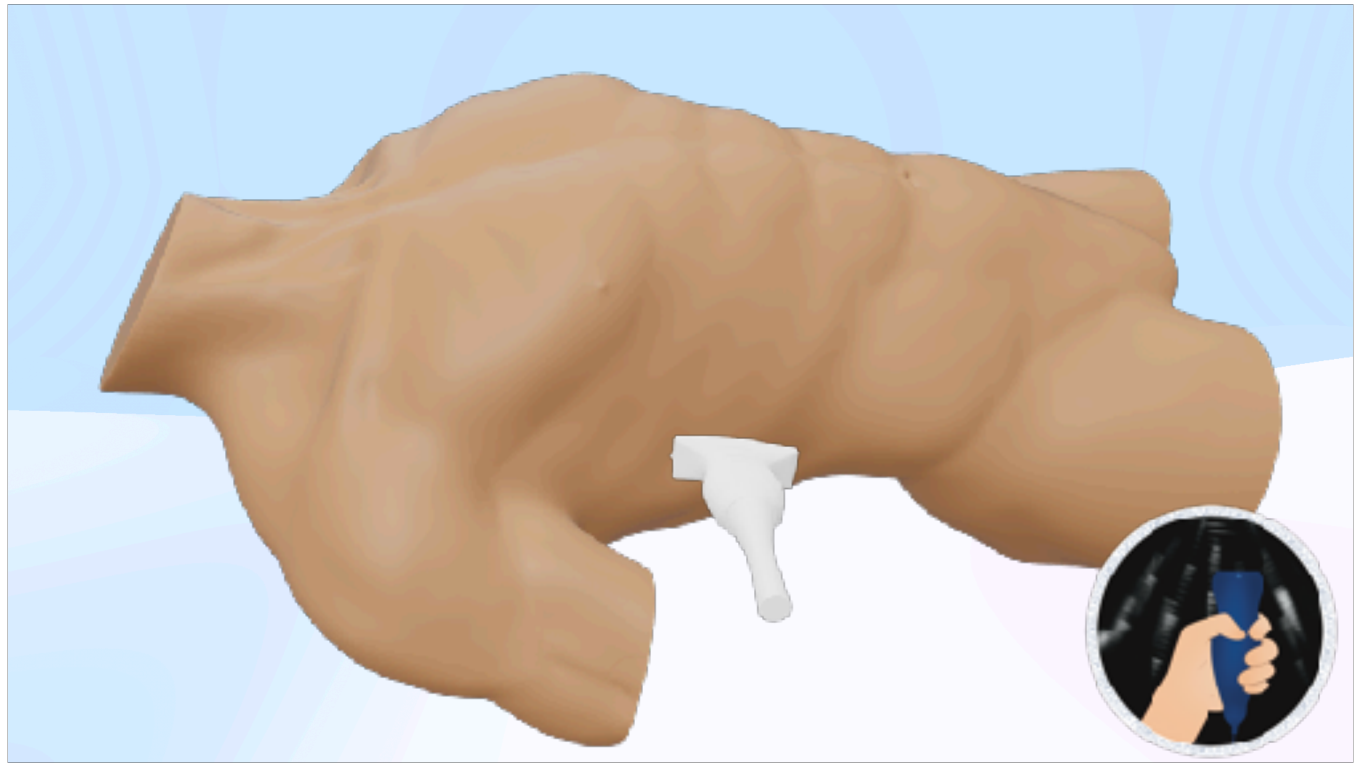


In here, we can see that we can use a very anterior medial approach to see the right kidney.

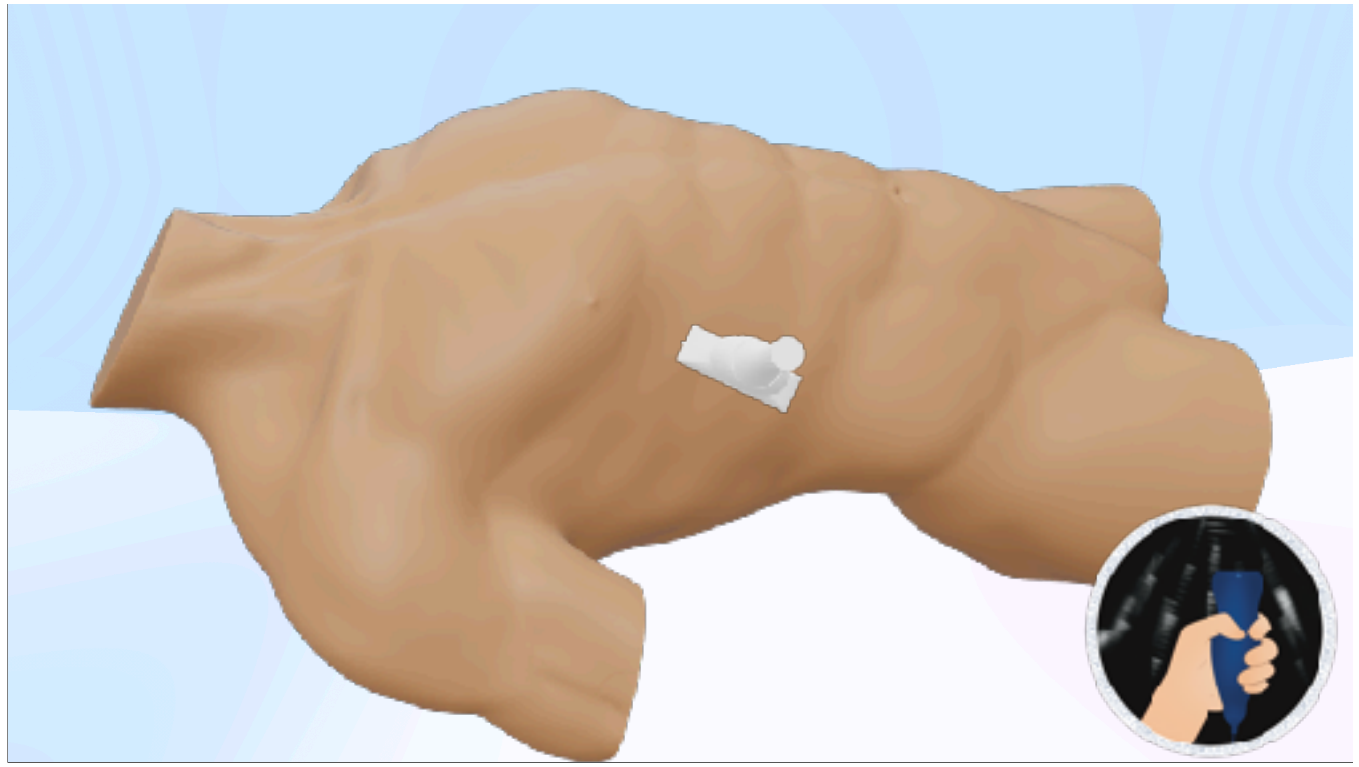
With the left kidney, things are slightly different. The left kidney is higher than the right, and we will have more rib shadows to contend with. Also, the spleen is a smaller organ and provides fewer acoustic windows. The left kidney can also be surrounded by colonic bowel, which may compromise its evaluation.



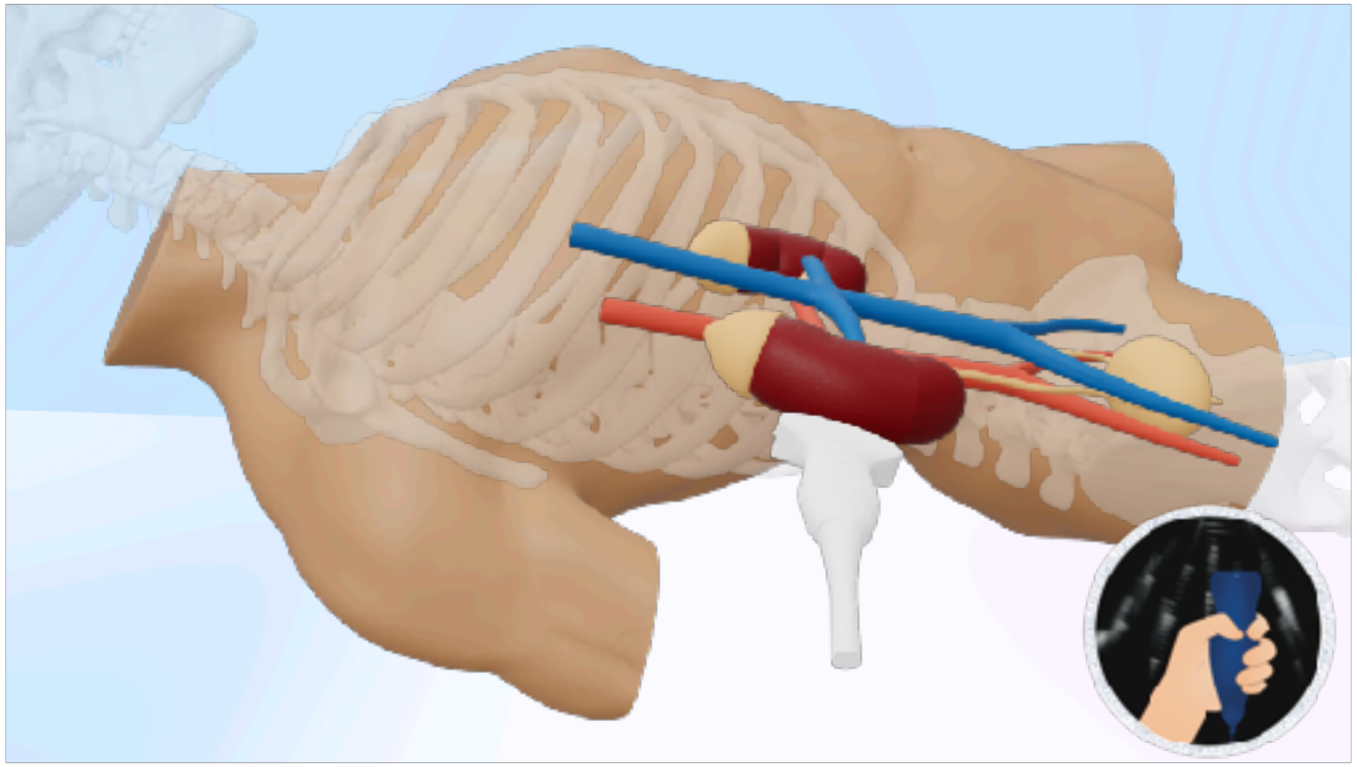
To evaluate the kidneys, one can use different transducers depending on the patient.
Usually, in children and very thin people, a linear transducer can be adequate and provide high-definition imaging of the kidney.
In adults, however, we will use lower-frequency probes, such as the phased-array and curved linear probes.
The phased-array transducer has a small footprint, making it ideal for evaluating kidneys through the ribs.
The curvilinear probe has a larger footprint; however, we need to account for the patient's acoustic shadows and position the probe accordingly. We need to evaluate the kidney using different views to better understand the anatomy with this probe.



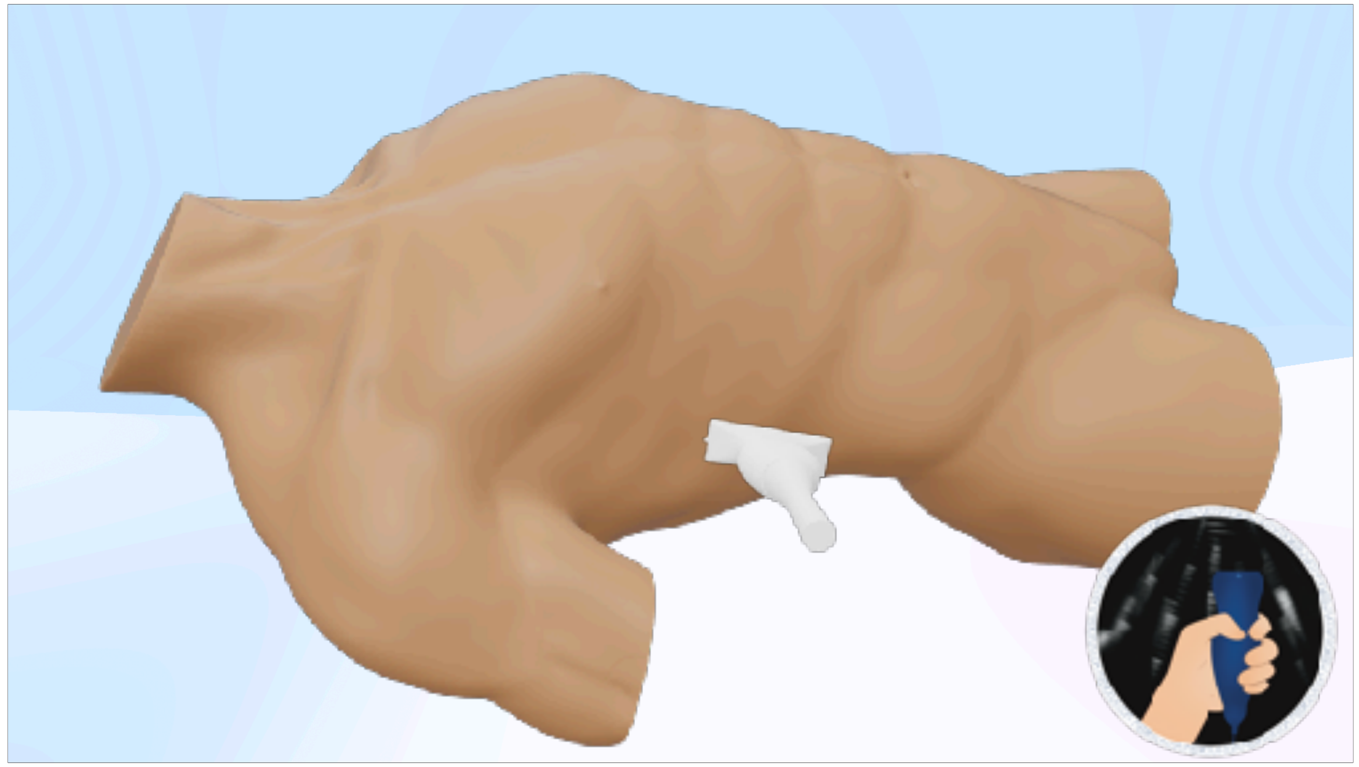
Here, we see an initial position to locate the right kidney.
As you see, the probe is in the middle part of the trunk. This view will usually get you a long-axis kidney.
As you find the kidney, you can use different planes to evaluate it

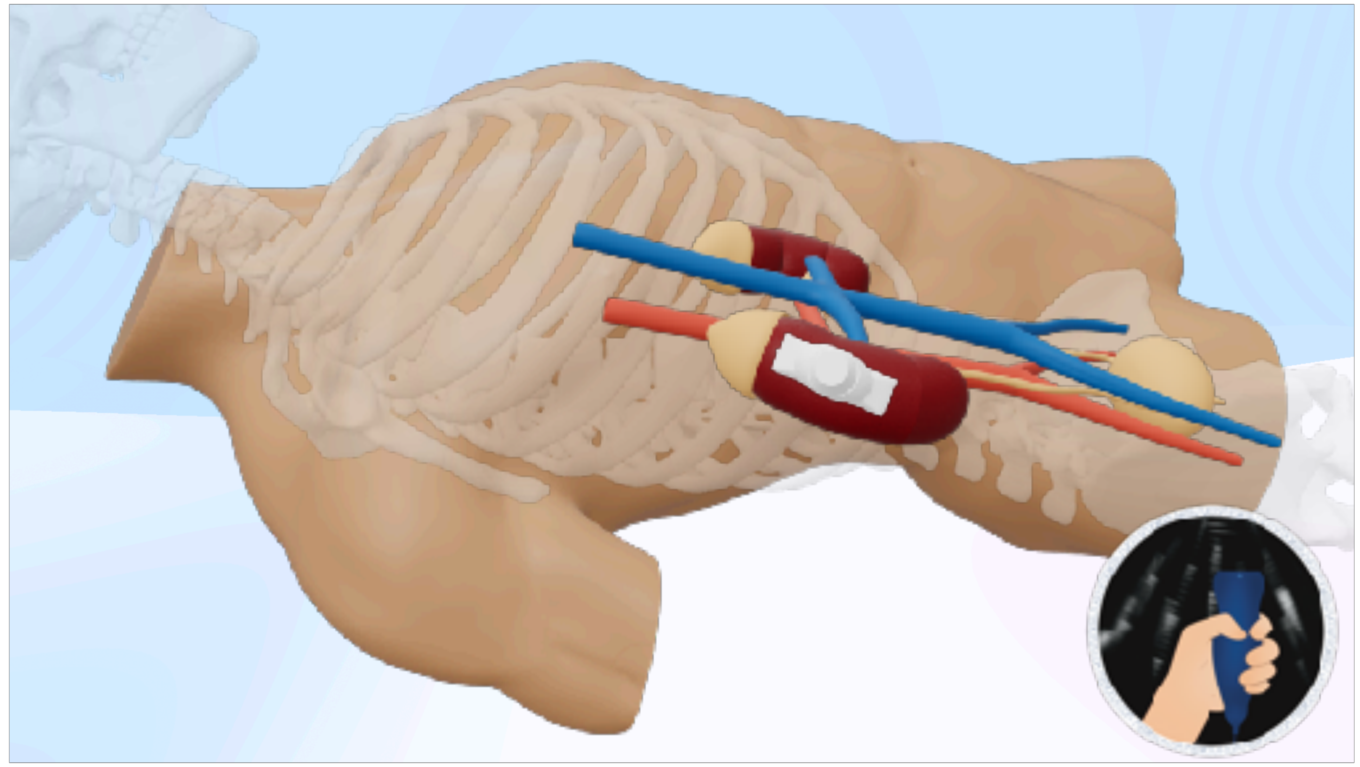


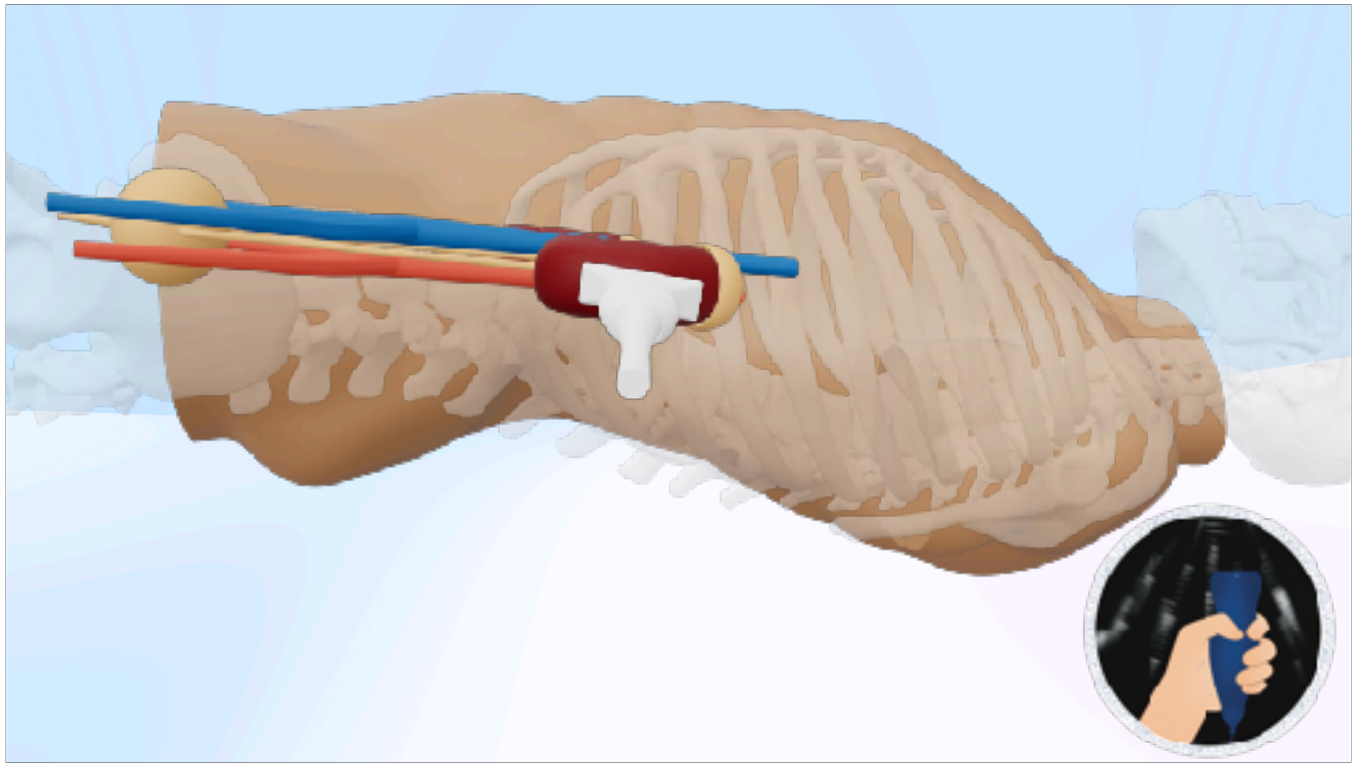
This position will usually give you a better visualization of the Morrison´s pouch.



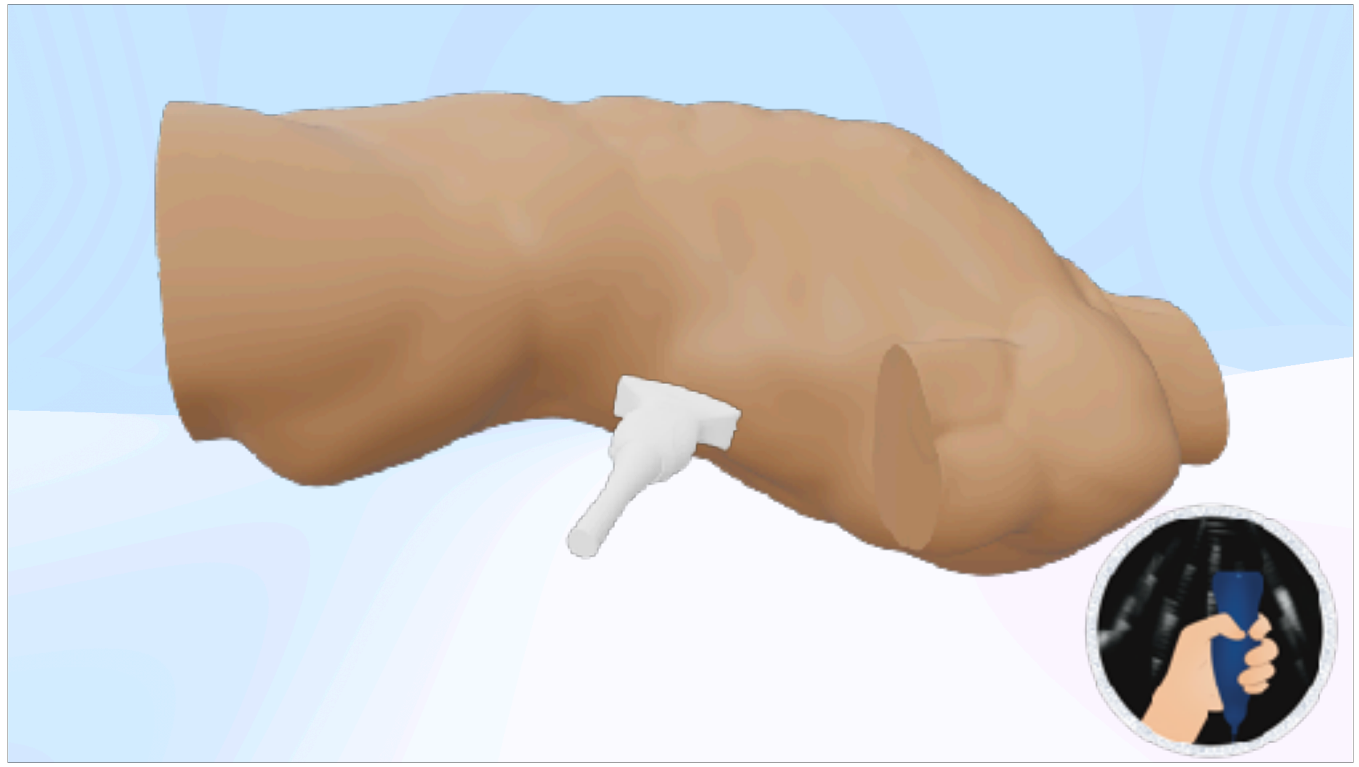
Here you can see how the position of the probe looks for the kidney



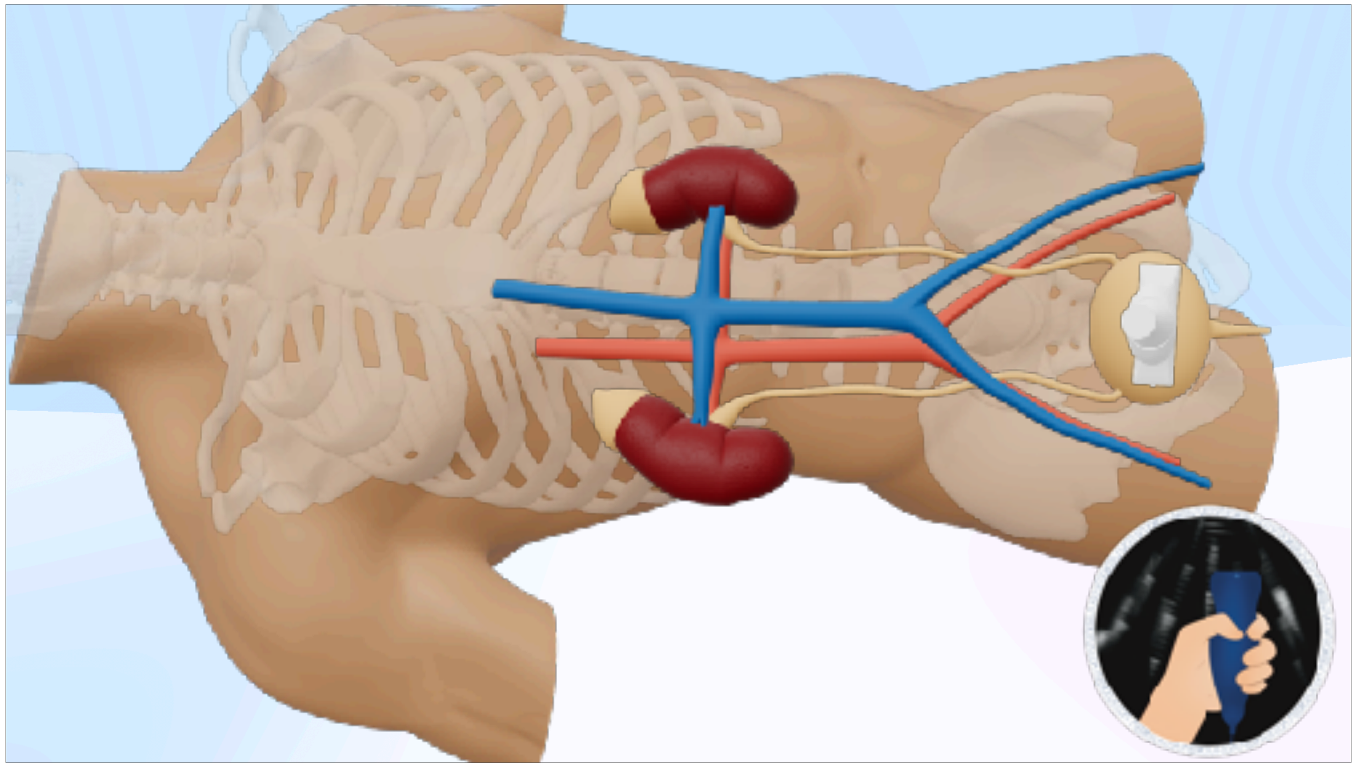




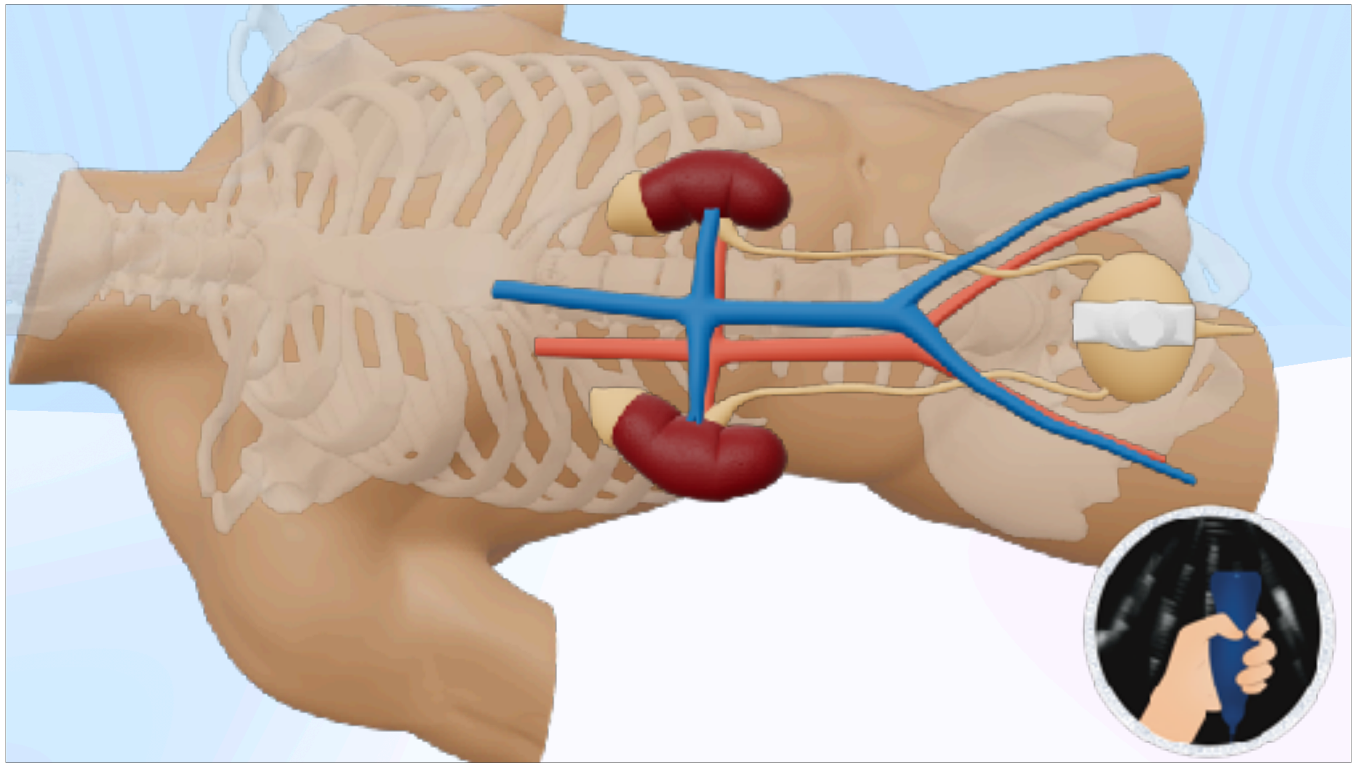
For the left kidney, aim for a higher intercostal space and rotate the probe so the base is more proximally oriented toward the front for the best results.
Always evaluate the kidney in different planes.
The longitudinal axis is the most important for internists.
The radiology team should perform the full evaluation of the kidney.



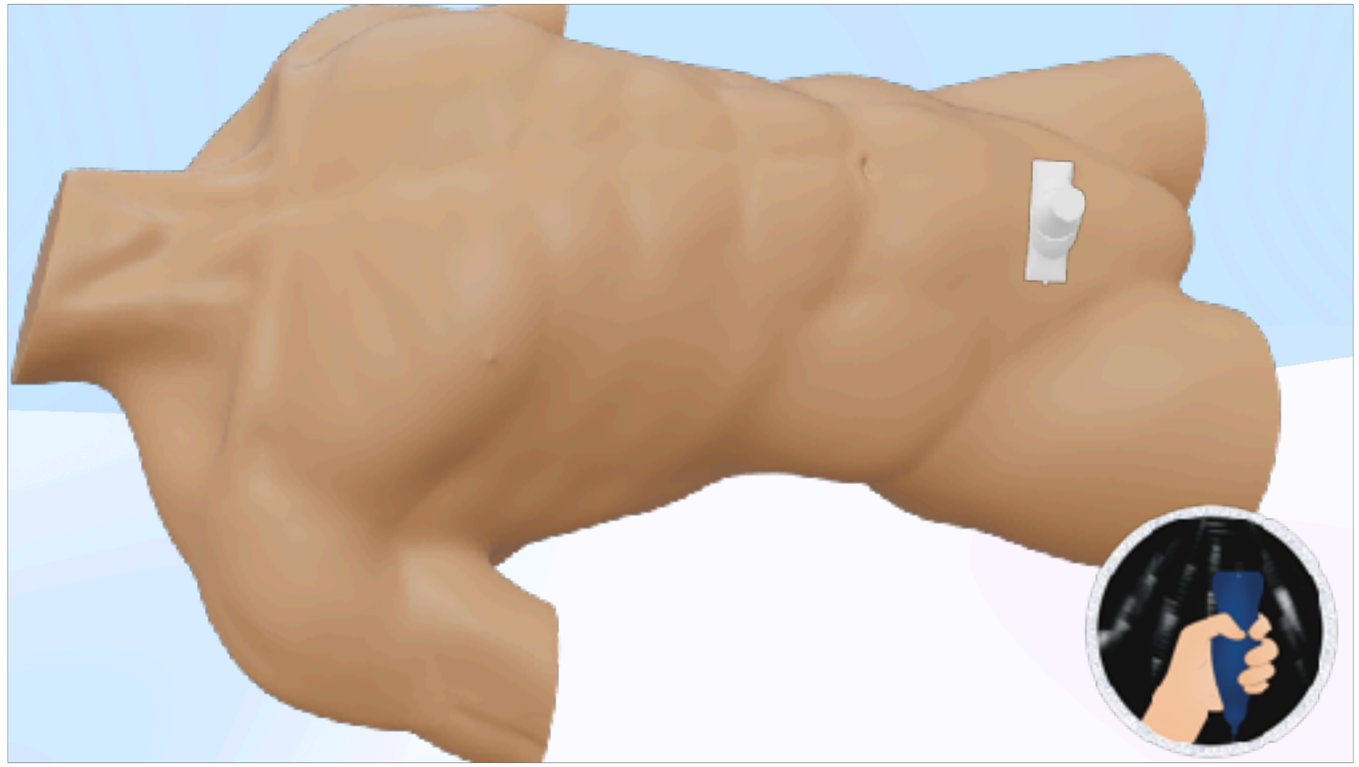
Here an initial position to look for the left kidney. The Probe indicator is cephalad and the transducer is slightly tilted.



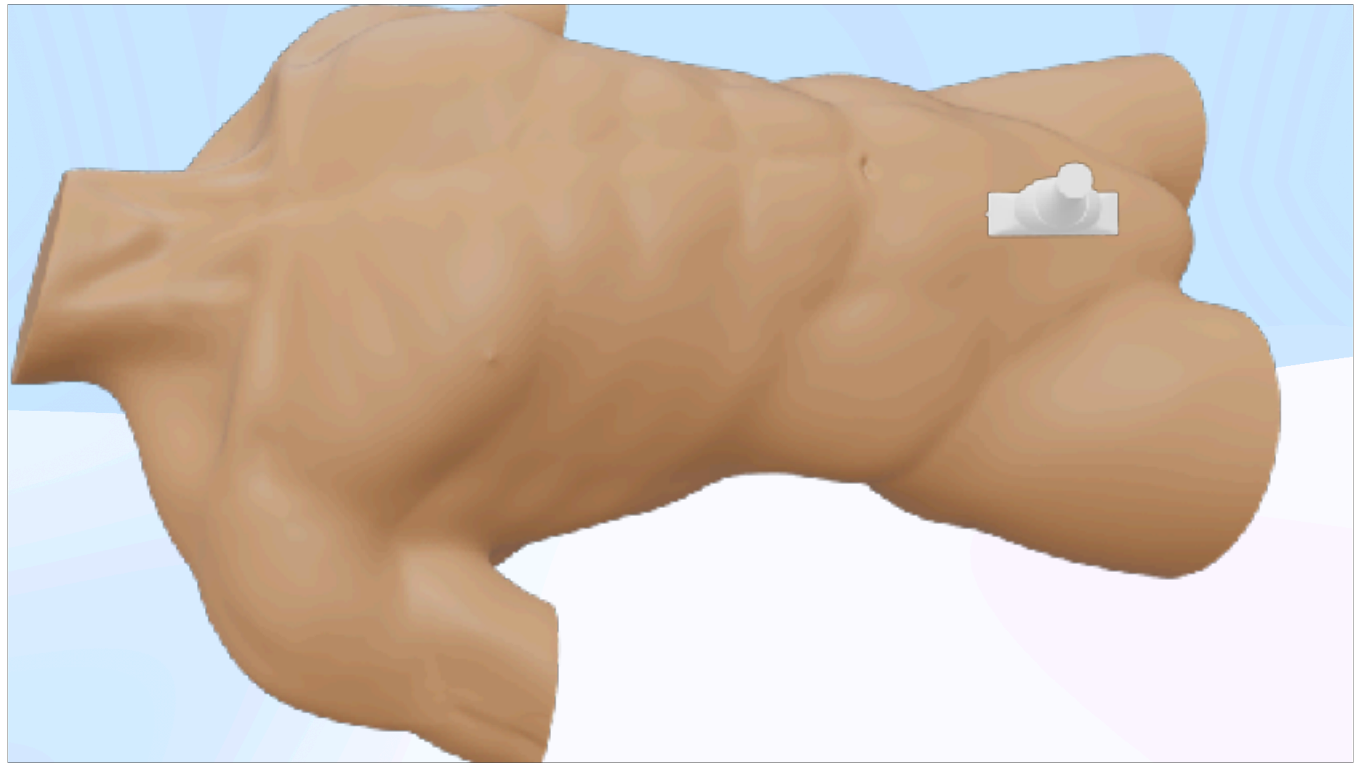
The urinary bladder should be evaluated full if possible and in two different axis. The transverse as illustrated here and



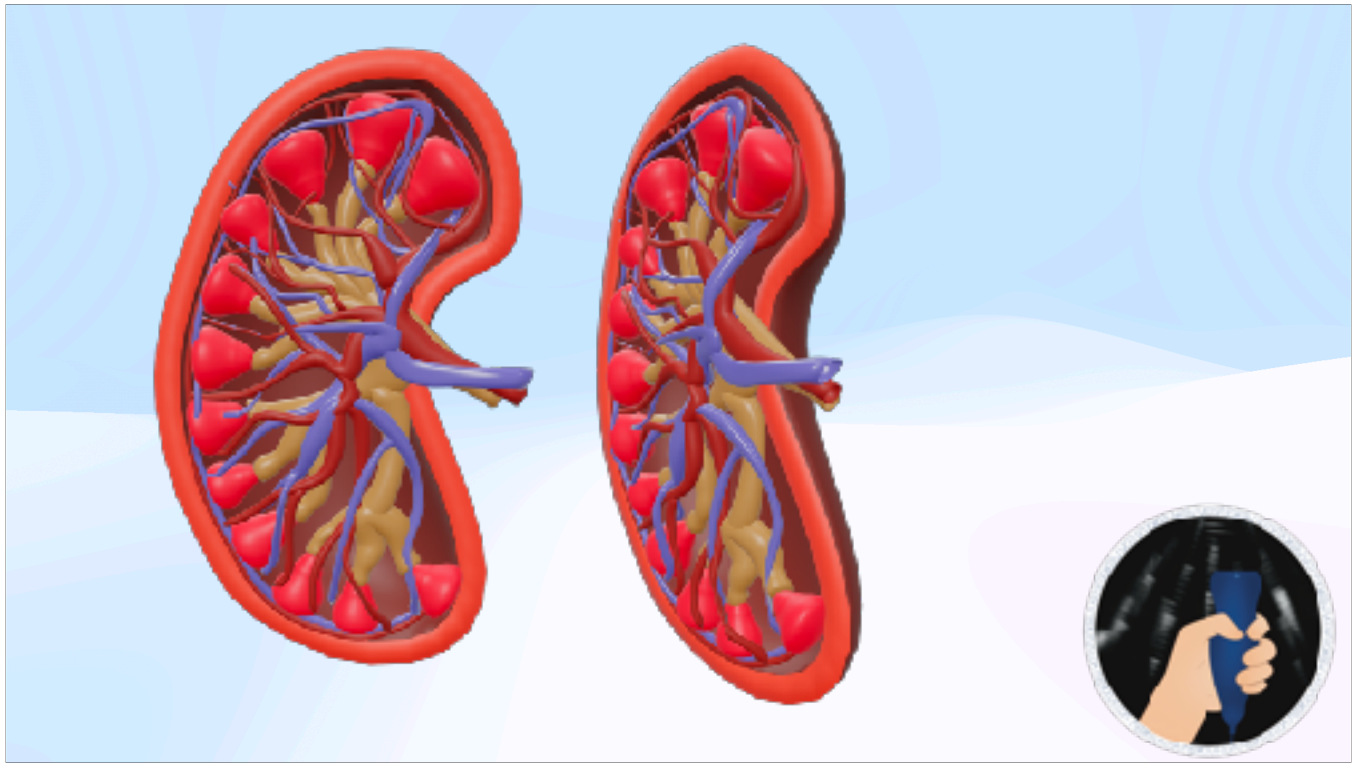
a longitudinal



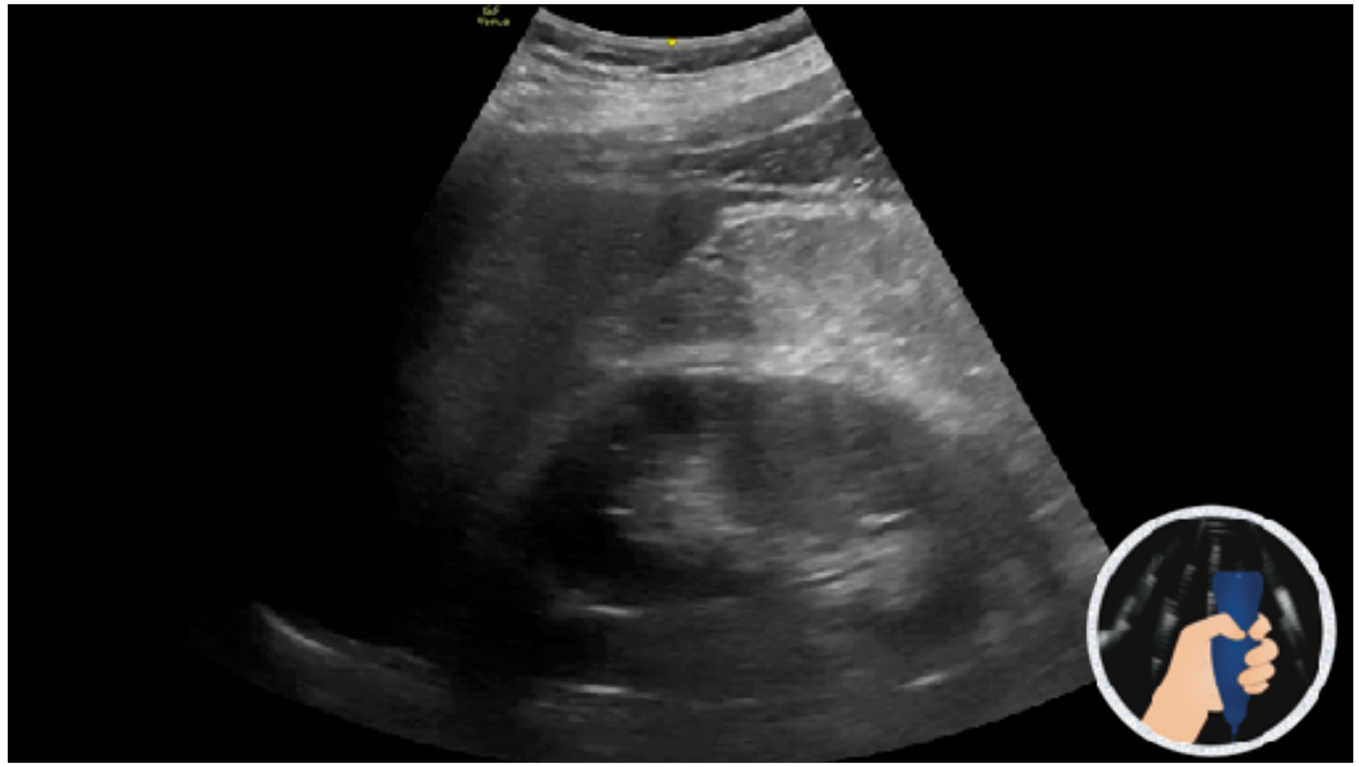
The probe should be placed with the indicator to the right of the patient for an axial or transverse cut of the urinary bladder.



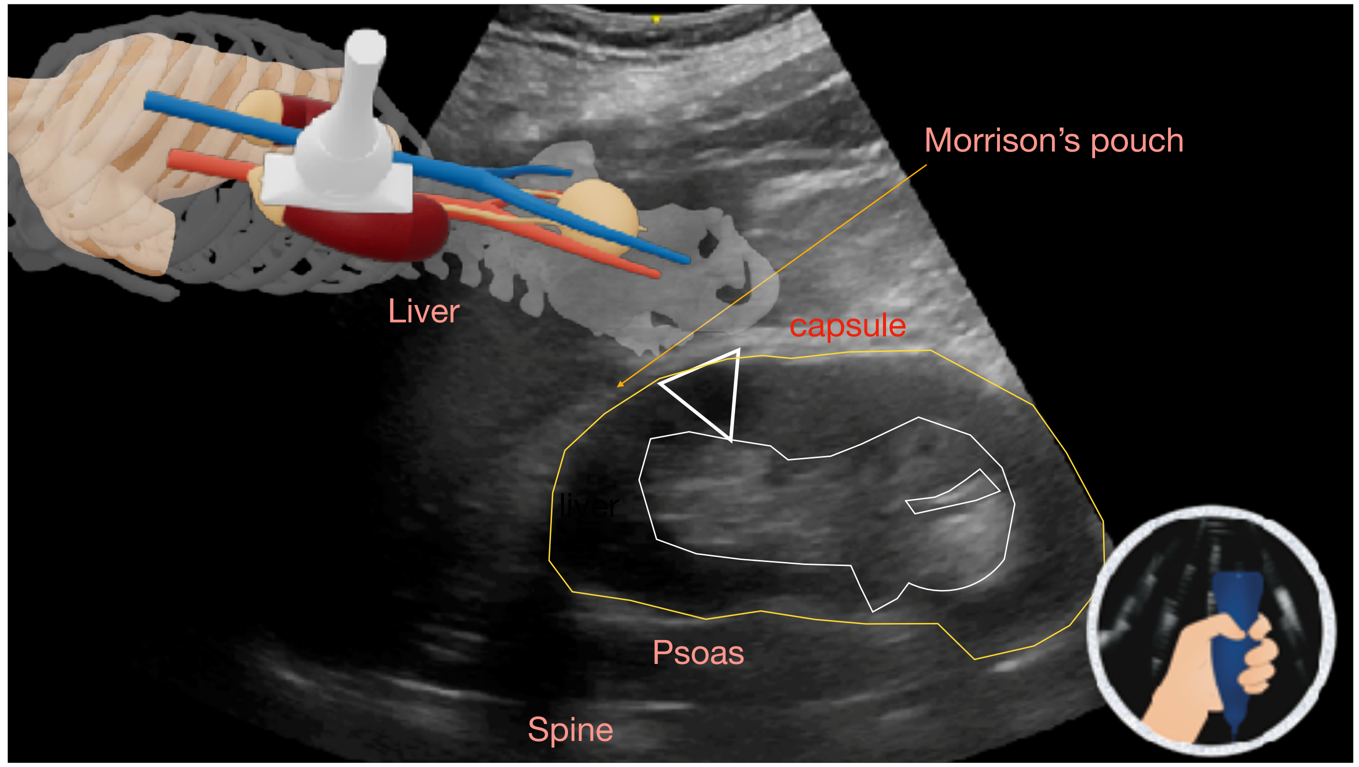
The probe should be placed with the indicator cephalad along the long axis.



This is an interesting illustration that shows the parts of the kidney that have the most fluid. These parts will appear hypo echoic.
Take a look at the pyramids. You can see that indeed these are cone/shaped/pyramid shaped structures.
The veins, arteries, collector tubes, renal pelvis are tube 3D structures that require us to think in a 3 D shape structure.

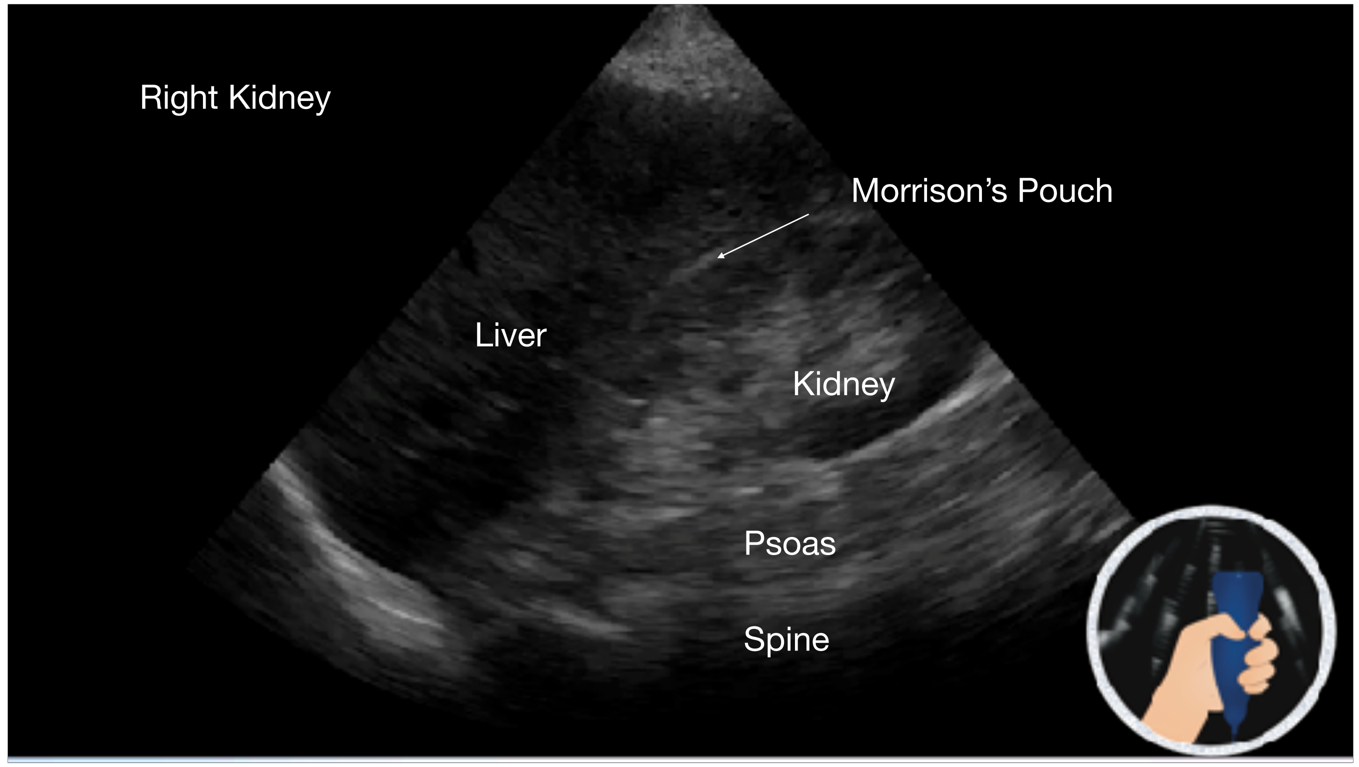


Here we see a video of a normal right kidney. Please take a moment to see all structures.

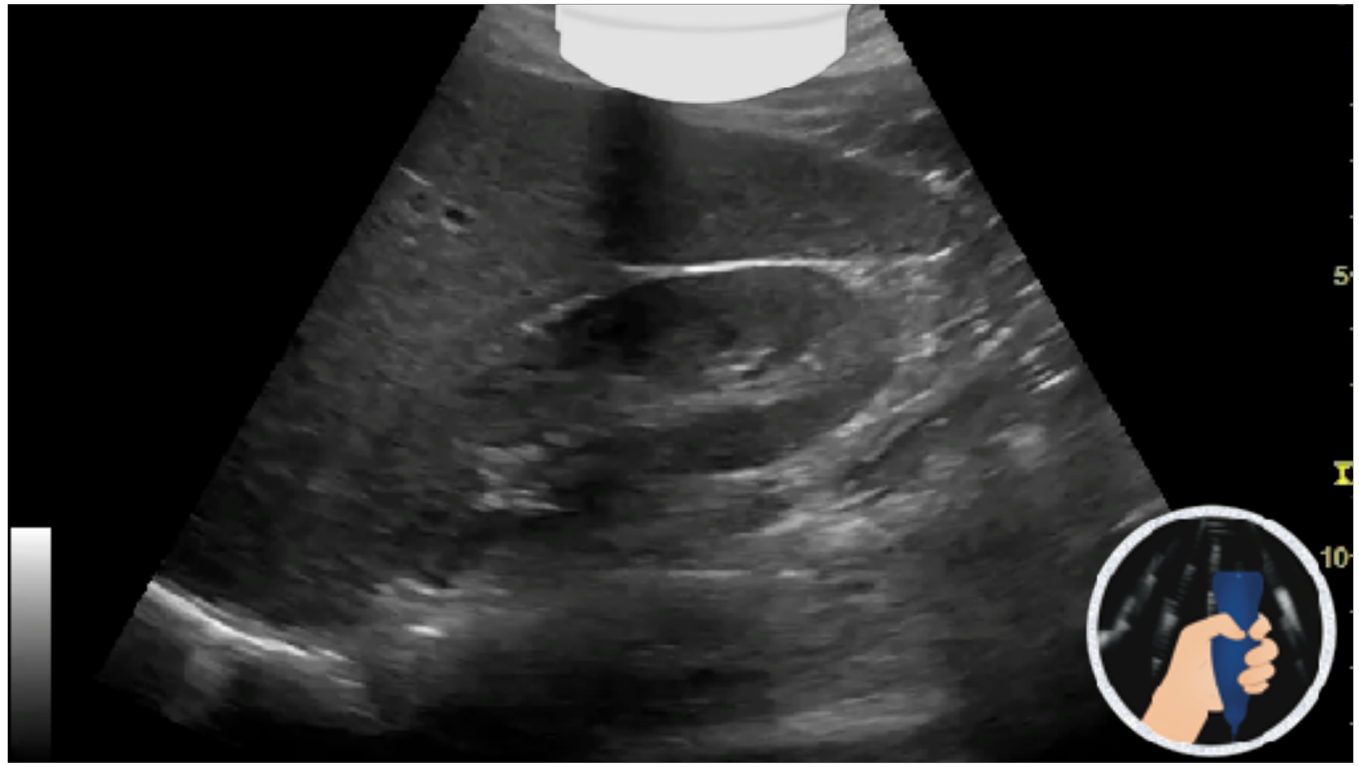


The approximate position of the probe is shown.
We can se the whole kidney from the upper pole which is near the liver, to the lower pole. The Kidney has a capsule. The cortex is very hypo echoic. The Medulla shows is hyper echoic thanks to the fat and fibrous tissue that supports the kidney.
The triangle is a very easy to see pyramid. There is a structure that is a collector tube or an artery.
We do not see the pelvis or the ureter.
Surrounding the kidney you can see the Morrison's Pouch which is a potential space that can harbor abdominal fluid such as ascites.
In the far field you see the Psoas and the spine.
Take a moment to see all the structures.

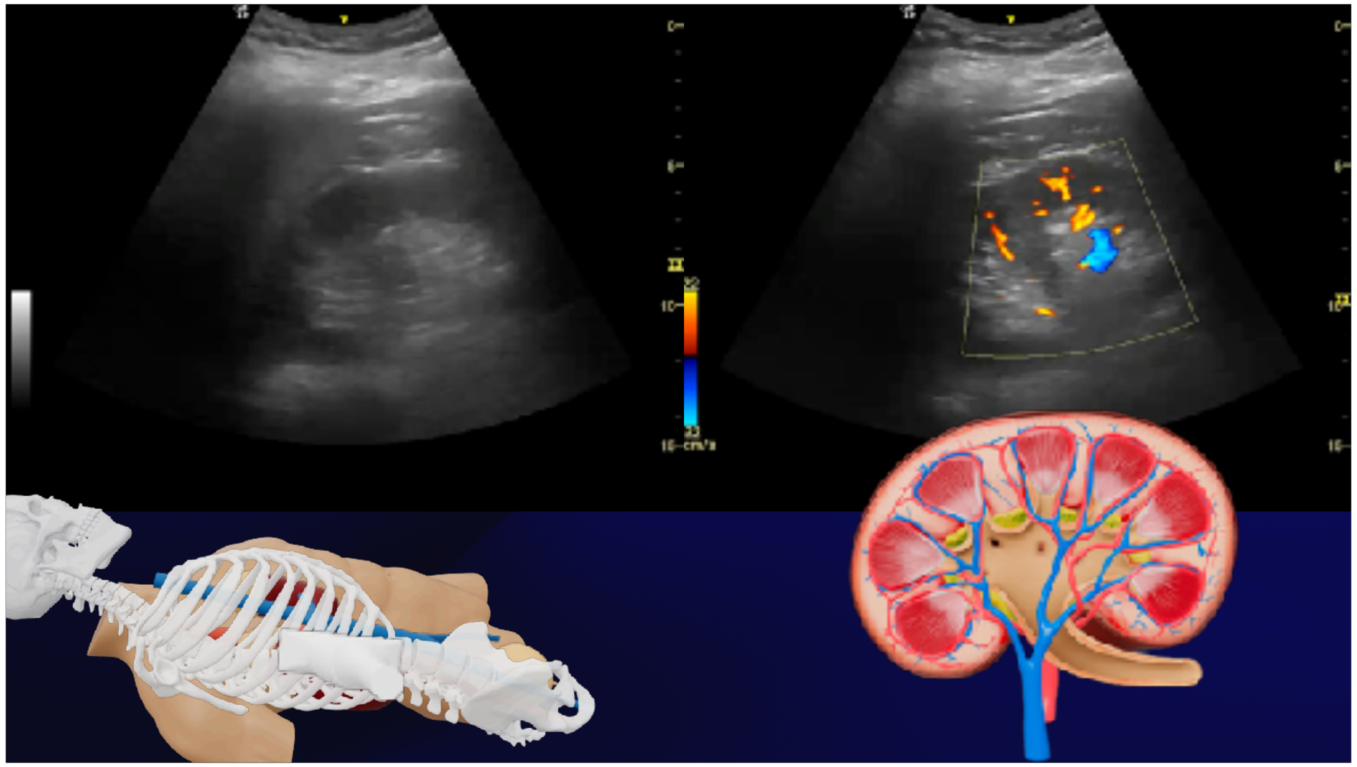
We can see the liver, Morrison´s pouch without fluid, the spine, and the psoas muscle.
The triangle demonstrates one of the pyramids.
Please take a moment to see all the structures



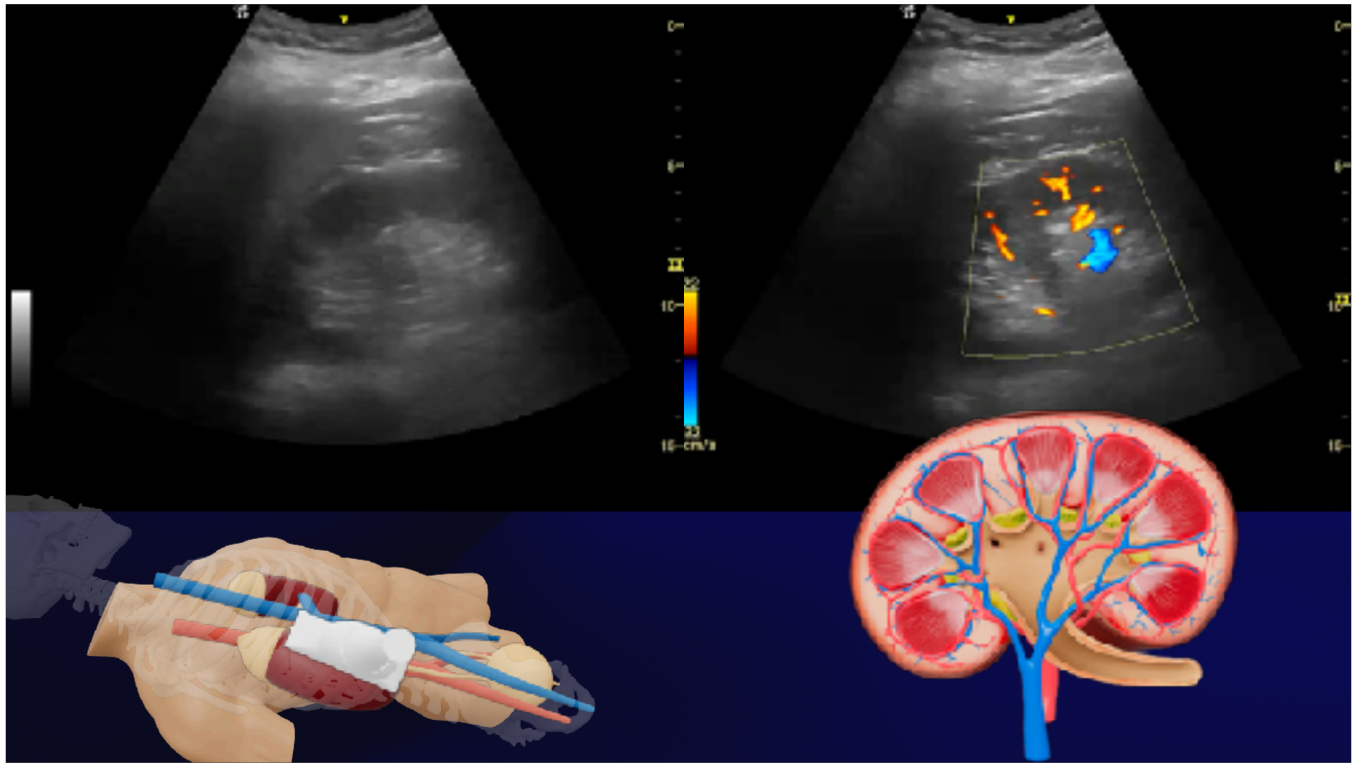
In this slide we see another kidney obtained with a phased array transducer. This is a projection from the left anterior axillary line is ideal to rule out fluid in the Morrison`s pouch. Gives a good view of the kidney itself. In this projection we use the full potential of the liver as ultrasound window.



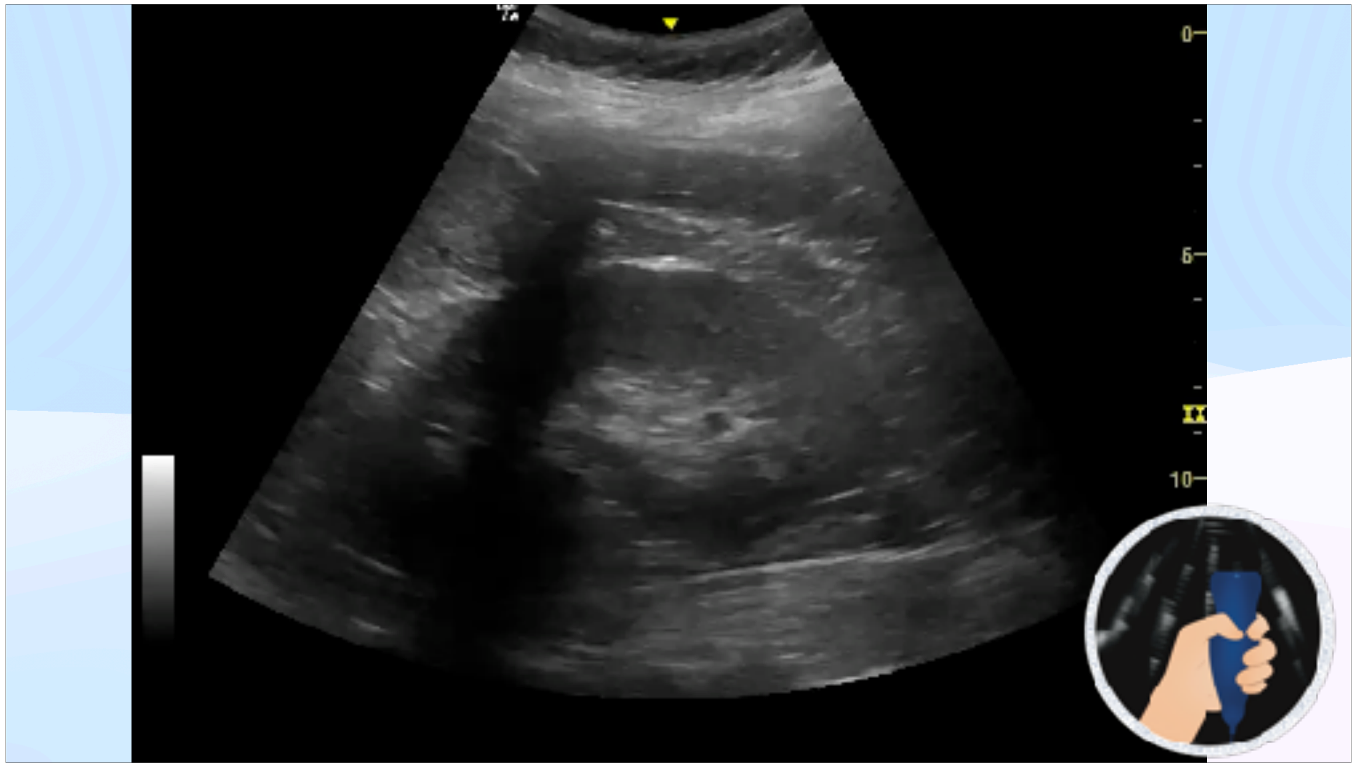
This is an image very similar to the prior one, but obtained with a curvilinear probe.



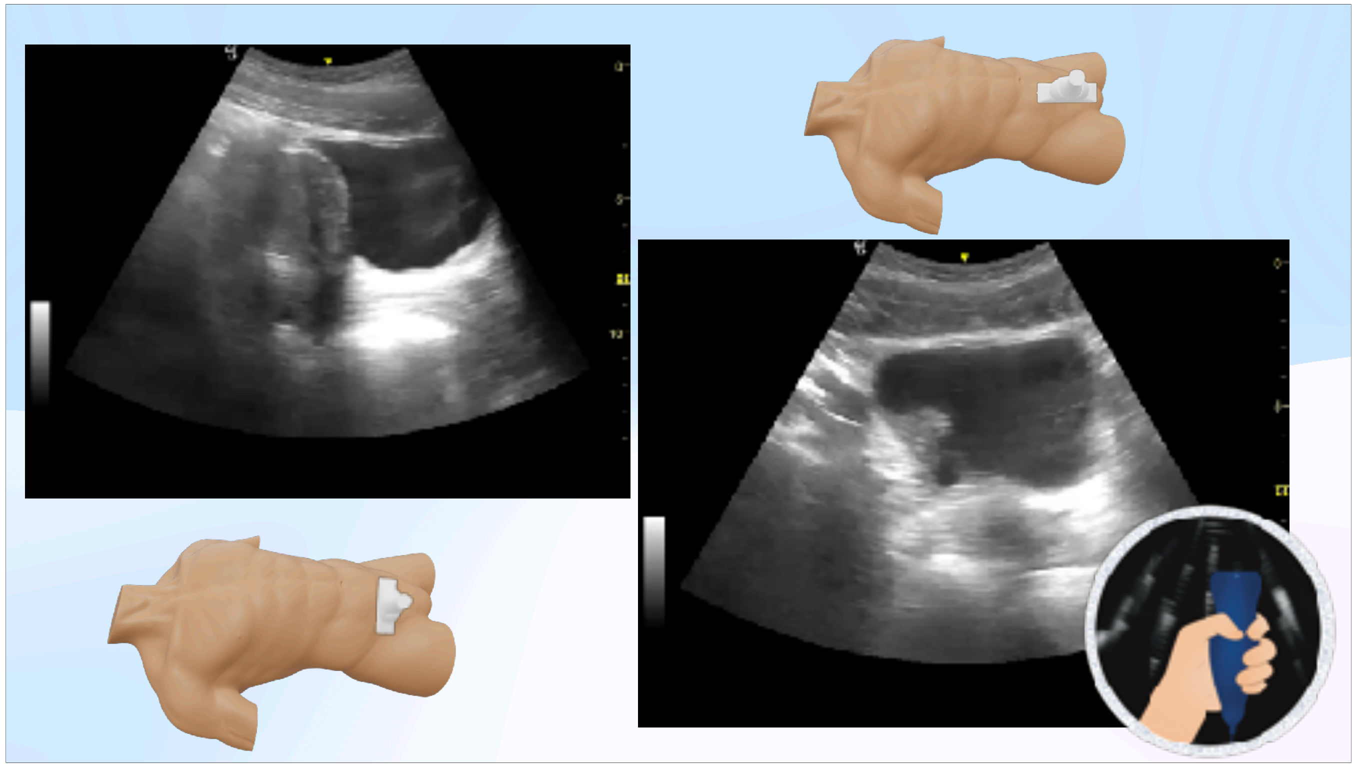
This is a more lateral approach taken from the middle axillary line and below the ribs showing a longitudinal cut. I have added color Doppler so we can see the interstitial vessels.



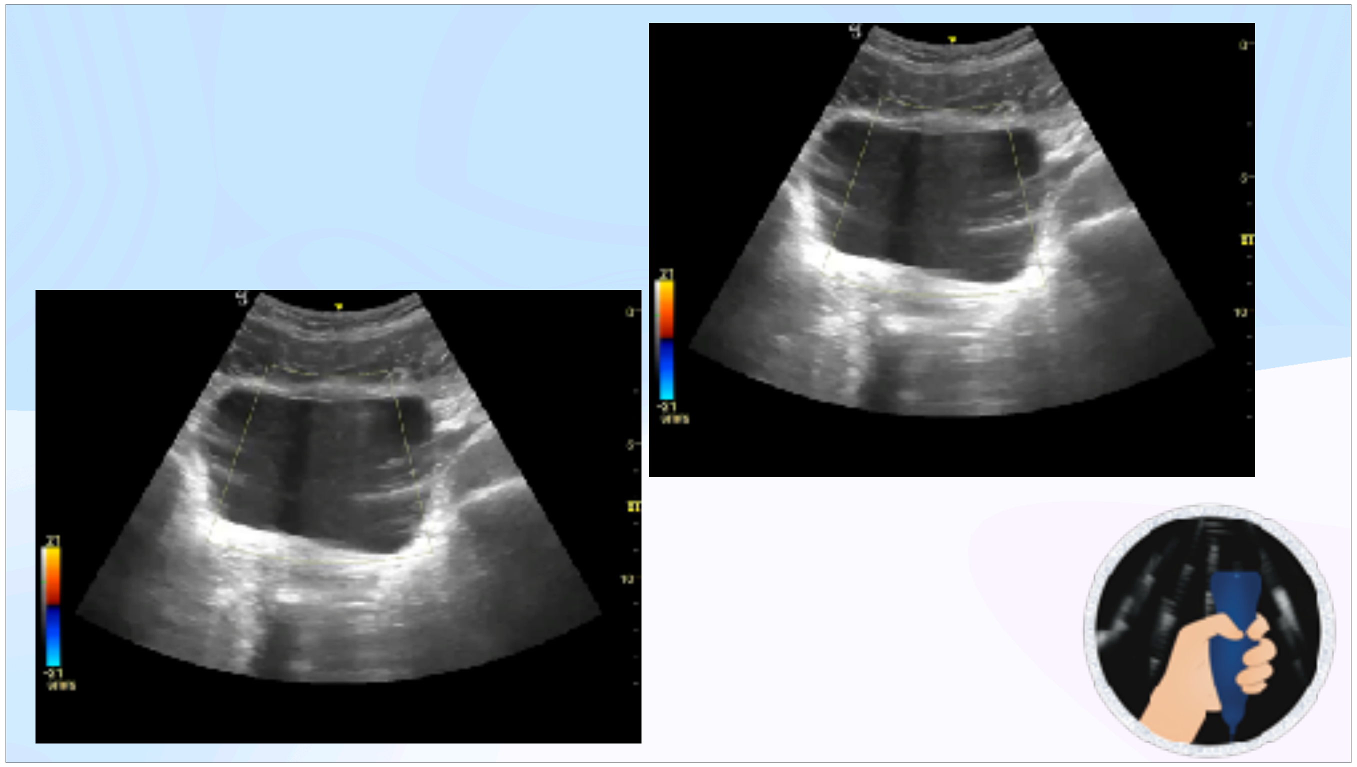
Now we see the probe on top of the kidney without the skeleton.
It is very important to set the Doppler velocity and the sensitivity (gain) when evaluating the kidneys. In this case, we have used 22 cm/s.
In normal circumstances, the ureter should not be visualized.



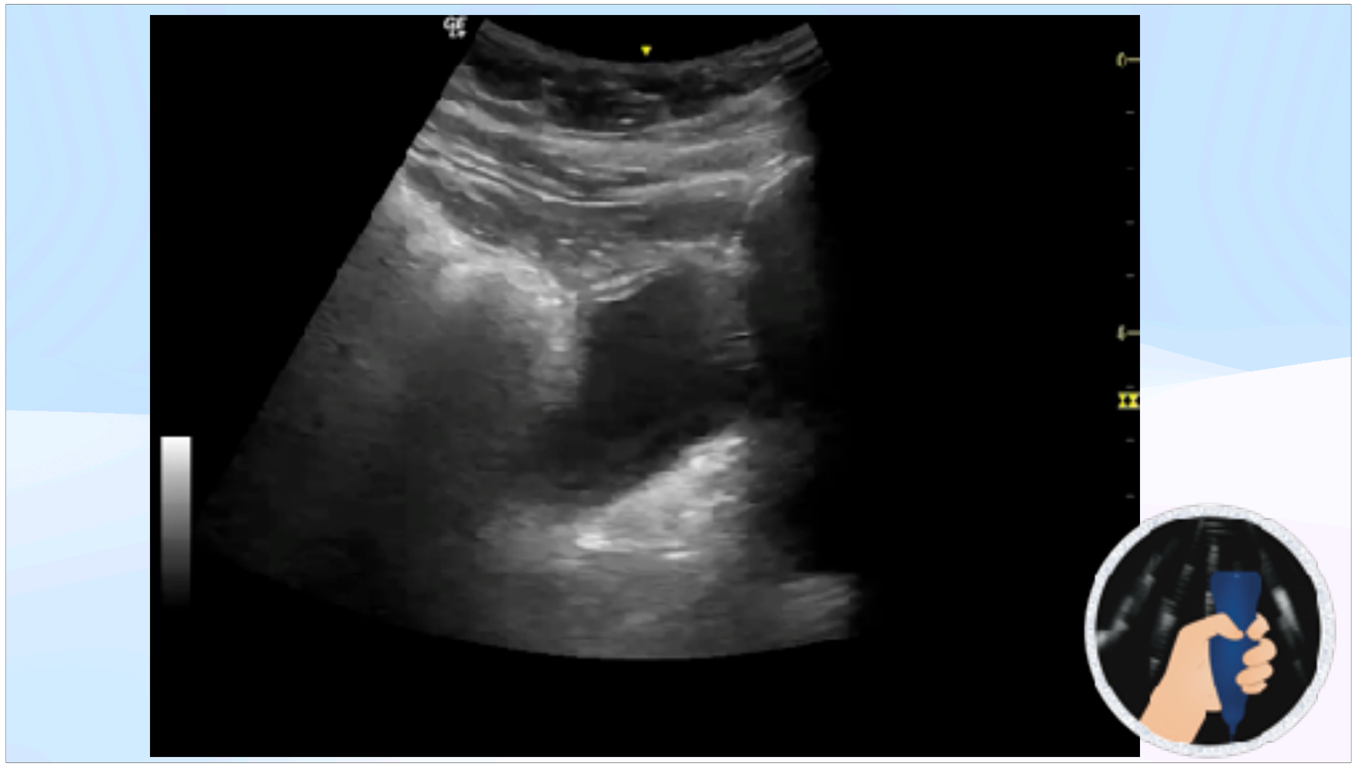
In this slide, you can see the left kidney, which is slightly higher than the right kidney because of the spleen. The spleen is a small structure compared to the liver. It is easy to see the capsule, cortex, medulla, and the renal pelvis, as well as Many Other structures. The Psoas is noted in the far Field. It is also noted that a rib is causing an acoustic shadow.



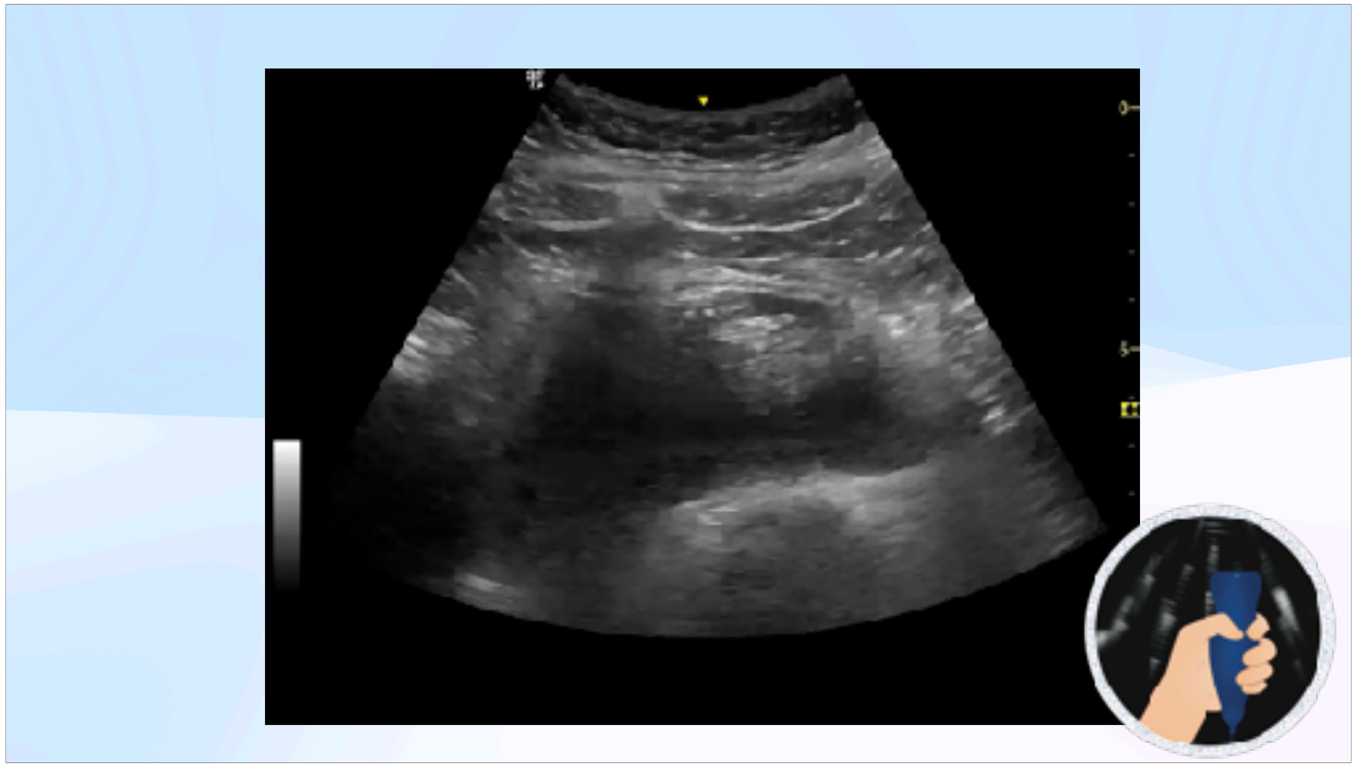
The urinary bladder evaluation consists of obtaining a longitudinal and transverse axis.
On your left-hand side, you will see a longitudinal axis of the female bladder. The structure you can see to your left is the uterus. This bladder is full and normal. There is some reverberation.
Also you can see acoustic enhancement in the far field, a common phenomenon due to the ultrasound low attenuation of the urine.
Changing the axis of your evaluation, you will find that the transverse view of the bladder is normal for the same patient. Obtaining these images is critical, as they can help diagnose various ailments. This is a female patient, and the uterus is evident in the upper ultrasound.
The longitudinal view of the bladder differs significantly from the sagittal view. Using your ultrasound settings, you can also measure the amount of urine present.



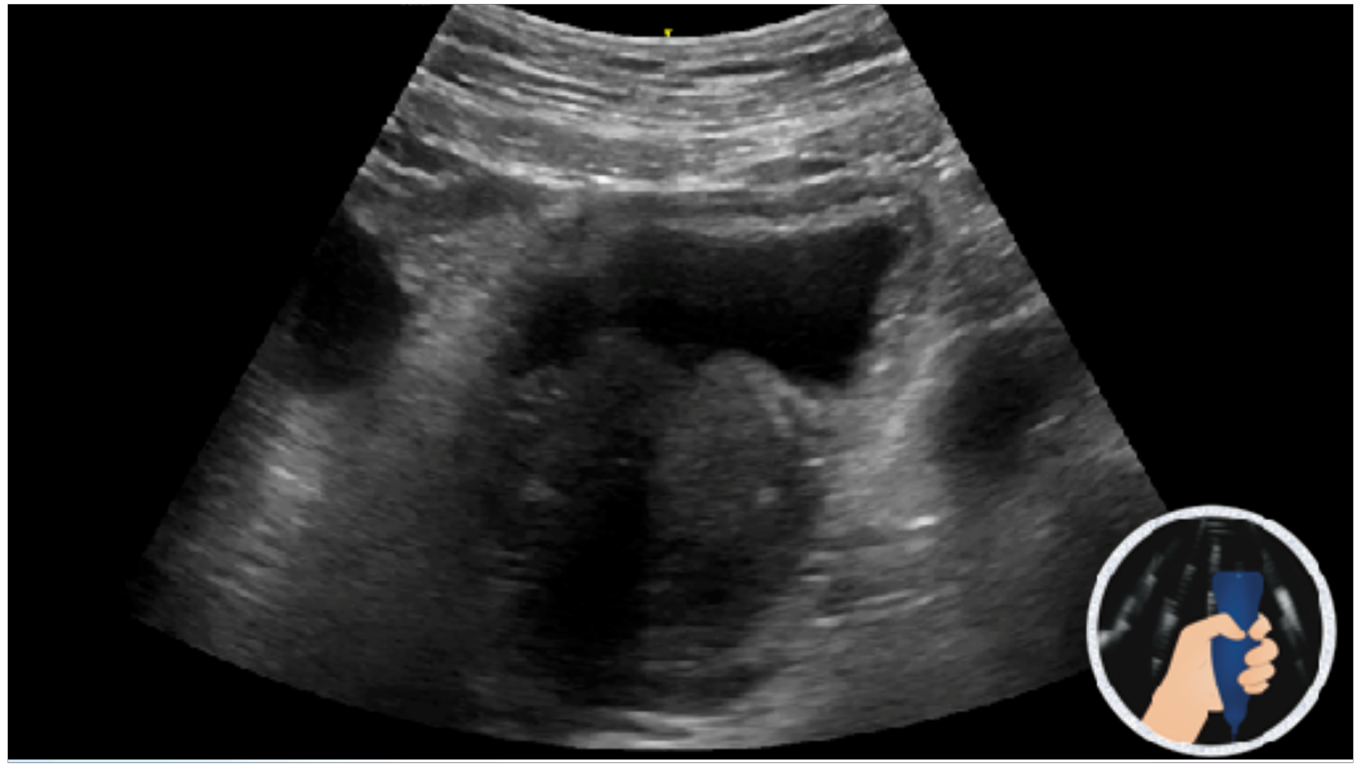
In this transverse view the bladder, we can see the Doppler signal from each ureter. The presence of this Doppler is a good indication that the ureters are patent and that your patient is producing urine. Please take a second to notice the Doppler from the base of both images, one pointing to the right and the other to the left. The lack of these jets may indicate that a ureter is blocked. Sometimes you will need to wait a few minutes to appreciate this dopplers.



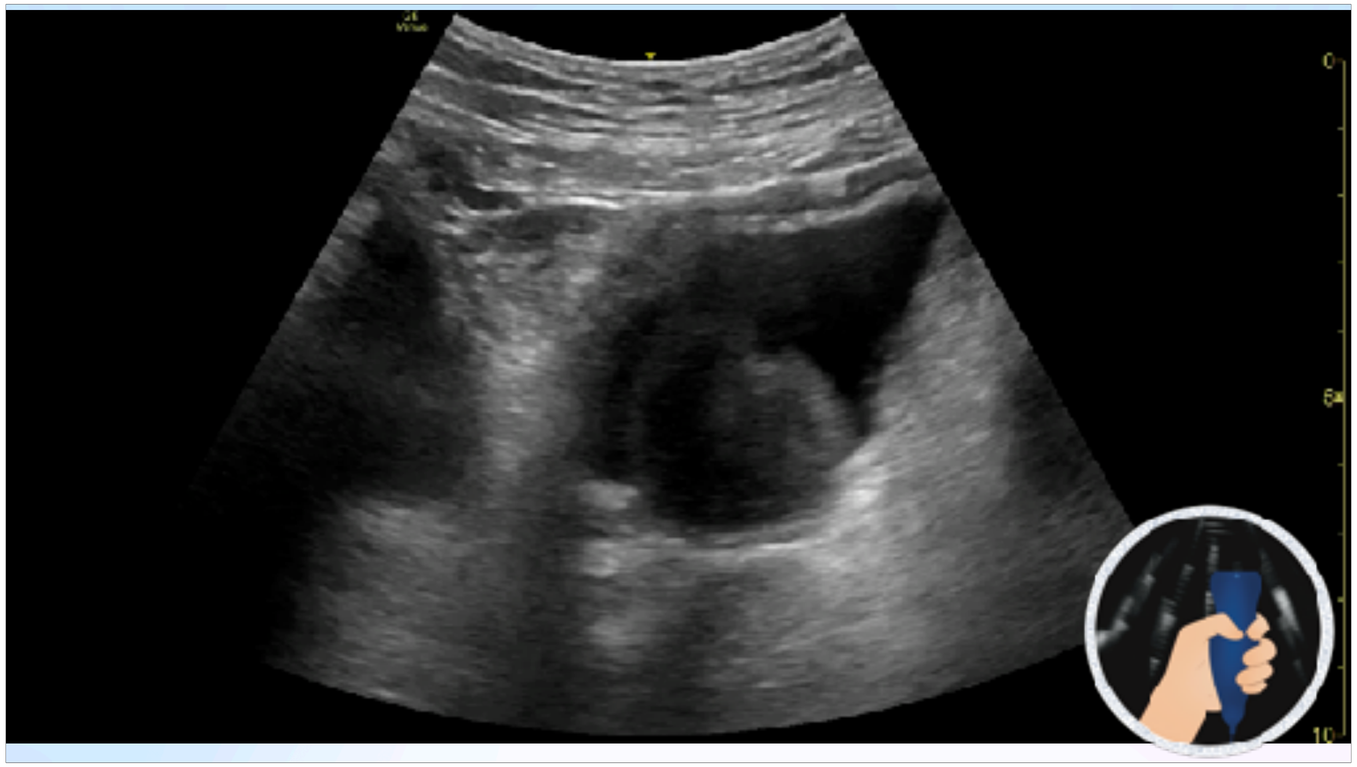
This is a longitudinal view of a bladder. As you can see, the bladder is not full, and it is difficult to see the structures; however, even this ultrasound can give us data.



Same patient, the bladder is not full. There are no foreign bodies and or gross abnormalities.



This is a transverse imaging of a male bladder. You can see a large bilobulated structure in the middle field. This is secondary benign prostatic hyperplasia. This patient was having symptoms of urinary tenesmus and strain.



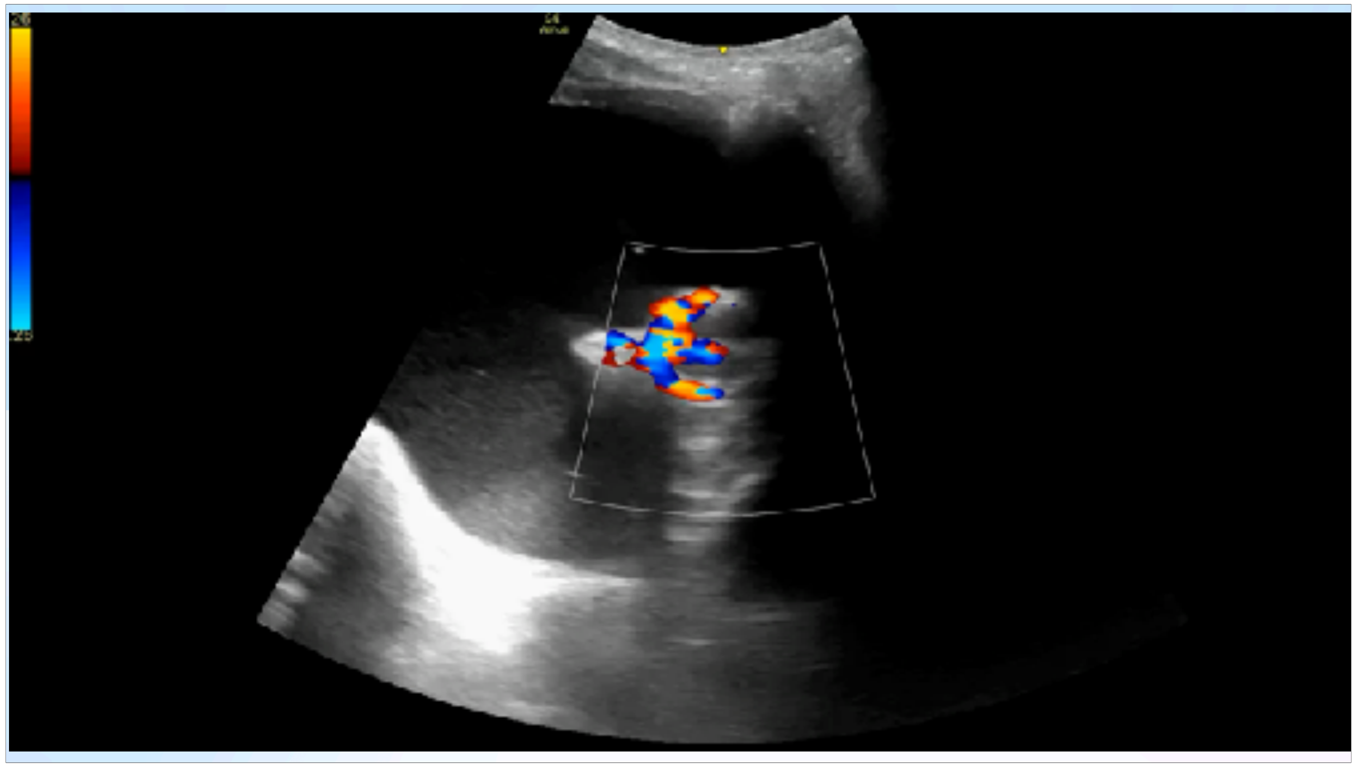
The longitudinal evaluation shows the prostate protruding into the urinary bladder. This patient was treated with an alpha blocker and referred to a urologist.

This is a patient who was evaluated because of an altered mental status. The patient's bloodwork was normal. The patient was an elderly male who was unable to provide any symptoms. The physical examination documented was unrevealing; however, he had a Foley that was not producing urine.

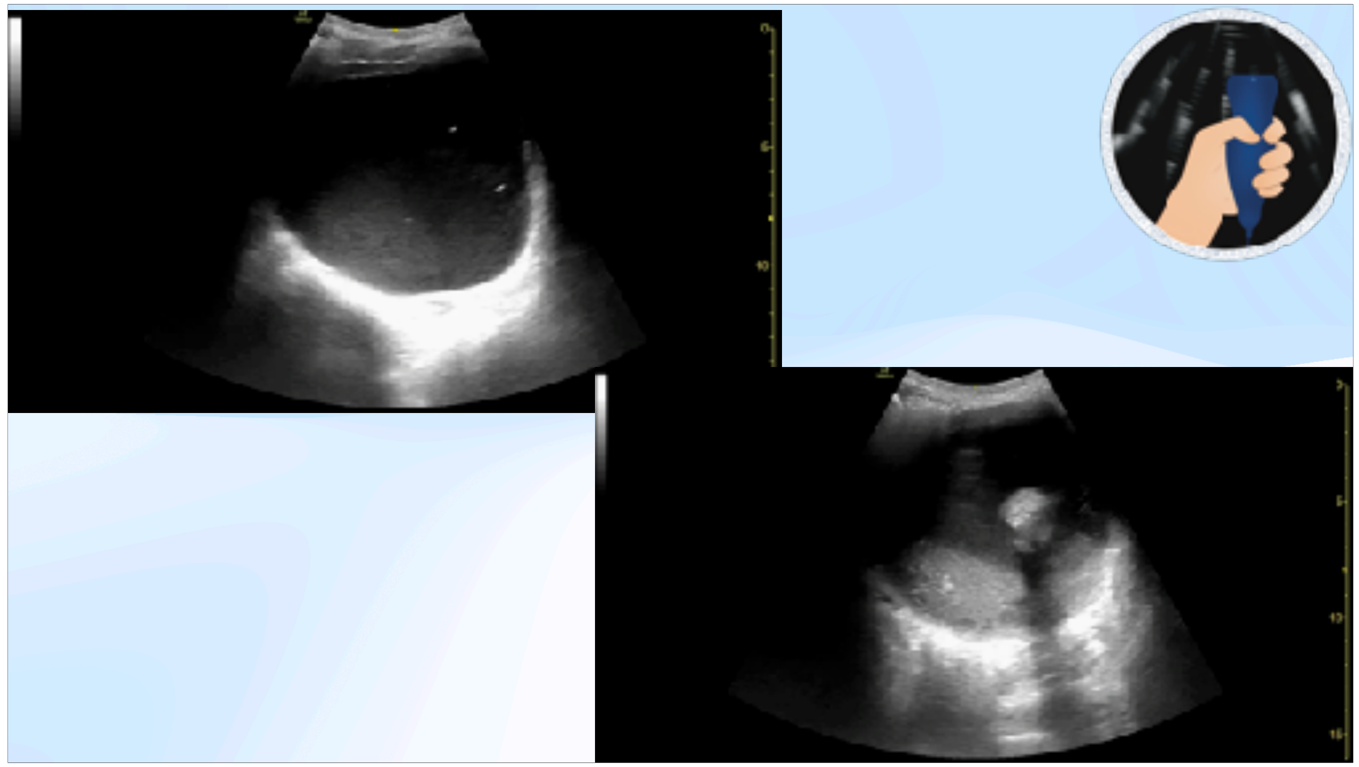
Because of that he was was receiving IV fluids.

A Point-of-care ultrasound was performed, demonstrating a well-placed Foley catheter.

At that moment we believed that the Foley was obstructed and needed to be changed. You can see the Foley right in the center. Of the bladder in longitudinal view. Is the structure in the center that looks like the half of saturn.



This is a useful Doppler artifact when evaluating structures made of plastic or silicone in any cavity. You can see how the Foley reflects or cause Doppler that are not associated to movement. This can be used to evaluate foreign objects within fluid cavities.

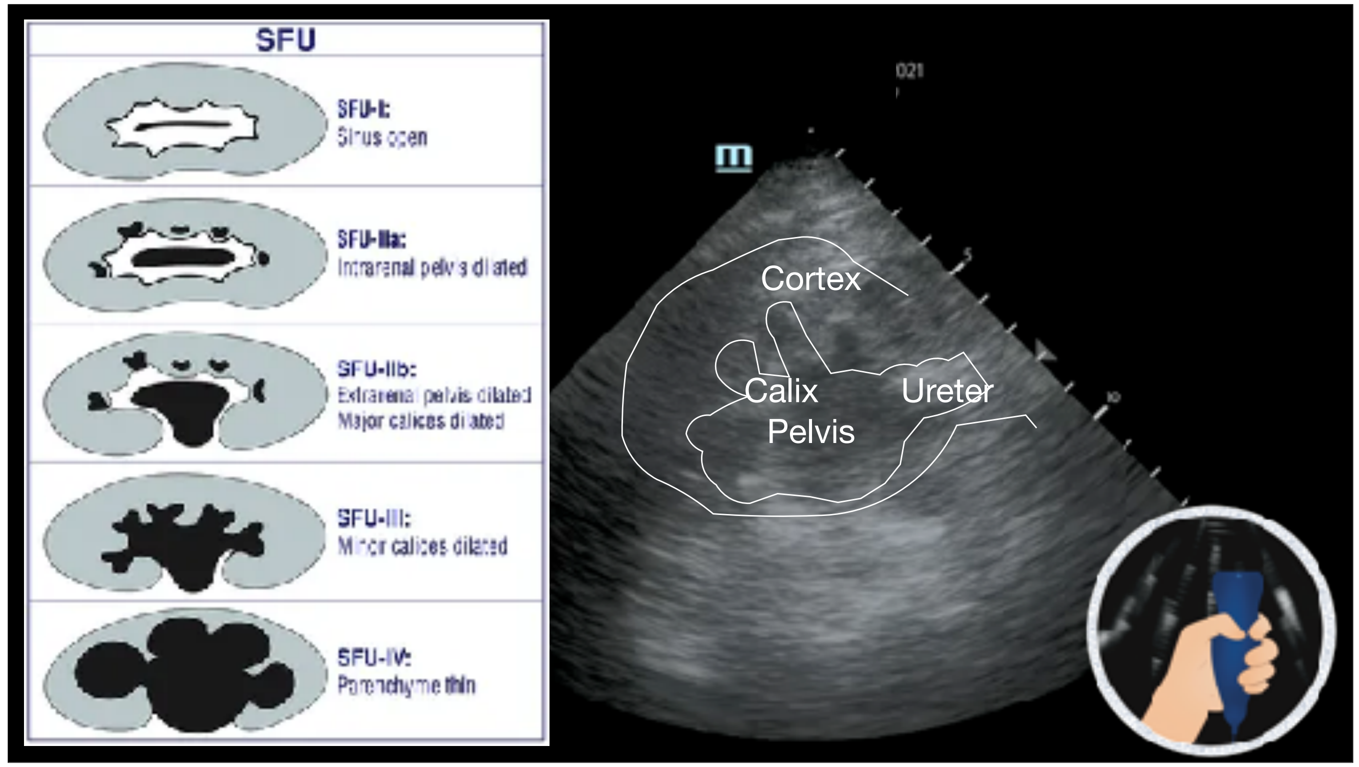


Here, we see the transverse axis of the patient's bladder with the Foley obstruction. You can see a significant amount of debris at the bottom of the urinary bladder. Foley catheter is in the center.

We proceed to change the Foley catheter and drain the urinary bladder. Hours later, our patient was significantly better with no alter mental status any longer. He was treated for a UTI and discharged later on during the day.

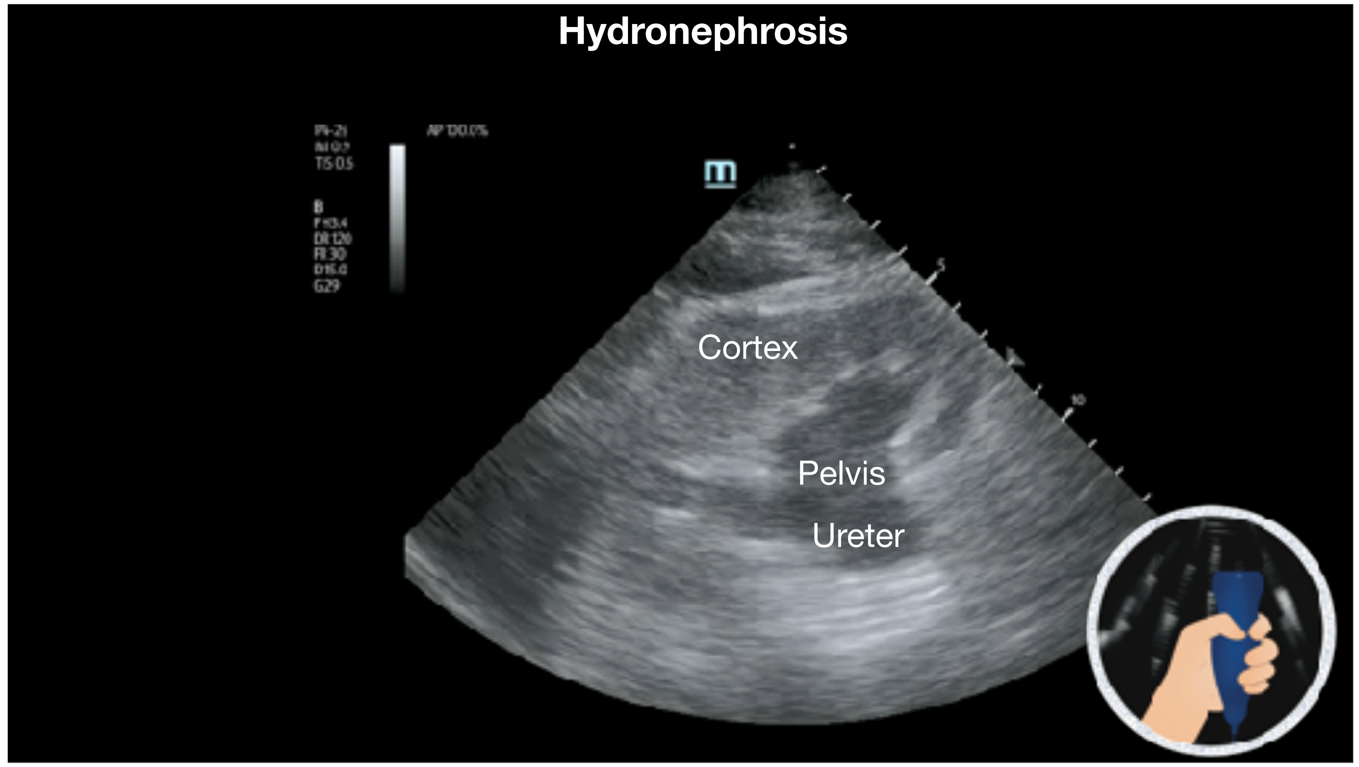
In the lower right you can see the urinary bladder with a significant amount of debris. The foley catheter causing acoustic shadow.

Looking at the past medical encounters, this was not the first encounter that the patient had for a similar problem.

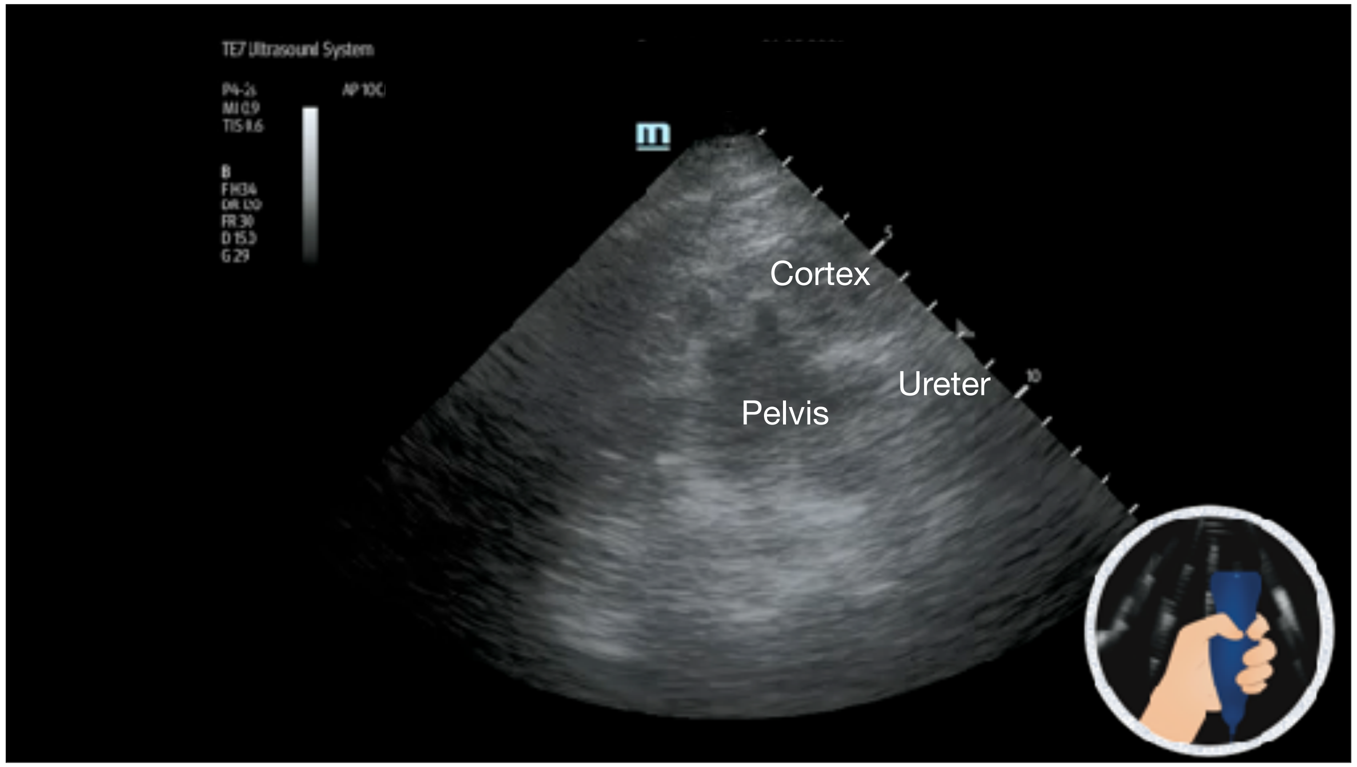


This is a video of an ultrasound of a right kidney of a patient who had right flank pain.
This is a kidney with hydronephrosis. Hydronephrosis is a common finding in the outpatient clinic as well as in inpatients. In this case it was determined that it was secondary to ureterolithiasis.
You can see the dilated calyces, pelvis and ureter, as well as the diminished cortex. If not treated promptly, hydronephrosis may damage the kidney

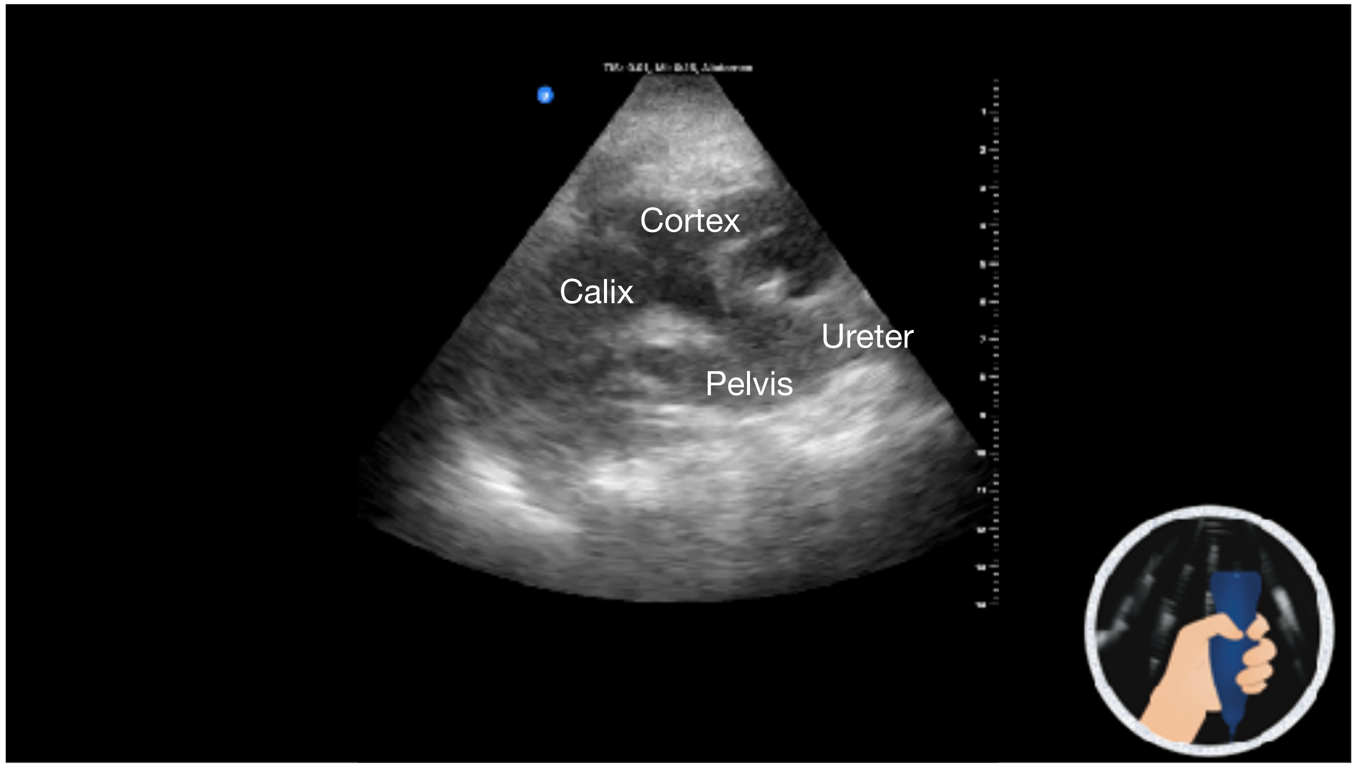
With the video I have attached a visual guide to hydronephrosis.



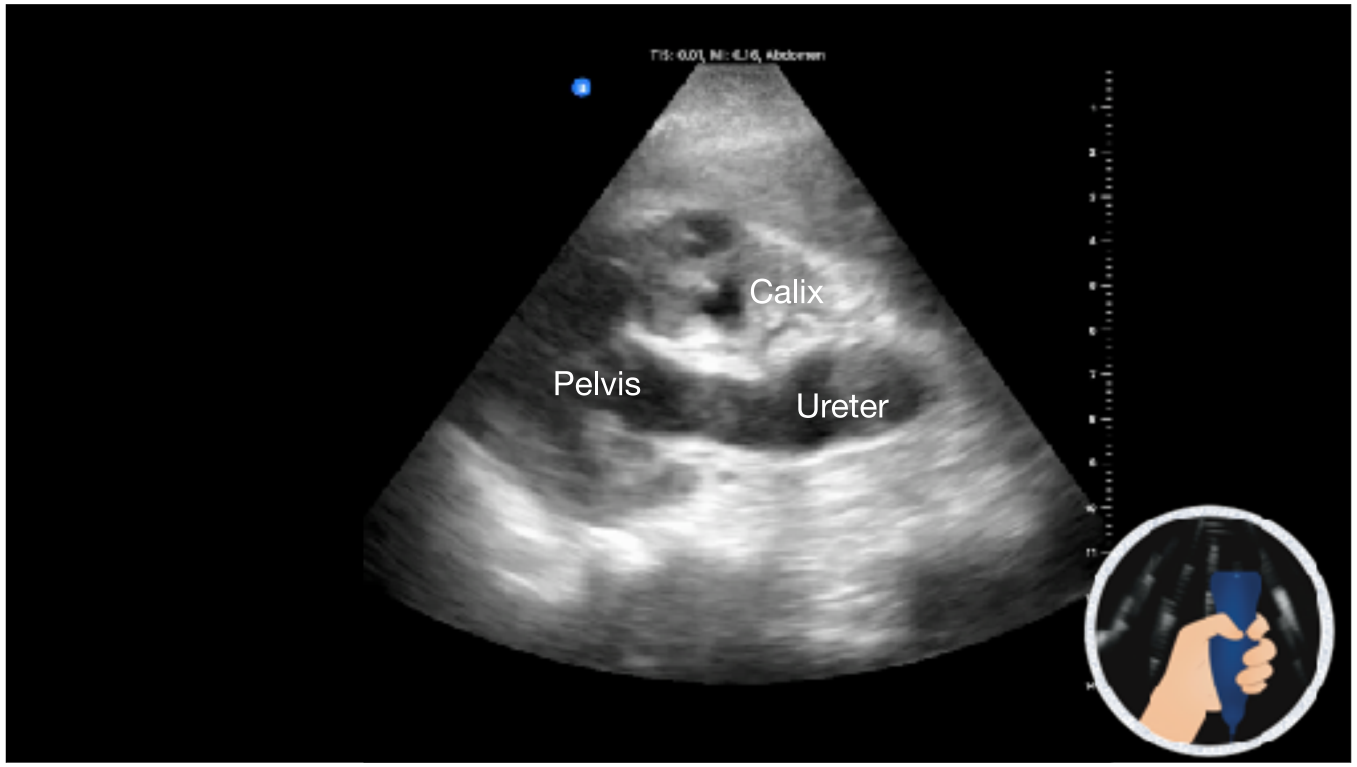
This is the right kidney of a subject with worsening creatinine. You can easily observe the different structures of the kidney. Hydronephrosis of one kidney is a rare cause of acute kidney injury or worsening kidney function.



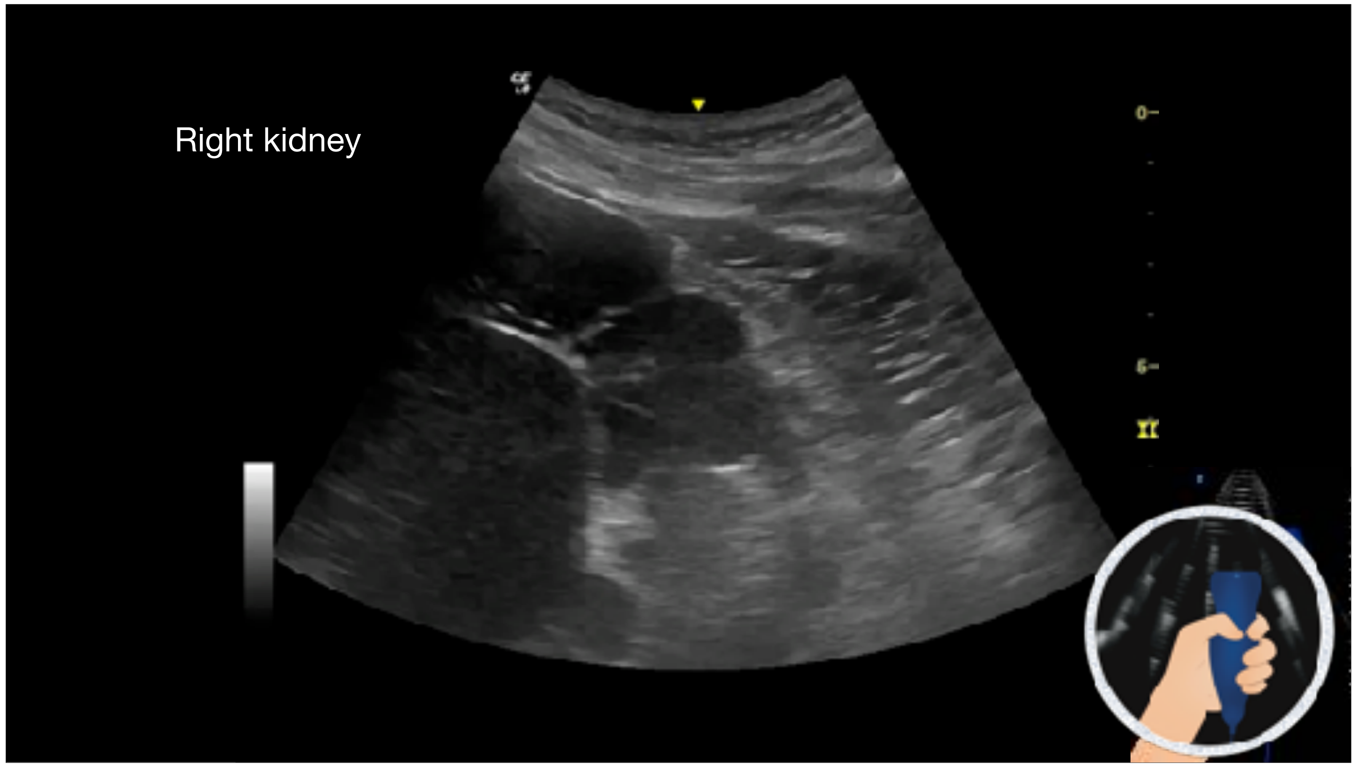
This is the left kidney of the prior subject. As you can see there is hydronephrosis.
The presence of bilateral hydronephrosis is more indicative of increased creatinine secondary to post renal causes.
Bilateral hydronephrosis can occur with uretherolithiasis, history of manipulation of the urinary tract, retroperitoneal fibrosis, tumors and more.
This is a study that will take not more than a few minutes at the bedside.
Bilateral hydronephrosis can be hereditary, hydronephrosis a condition that is often benign.



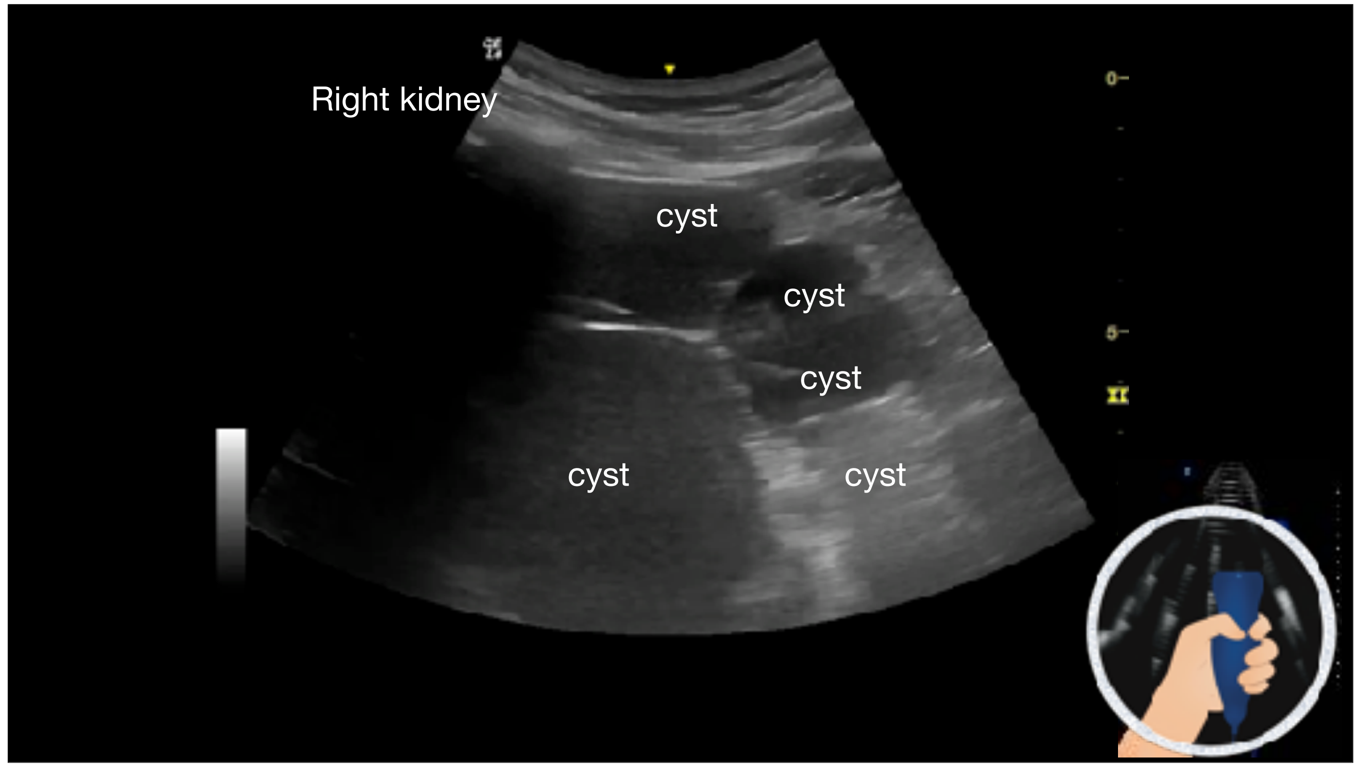
This is the right kidney of an elderly woman who was in the emergency department with sepsis and what's not able to give any history due to dementia.
At that moment, urinalysis was not available. As part of our examination, we perform a point-of-care ultrasound, which demonstrates clear hydronephrosis. After placing a urinary catheter, we were able to determine that the patient had a UTI.



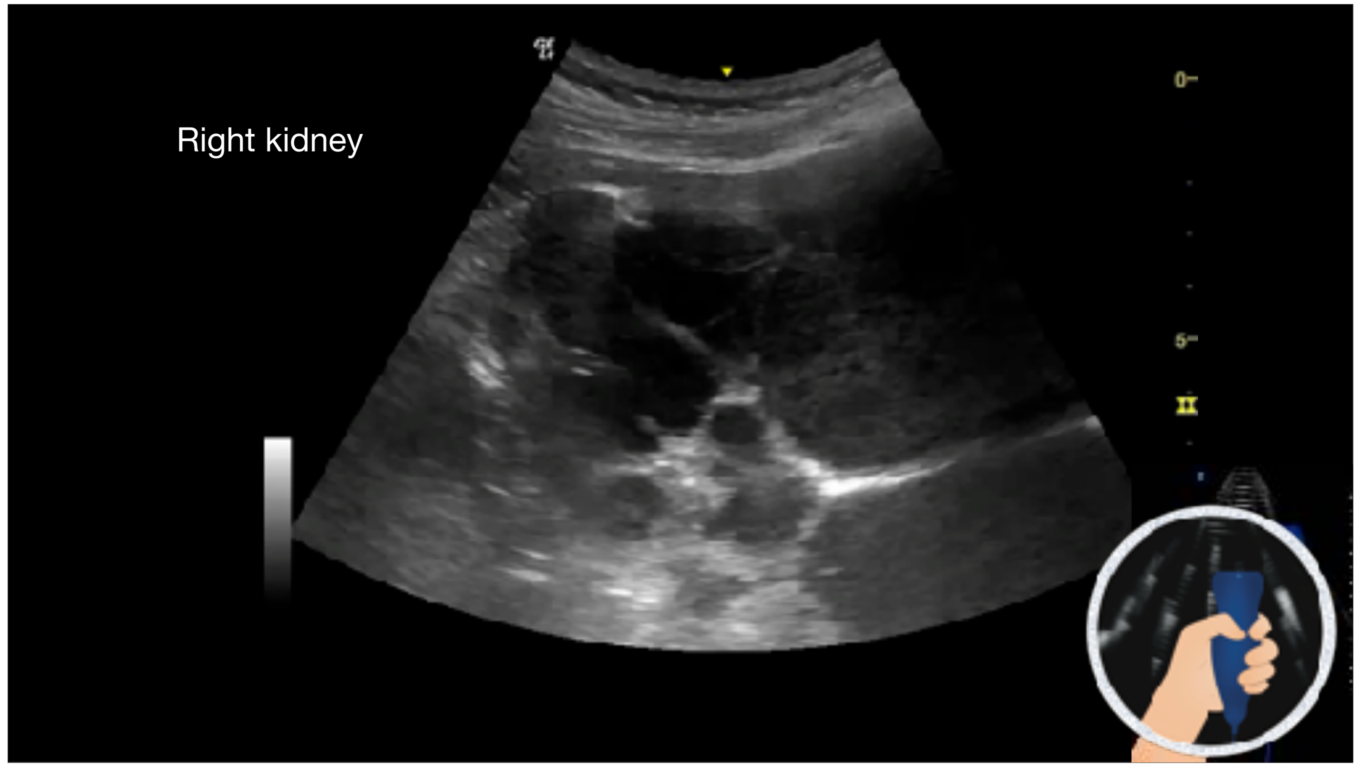
This is a more lateral view of the kidney, showing the different structures and a very enlarged ureter.
Thanks to POCUS we were able to determine that she had hydronephrosis, a CT without contrast showed a large stone blocking the ureter.
Because the patient was deteriorating she had a derivation and later was sent to the intensive care unit.
POCUS was of great help in steering the treatment of the patient from the beginning, saving time in diagnosis.



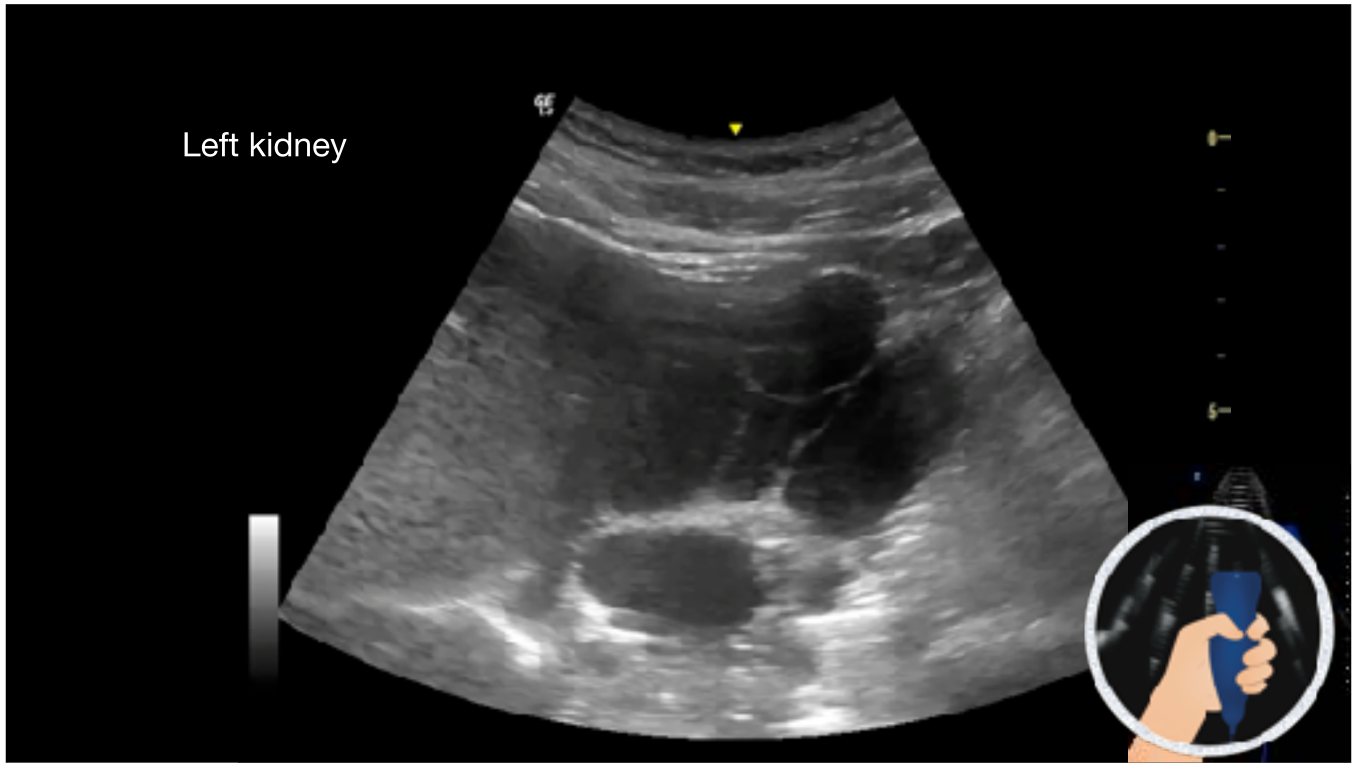
While performing a point-of-care ultrasound, one needs to be familiar with various abnormal findings. In this case, the anatomy was not normal because of polycystic kidney disease. This is the right kidney of a patient who presented to the clinic for a regular follow-up. He told us that when he was a child, he was diagnosed with a kidney problem.



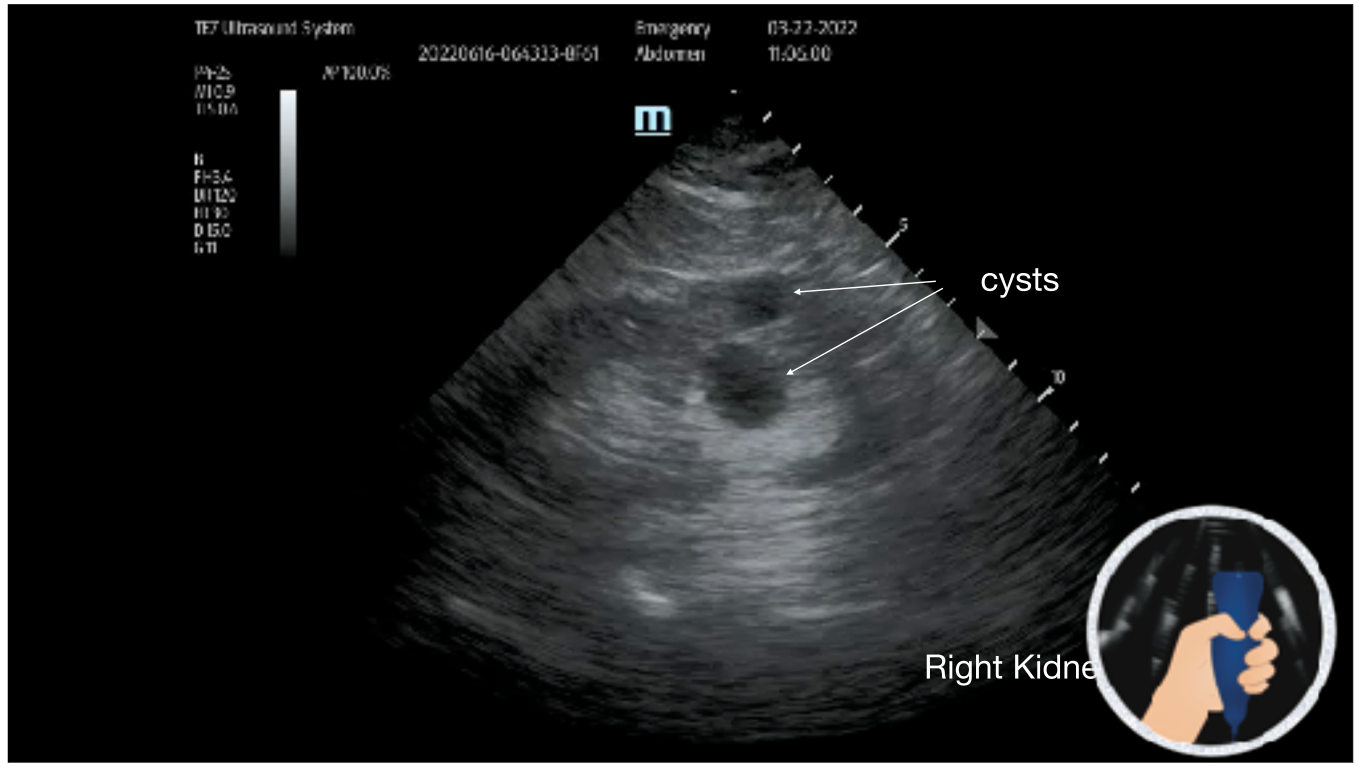
This is the left kidney of the same patient. You can see the multiple cysts in this patient, who was referred to genetic counseling. He's now being followed by nephrology and urology, too.



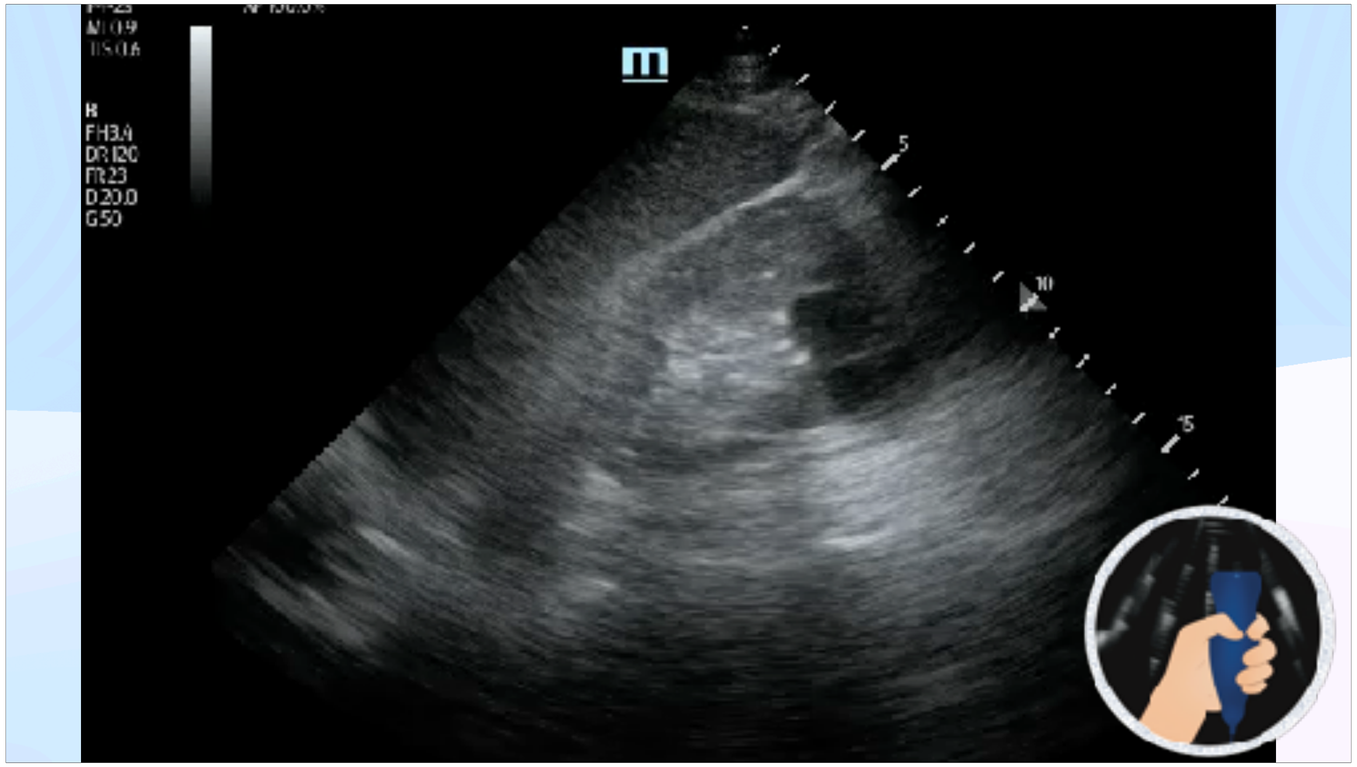
This demonstrates some kidney and liver cysts. The patient had autosomal dominant, polycystic kidney disease. Thanks to the clinic's point-of-care ultrasound, we were able to generate all the referrals and educate the patient about his condition.



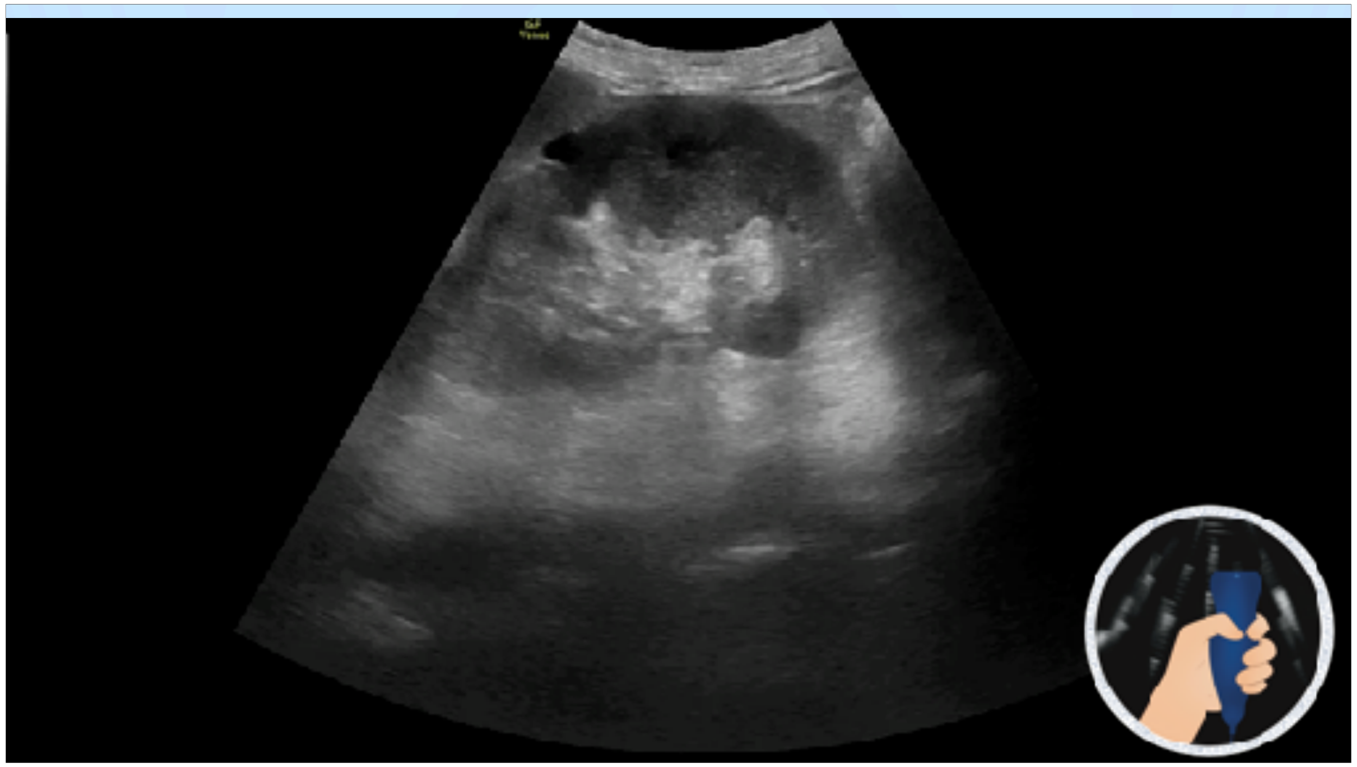
This is the left kidney of the patient.



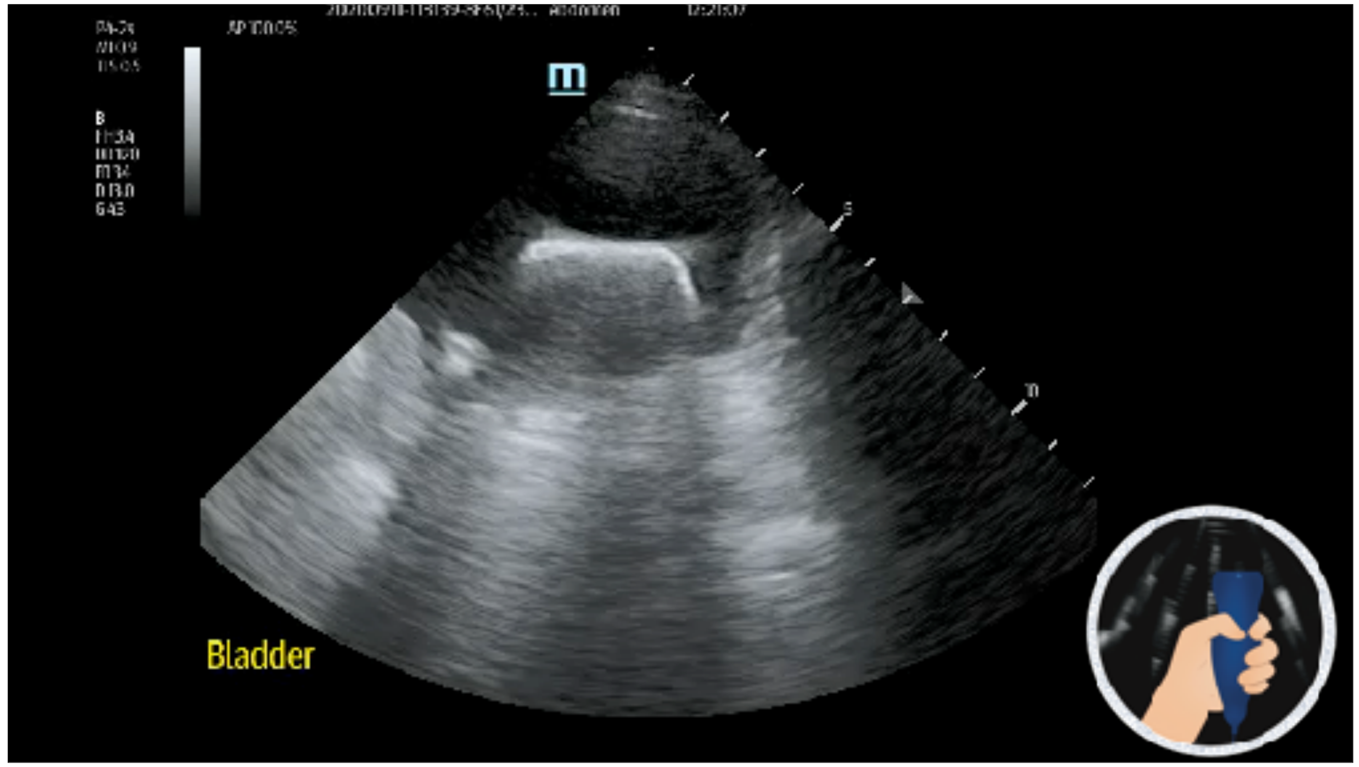
It is common to find cysts during kidney examination. In this case, we see two simple cysts. I will always advise ordering a formal kidney ultrasound to ensure that simple cysts are not complex cysts, which may require further evaluation by urology.



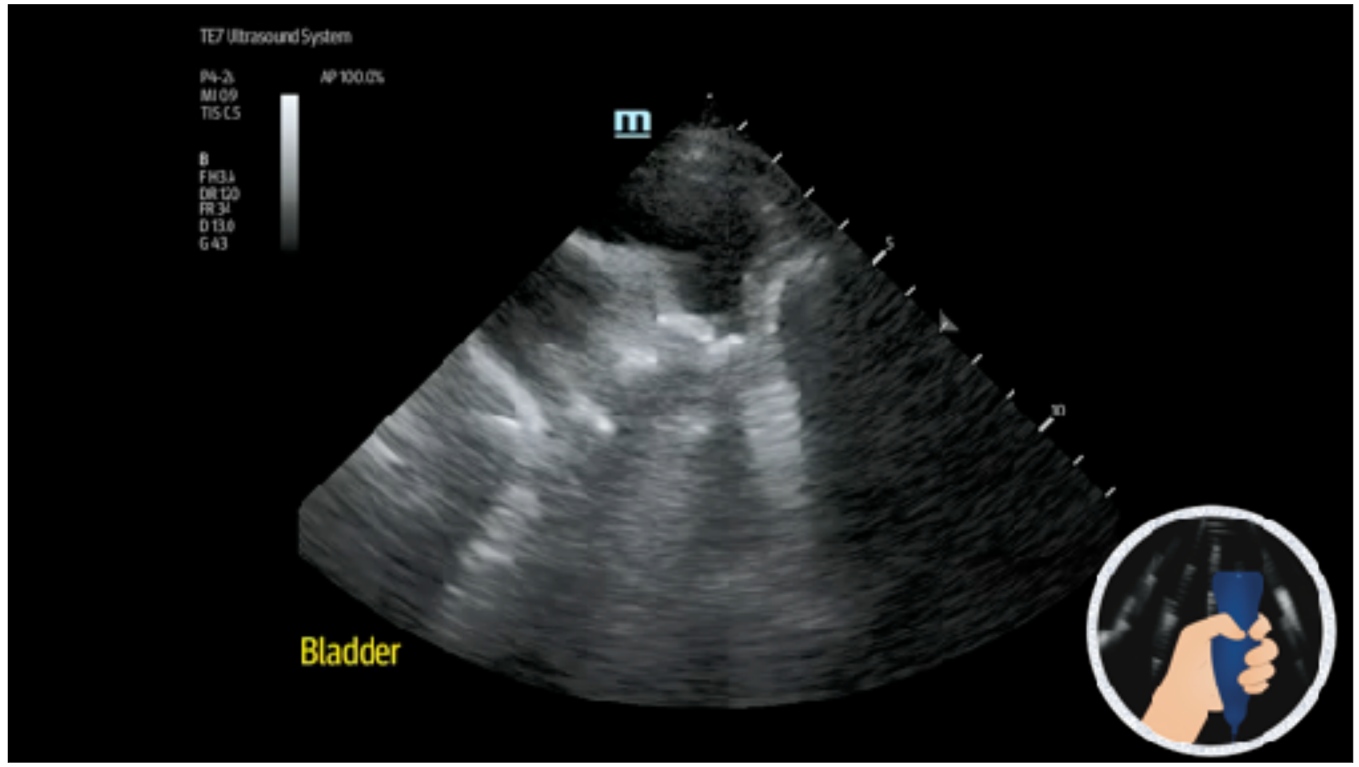
In this video, we see a lower pole simple cyst of the left kidney. The kidney also looks small with an atrophic cortex. The patient had a CKD stage four.



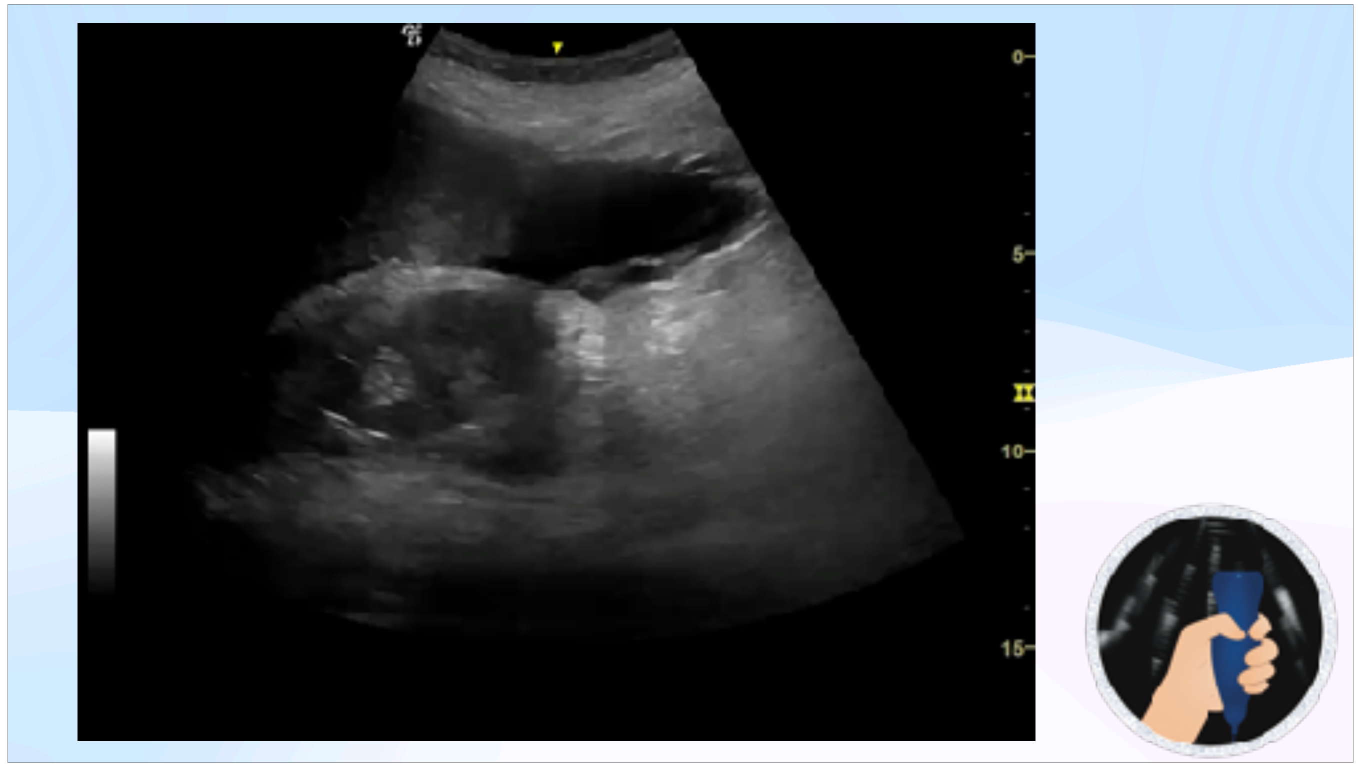
This is left kidney with a simple cyst of the cortex and medulla.



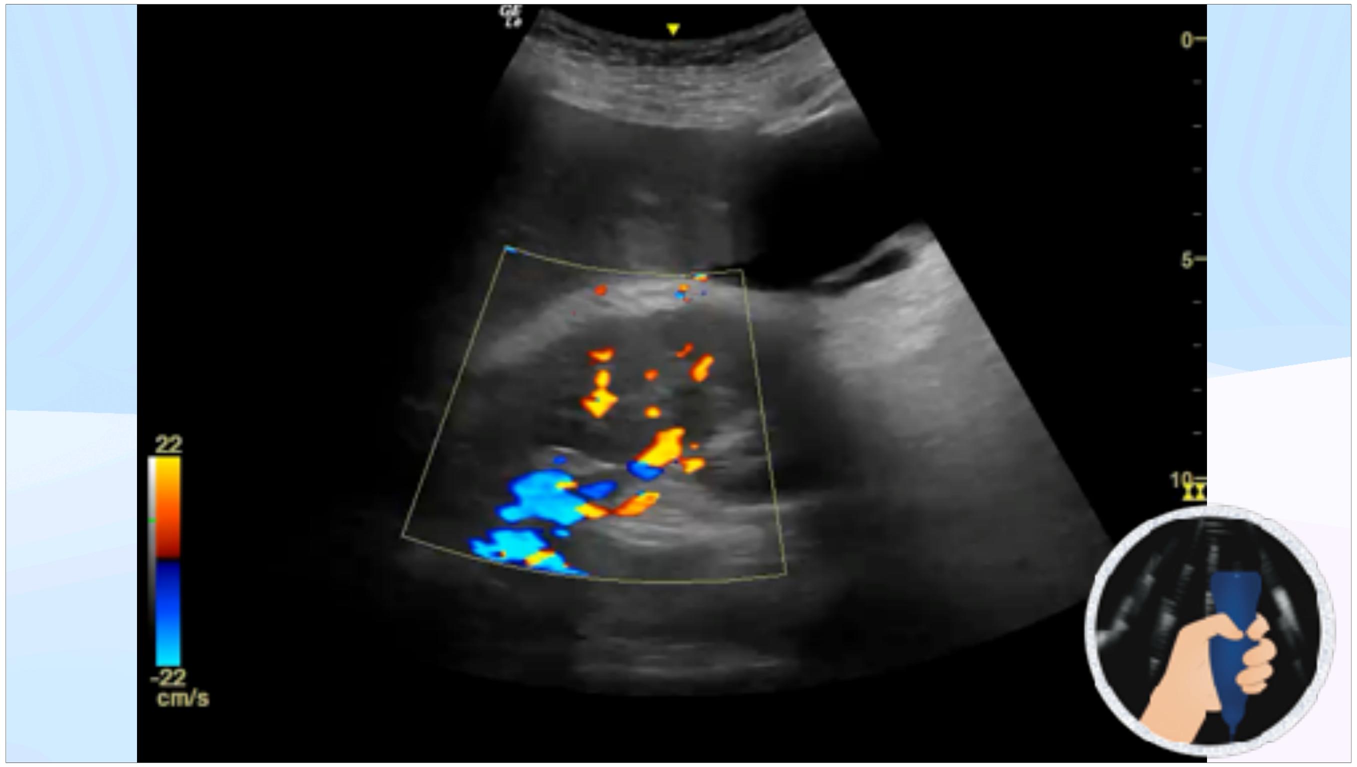
This is a patient who presented with hematuria. The patient was on an anticoagulant. This is a classic example of large stones in the bladder. You can see them, calcium-rich stones, with a very bright surface and significant shadow.



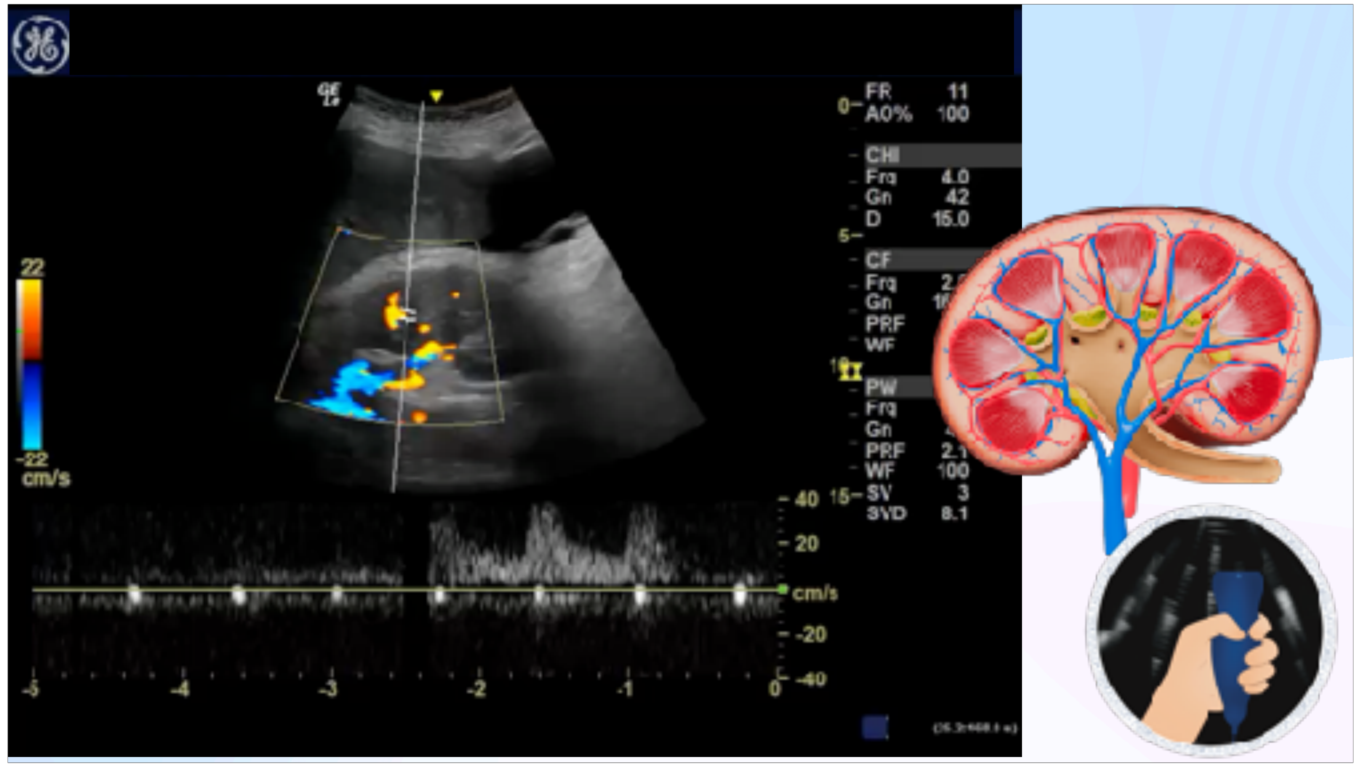
This is a longitudinal view demonstrating multiple stones. This patient was referred to urology; treatment for large bladder stones is on a case-by-case basis. Again, thanks for this ultrasound. The final treatment for this patient was expedited due to early diagnosis.



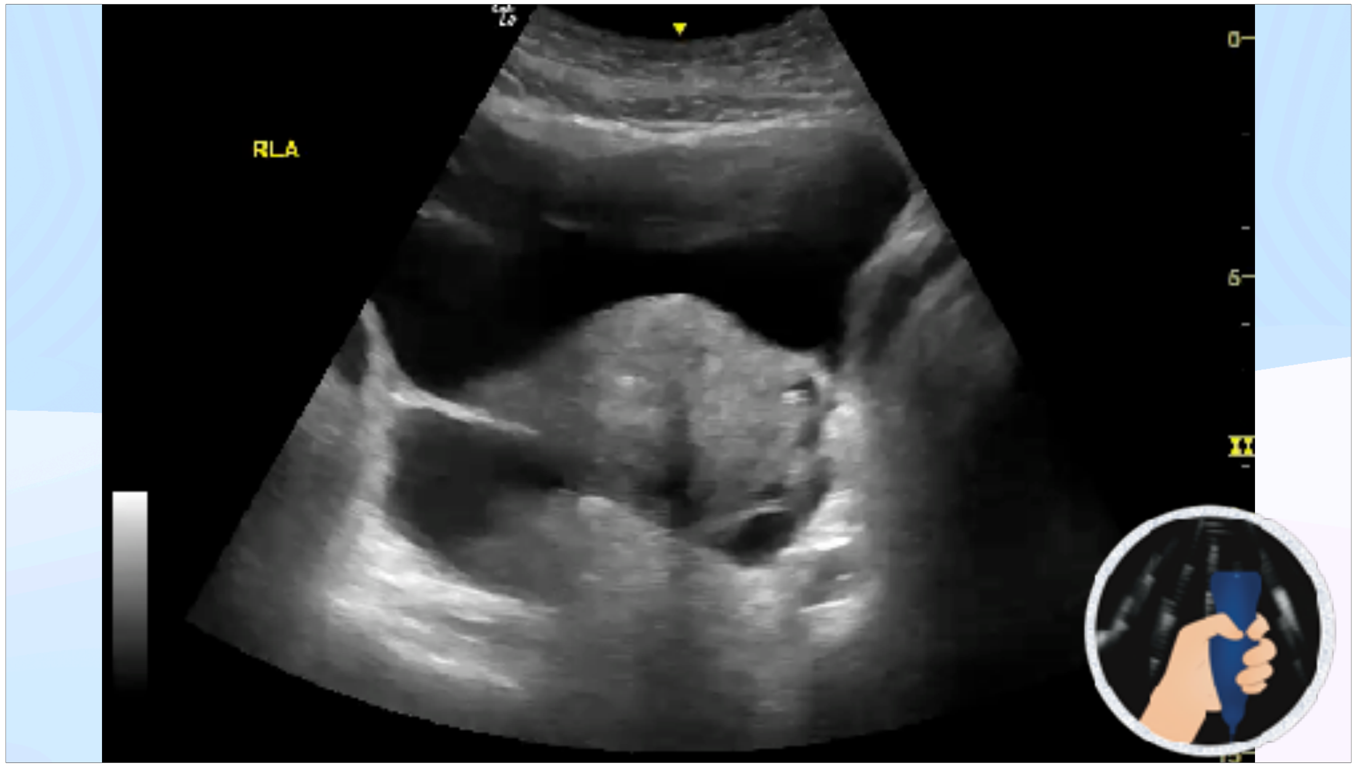
In this video, we see a right kidney below an enlarged liver. You can see fluid over the capsule between the Morrisons pouch. This is a classic example of ascites; however, the presence of fluid must be interpreted in the context of the patient's history.



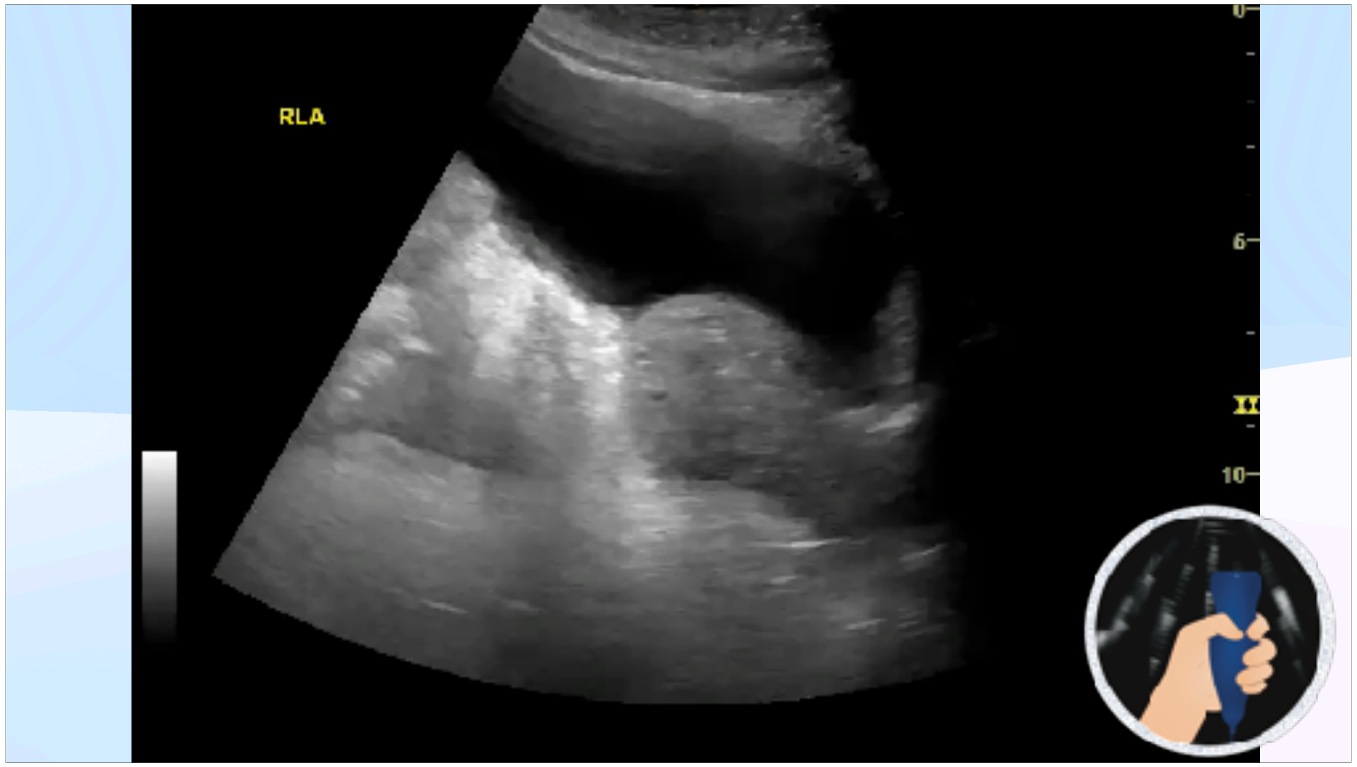
This is the color Doppler of the patient's kidney with ascites secondary to cirrhosis. This is reassuring since we started the patient on diuretics that day to improve ascites.



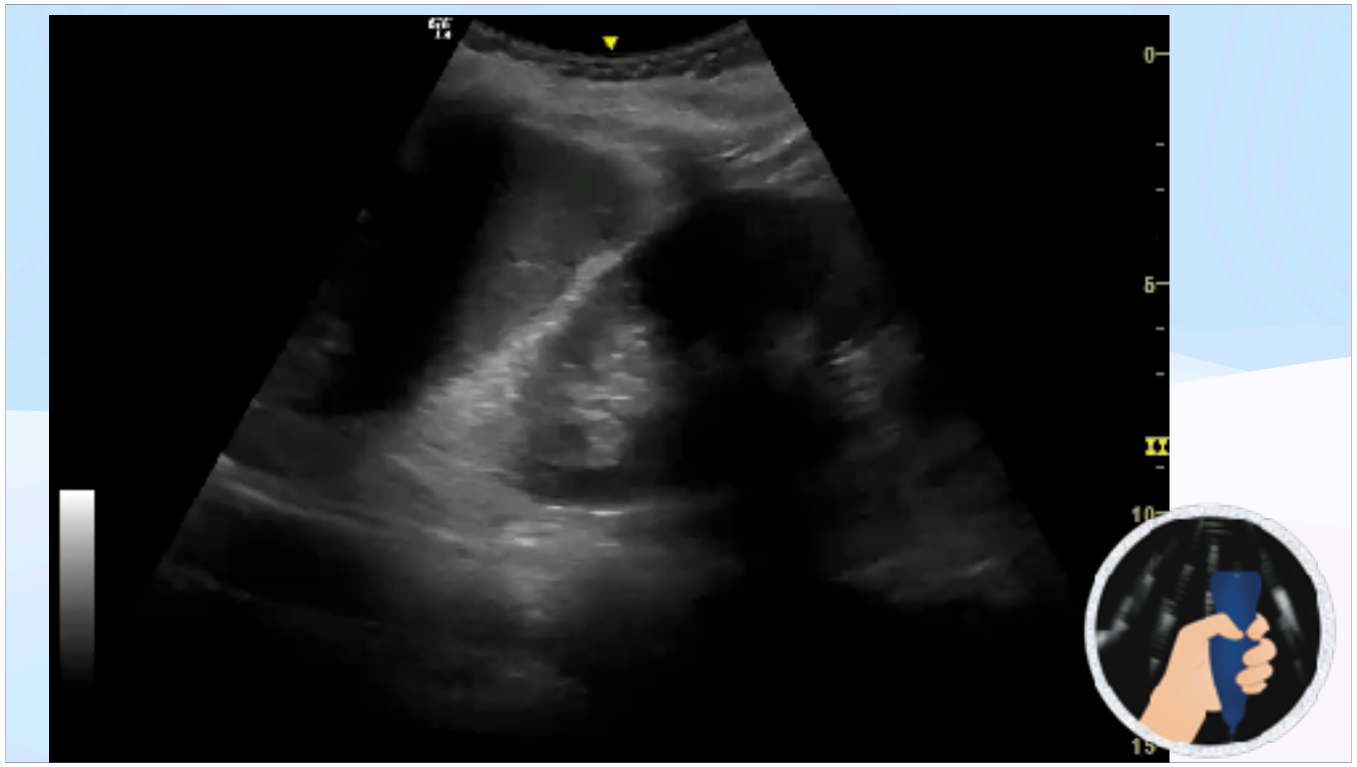
This is a continuation of the last patient. This ultrasound demonstrates normal interstitial kidney Doppler with normal arterial and venous phase. The patient has normal creatinine levels and significant ascites. We used the ultrasound to measure the amount of ascites every other week and the kidney dopplers to make sure that we didn't over diurese the patient. Once the ascites was controlled, we decreased the loop diuretics and kept the patient on a basal dose of spironolactone with regular follow-up. In this case the use of the ultrasound, gave us the window of the amount of fluid that the patient had, some reassurance that the kidneys will tolerate diuresis and the opportunity to talk to the patient with images that he could understand and show the patient the progress in each session with the treatment.



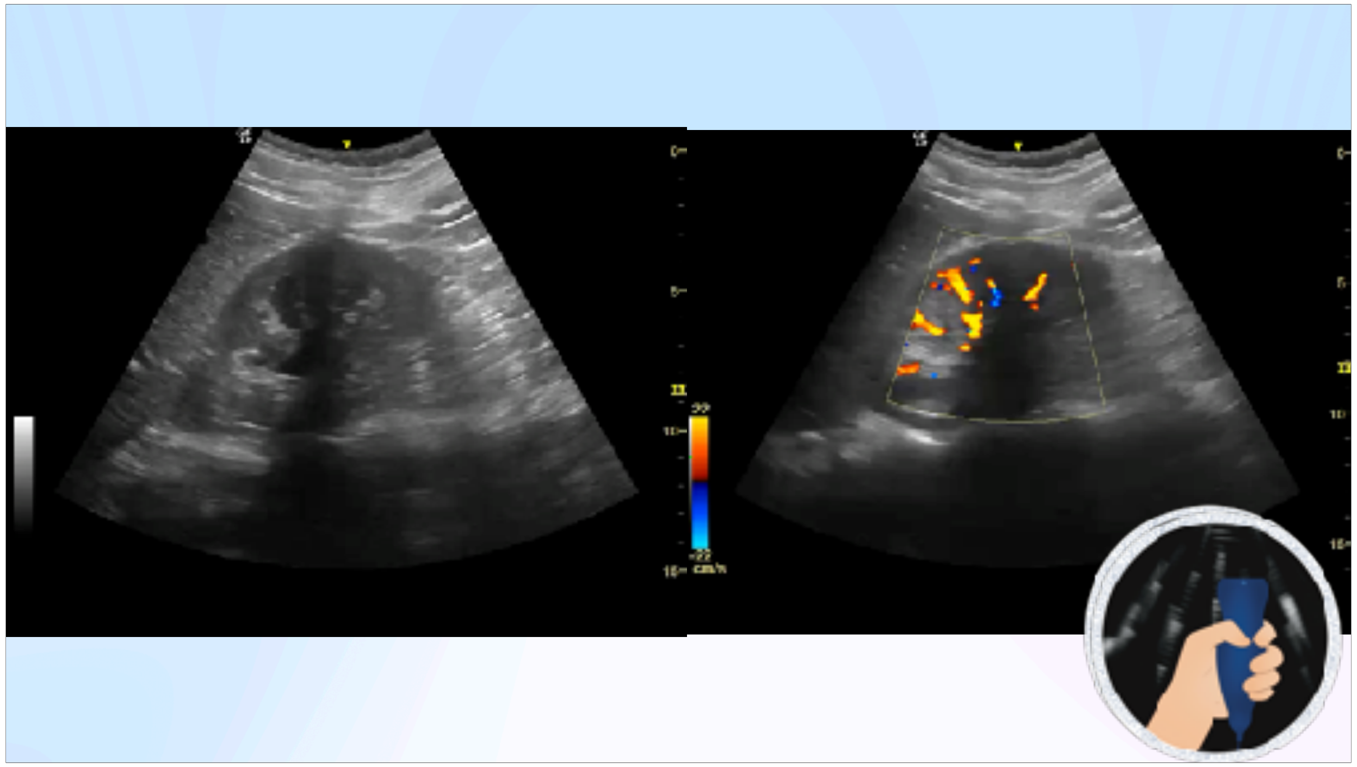
This is an axial view of the urinary bladder.   A uterus is apparent, and there is fluid below the urinary bladder and the uterus. This is a classic finding of ascites or free fluid around the urinary bladder. Remember that the presence of fluid in the peritoneal cavity must be correlated with the patient's history. Not all free fluid is ascites.



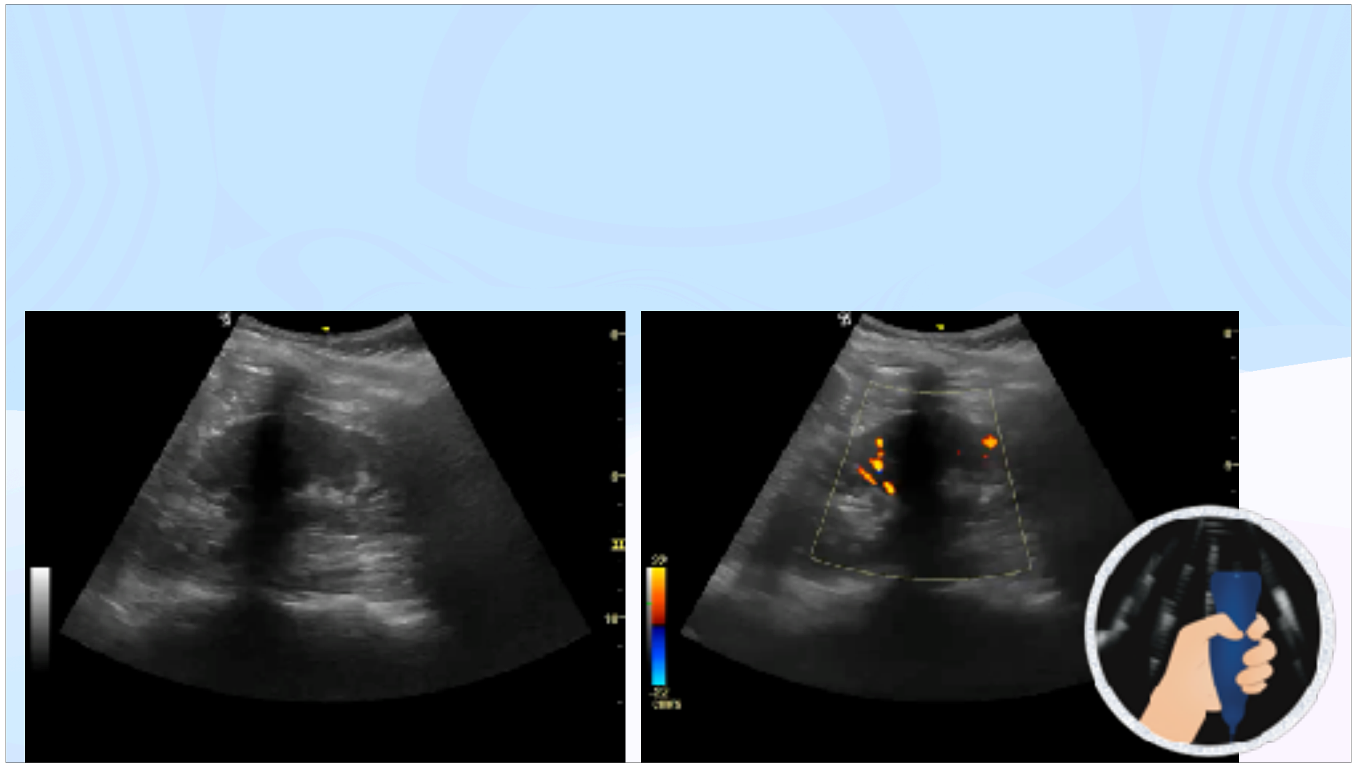
Same patient with a longitudinal access of the urinary bladder. This case fluid is present but not so apparent.



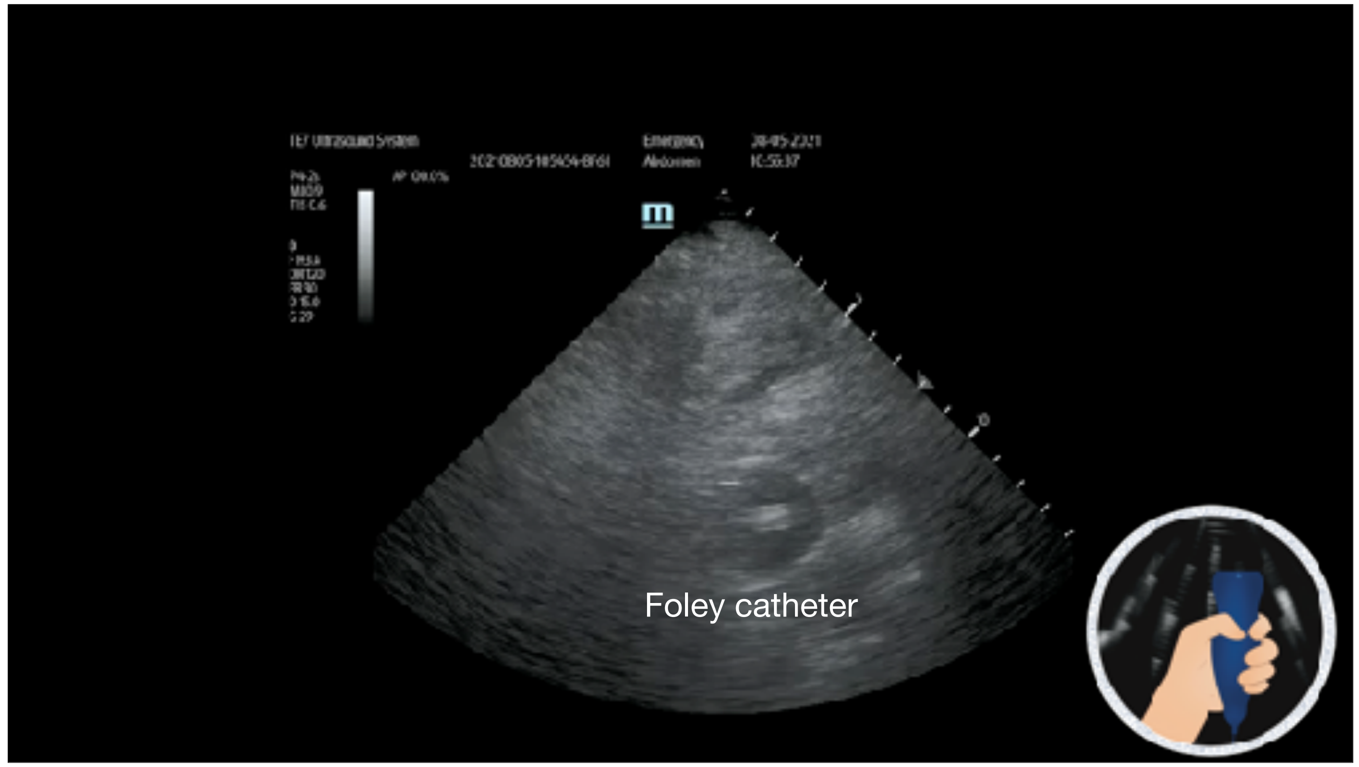
This is the left kidney. You can see that the spleen is likely enlarged. Please notice that there is no fluid in the splenorenal recess. This recess is a fibrous capsule that holds the kidney and spleen together. The presence of free fluid in this space is usually secondary to trauma, rupture, or peritoneal carcinomatosis. Rarely will you see fluid in this area, secondary to ascites alone.



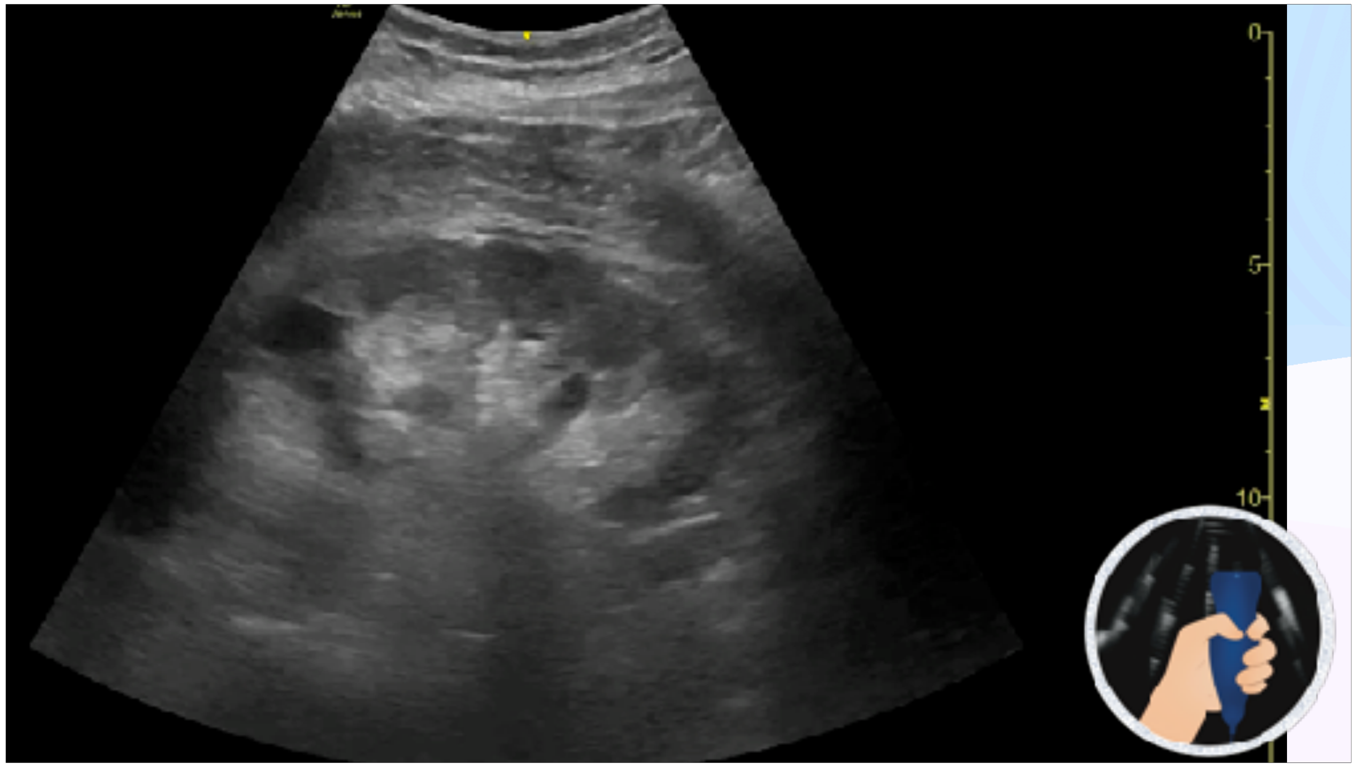
This is the color Doppler of the prior kidney



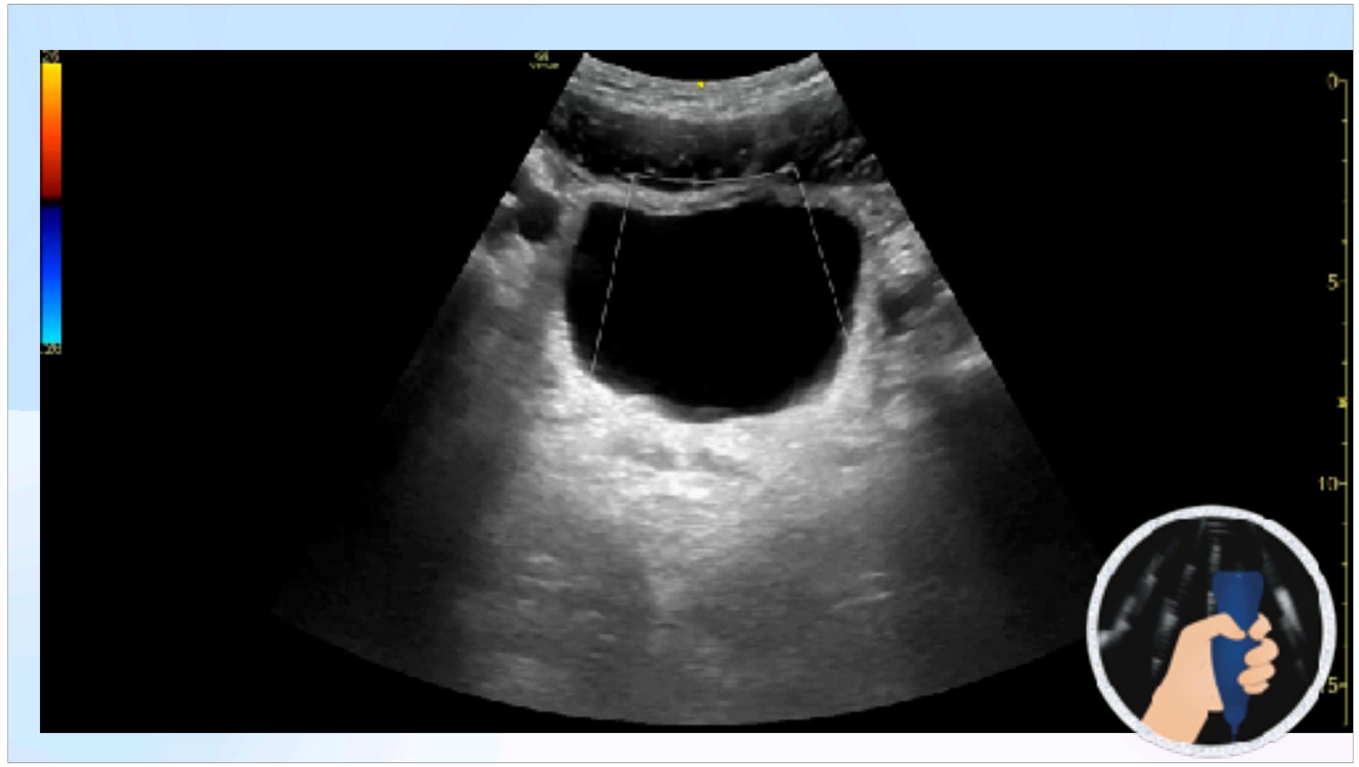
It is important to notice that there is an acoustic shadow right in the center of this kidney ultrasound. This is common when using curvilinear probe because of its large footprint. When the acoustic shadow is unavoidable, evaluation of the kidney should be performed from multiple angles.



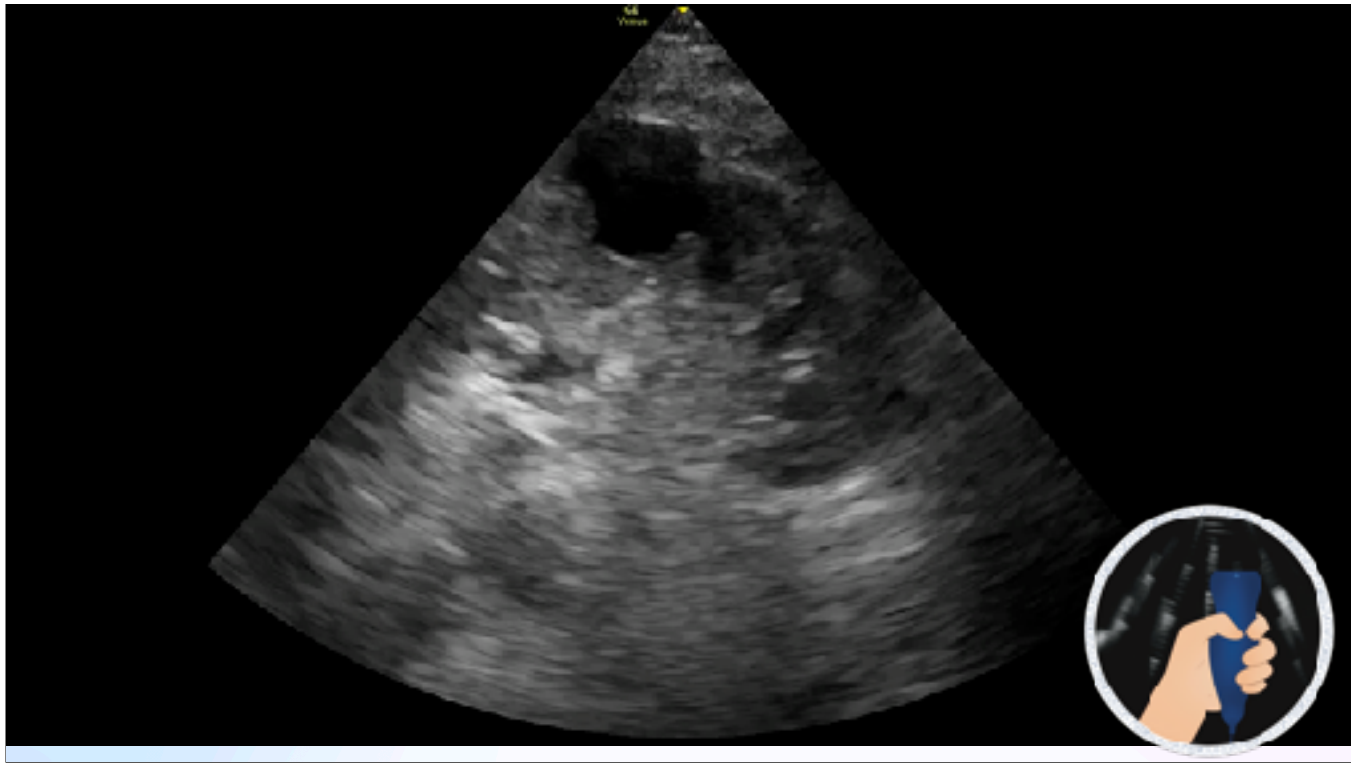
This is an important image. Sometimes we need to figure out where the Foley catheter is and if it is working. Here, we have a Foley catheter in the bladder, obtained with a phased-array transducer. The urinary bladder is empty, confirming that the catheter is working.



In summary, evaluating the kidney and urinary tract is of great value to the internist.
It can provide quick information about the anatomy and function of the kidney. This can be of significant use when evaluating a patient with acute kidney injury, volume status, anatomical defects, malfunction of hardware that is used to evacuate the urinary track.



The evaluation of the bladder is very important, as it can tell us whether the ureters are open and whether fluid is present in the bladder, a sign that the patient is producing urine, Evaluating for stones, hardware and multiple order conditions.
In this axial cut of the urinary bladder, we can clearly see one of the ureteral jets, showing us that there is urine being produced and the ureter is patent



It is necessary to be on the lookout for abnormal anatomy. And this slide. We can see clearly the presence of simple cysts. This patient should undergo a formal ultrasound.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