431 Radiology Team

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Lecture 8: Radiological Anatomy & Investigation of Urinary System

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◆Important ◆Doctor's notes ◆Team's notes

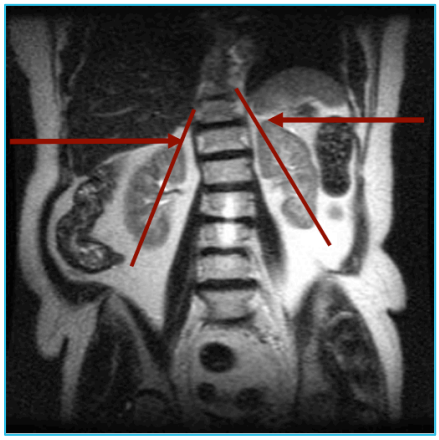
We thank 430 & 429 Teams for their helpful notes

Urinary System:

- Kidneys are retroperitoneal organs.
- Their function is to maintain electrolyte homeostasis and waste excretion.
- They empty medially into the ureters.
- Ureters course inferiorly into the pelvis and enter the urinary bladder.
- The urine is temporarily stored in the urinary bladder till it is cleared to the exterior through the urethra.

Kidneys:

- On either side of the lower thoracic and upper lumbar spine.
- Usual location: between upper border of 11th thoracic vertebra and lower border of 3rd lumbar vertebra.
- In upright position the kidneys descend by 2 or 3 cm.
- Both kidneys move with respiration.
- Right kidney is 2 cm lower than the left kidney. (and shorter)
- Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles.
- In lateral plane, the axis is directed downward and anteriorly.
- Lower pole is 2-3 cm anterior to the upper pole.
- Normal size: in adults the average is 11 cm (best method to measure the size of the kidney is ultrasound)



- Right kidney is shorter than left kidney by not more than 1.5 cm.
- As a rule: the length of the kidney is 3.7 +/- 0.37 times the height of the 2nd lumbar vertebra measured on the same film using the posterior margin of the vertebral body.

❖ To measure the size of the kidney:

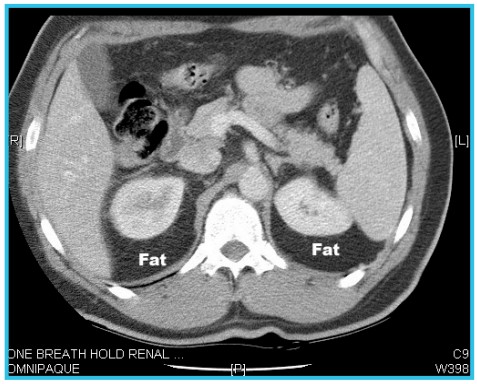
1- From upper to lower pole, lateral to medial.

or 2- Compare the vertebral bodies to the size of the kidney
the kidney is almost 3.5 vertebral bodies.

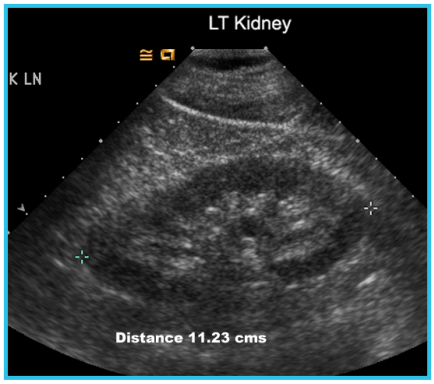
❖ Axial (Transverse) section: Kidney is seen rounded or semi-rounded.

❖ Sagital section: the kidney is seen from upper to lower pole.

IVU (Intravenous urography) – IVP (Intravenous Pyelogram)



CT – Axial (transverse)



Ultrasound

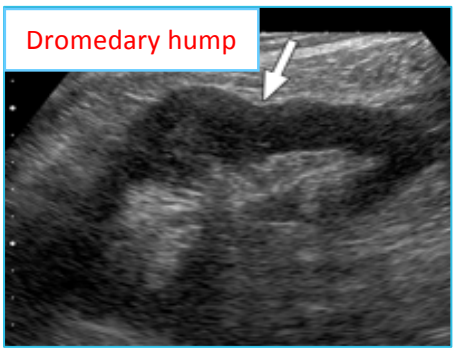
Kidneys:

- Bean shaped structure.
- There may be fetal lobulations – present as notches on the lateral aspect of the kidneys
- Local bulge or convexity may be seen along the lateral aspect of left kidney – called dromedary hump. (To differenciate between a normal dormedary hump and a mass: when you see the nomral cortex, medulla and normal vascularity → dromedary hump)
- This may be either due to impression of the spleen or fetal lobulation or both.
- Kidneys are visualized on the X-Ray due to presence of perirenal fat.
- Kidneys are contained within the renal capsule and surrounded by perirenal fat and enclosed within the Gerota's fascia.
- Perirenal hemorrhage, pus and urine are contained within the fascia and detected on CT and Ultrasonography.
- A layer of paranephric fat surrounds and cushions the kidneys.

*Embryologically, the kidneys originate as distinct lobules that fuse as they develop and grow.

Imaging Modalities:

- Plain X-Ray: the intial exam in most requested exams and the first in the IVU study.
- Intravenous Pyelogram (IVP) or Intravenous urography (IVU).
- Retrograde Pyelogram.
- CT Scan.
- Ultrasound.
- Renal Angiography.
- Renal Scintigraphy.
- Cystography.
- Voiding Cystourethrography.

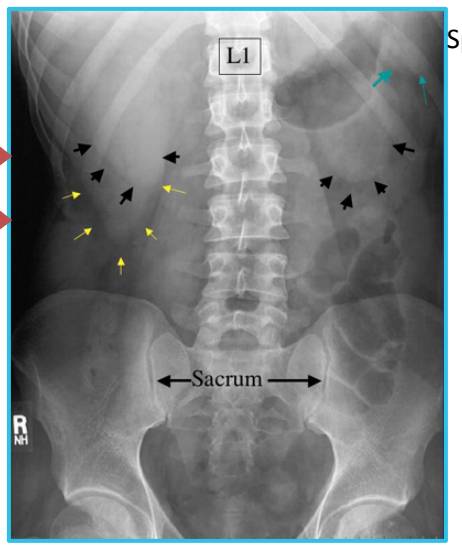


Plain X-Ray:

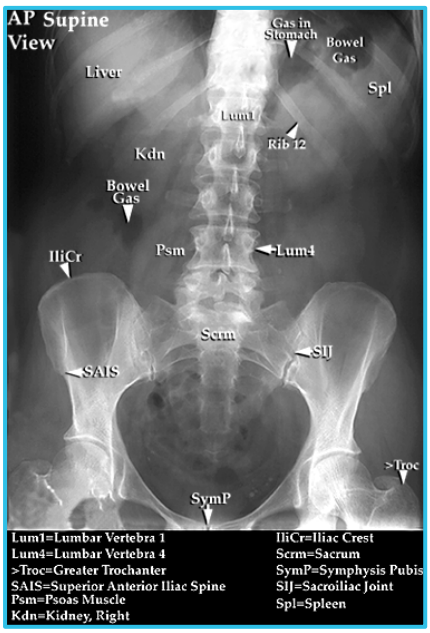
Used for:

- Screening for urinary calculi (stones).
- Diffuse abdominal pain.
- Essential part of IVP.

❖ The good thing is that opaque (calcified) structures are more visualized.
❖ The kidney as soft tissue can been seen sometimes because it's surrounded by fat. The difference between the density of the fat and kidney (soft tissue) gives some kind of visualization.

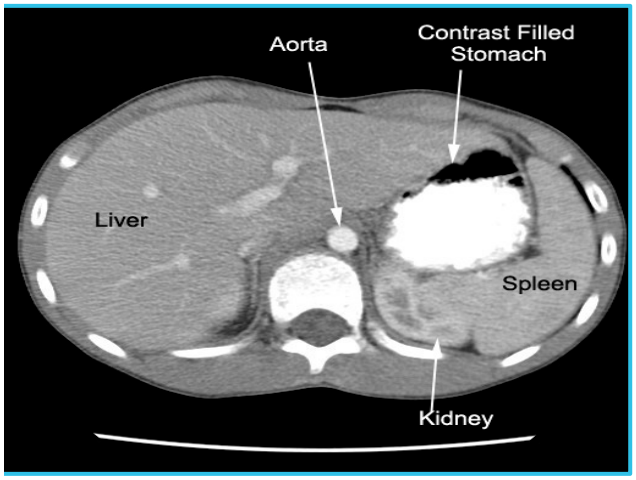


CT Scan showing left kidney higher than right



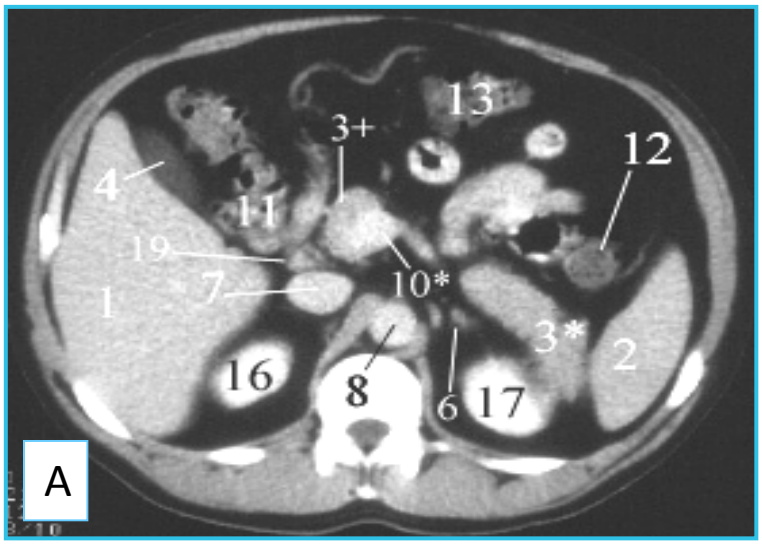
CT-Scan:

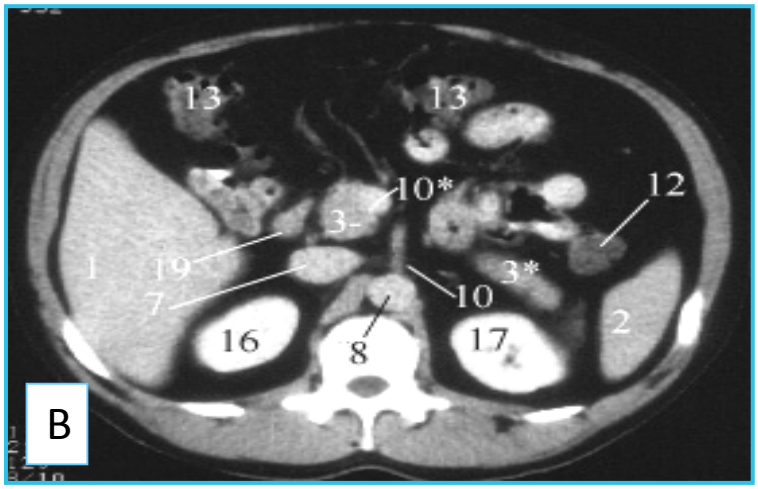
- Used selectively for specific indication (To see if there is renal tumor). (Not done to every patient because of the radiation and not available in every facility)
- Excellent anatomic details.
- Ionizing radiation. (Contraindicated in pregnant women)
- Usually requires IV contrast. (Contraindicated in renal failure patients)
- (Our first choice is usually X-Ray, then ultrasound. If needed, we order CT)



At this level, the superior pole of the left kidney is seen.

It is important to know the structures related to the kidney, and be able to identify them in the images.



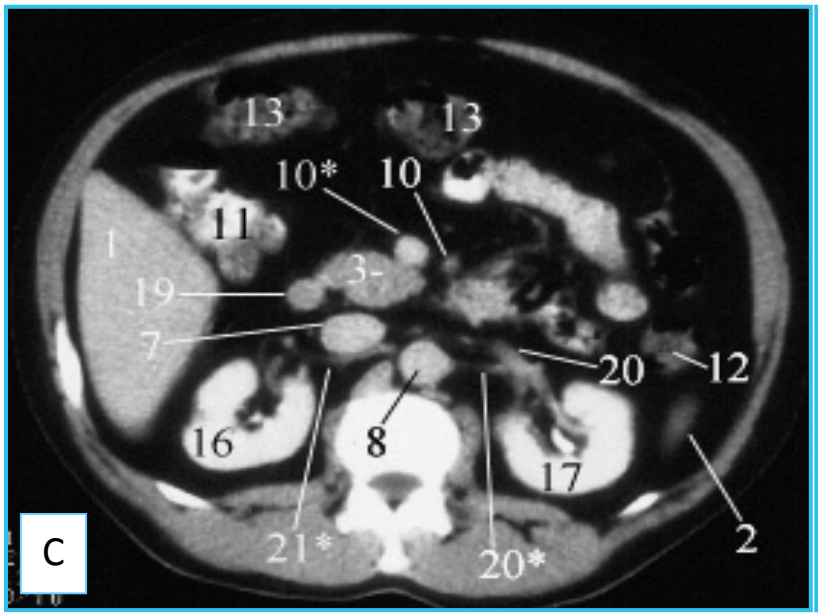


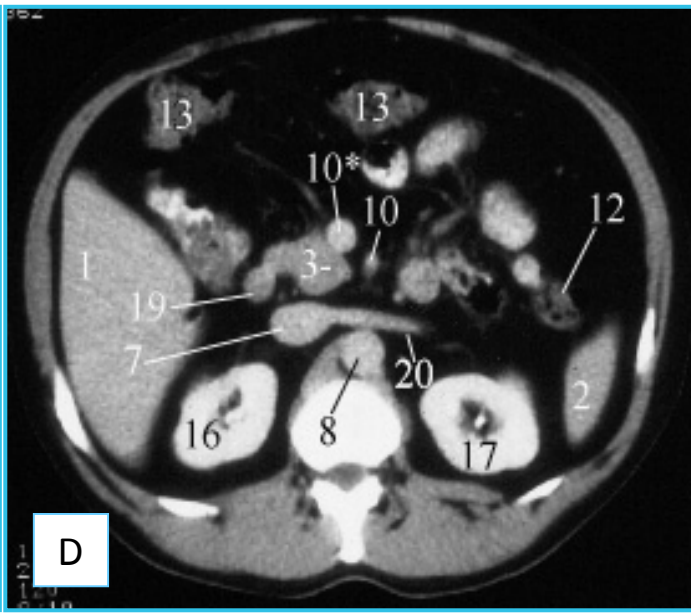
A)

1= Liver.
2= Spleen.
3+= Head of the pancreas.
3*= Body and tail of the pancreas.
4= Gallbladder.
6= Left Adrenal Gland.
7= Inferior Vena Cava.
8= Aorta.
10*= Superior Mesenteric Vein.
11= Ascending Colon.
12= Descending colon.
13 = Transverse colon.
16= Right Kidney.
17= Left Kidney.
19= Duodenum, 2nd part.

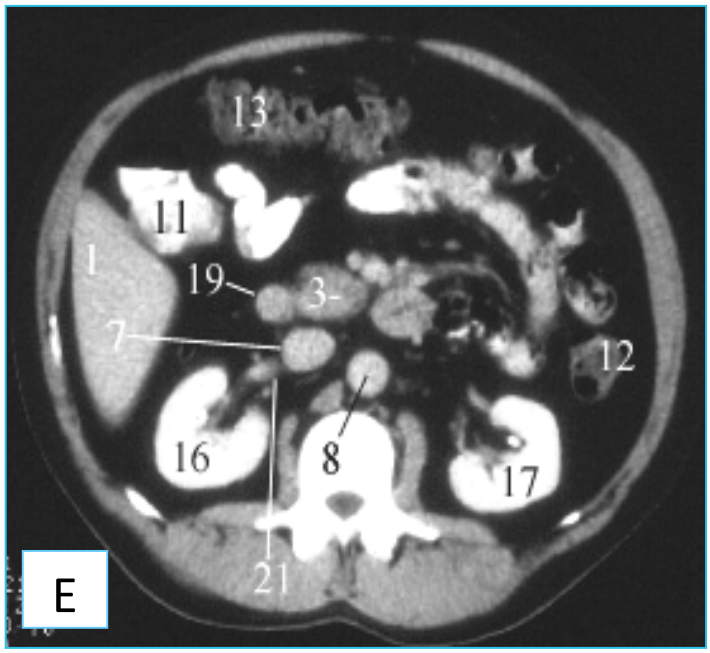
B)

3- = Uncinate process of the pancreas.
10= Superior Mesenteric Artery.

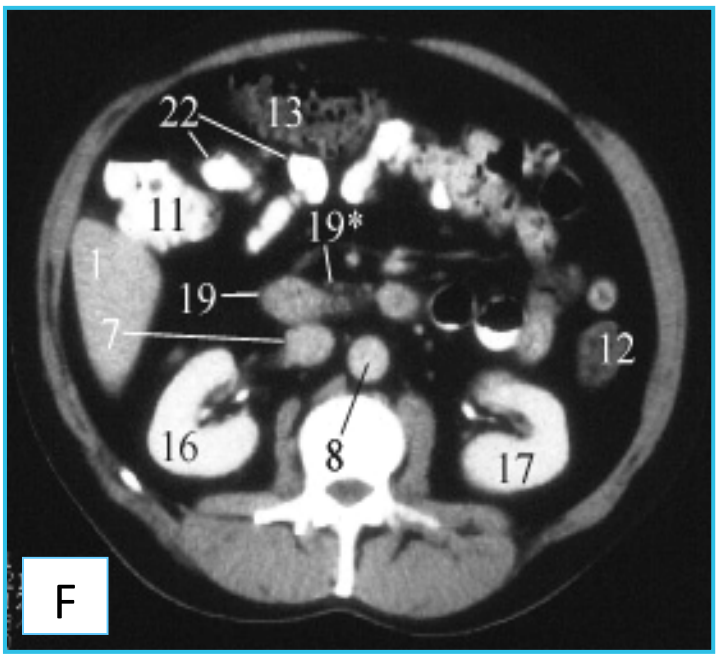




20= Left renal vein. 20*= Left renal artery. 21*= Right renal artery.



21= Right renal vein.

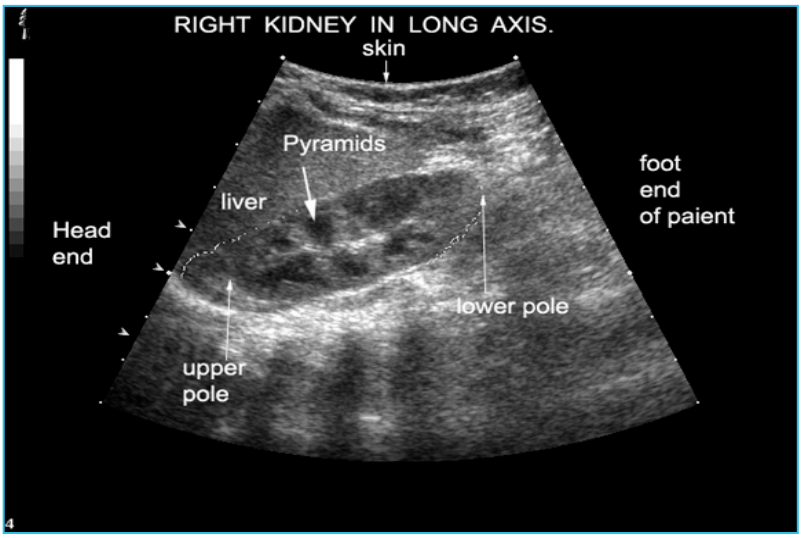


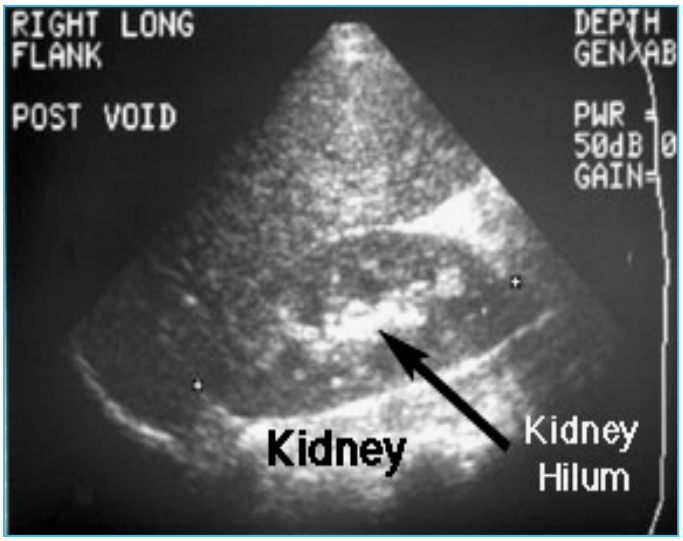
19*= Duodenum, 3rd part.

22= Small Intestine.

Ultrasound:

- Excellent renal and bladder anatomy.
- Can assess blood flow. (By Doppler, can detect stenosis)
- To differentiate between solid and cystic masses. (Cyst -fluid- appears black)
- Can be used to evaluate the prostate or to guide biopsies.
- Poor urethral anatomy. (Because it's difficult to follow their course)
- No functional information. (It's an anatomical modality)



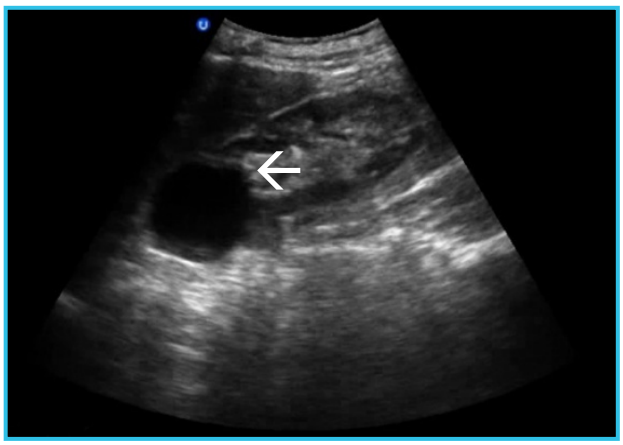


Ultrasound of the right kidney:

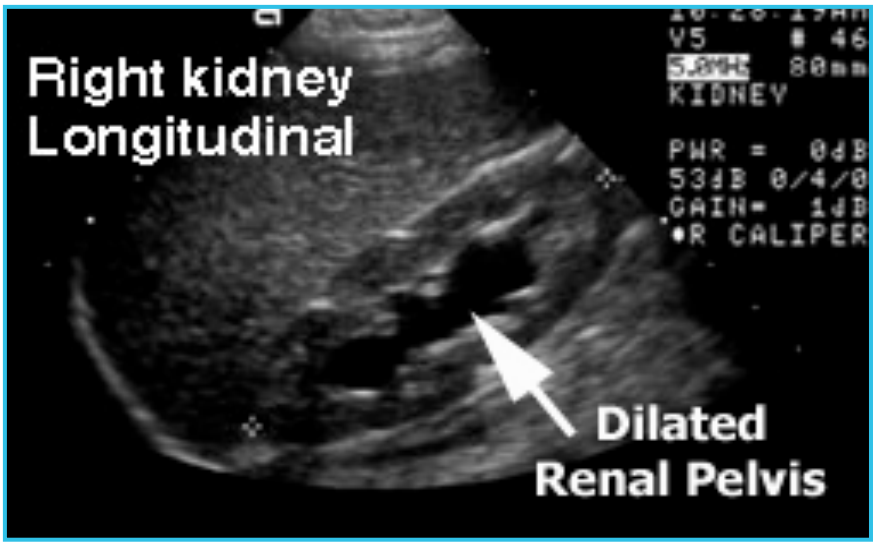
- Capsule
- Cortex: grey.
- Medulla: consists of pyramids.

Normal study: The hilum appears white (brighter than other structures) because of the fat in the renal medulla surrounding the pelvis.

Both fat and stones appear bright in ultrasound. So, how do we differentiate between the two?
There will be shadowing in case of stones.



Renal cyst



Hydronephrosis

*Dilated renal pelvis could be due to hydronephrosis or cyst.

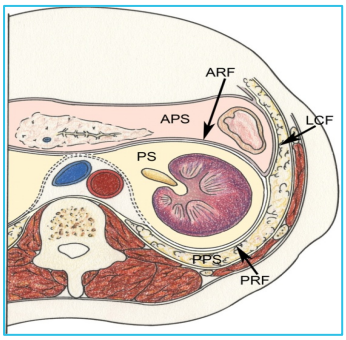
*To differentiate between the two, look at the shape and location

*Cyst would be regular in shape and not involving the entire kidney.

Spaces Around the Kidney: (Important to see because infection or bleeding can exist around the kidney)

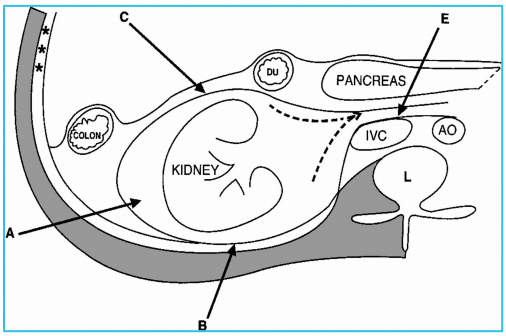
*Details of the boundries are written in the slides, but the doctor didn't mention them during the lecture.

1) Perirenal Space: bounded by the leaves of the Gerota's fascia.
- The leaves fuse superiorly, laterally and medially.
- It encloses the kidneys, adrenal glands, renal vasculature and proximal ureter.
- The fascial envelope is functionally open caudally just above the pelvic brim.
- Ureter emerges from the perirenal space and traverses caudad in anterior pararenal space.



2) Anterior Pararenal Space is bounded:
- Anteriorly by the posterior parietal peritoneum.
- Posteriorly by the anterior portion of the renal fascia.
- Laterally by the lateral conal fascia.
- Contains: pancreas, 2nd,3rd and 4th portions of the duodenum, ascending and descending colon, vascular supply to the spleen, liver, pancreas and duodenum.

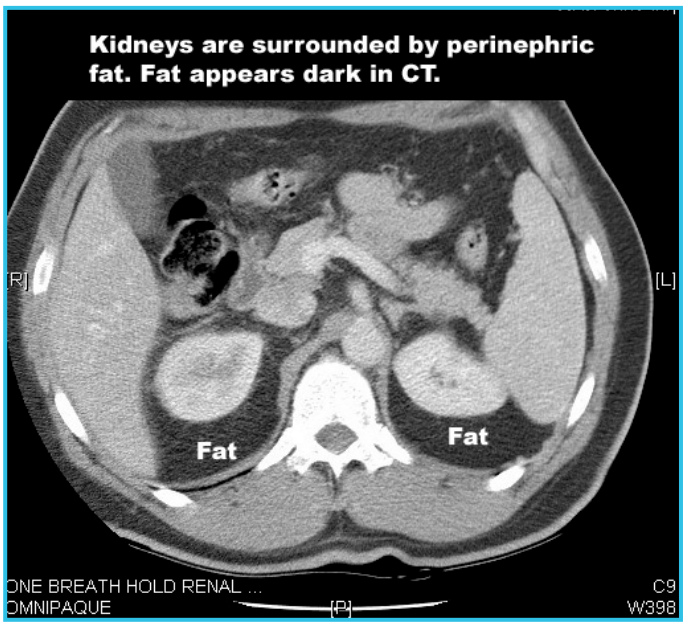
3) Posterior Pararenal Space is bounded:
- Anteriorly by the posterior portion of Gerota's fascia
- Posteriorly by the transversalis fascia
- Contains only fat, scattered vessels and nerves

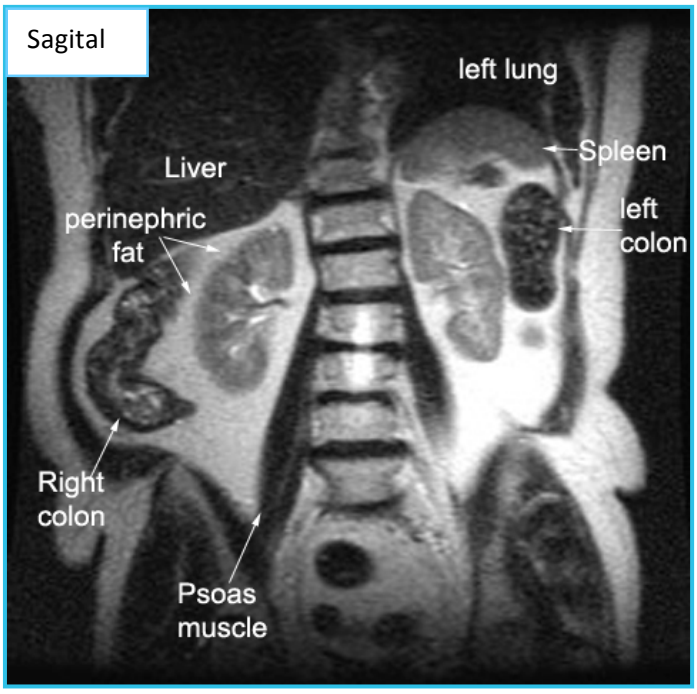


All three spaces potentially communicate at the pelvic brim.

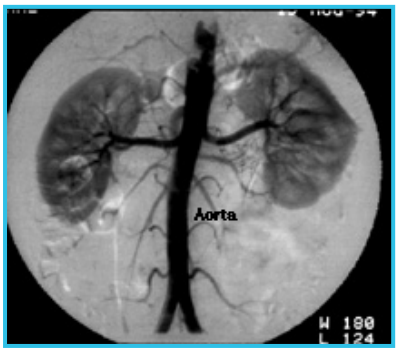
- Modalities that can be used to assess the function of the kidney:
- Nuclear
- PET scan
- IVU and CT with contrast (to some degree)

- Stones (calcification) appear bright (white), hyperechoic





Renal Vasculature:

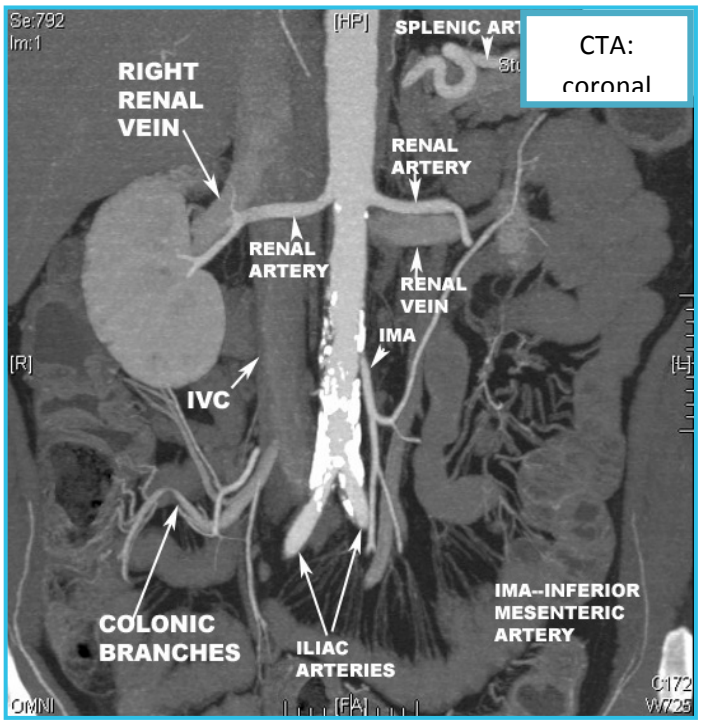


Angiography is used to evaluate the renal vessels. (golden standard)

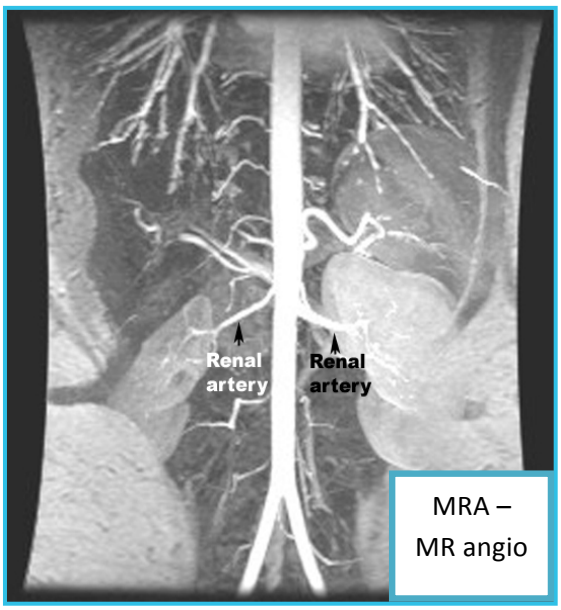
- Urinary tract hemorrhage.
- Renal artery stenosis. (And hypertension)
- Partial nephrectomy. (Therapeutic use)
- Significant risk of complication.
- Very expensive.

(Doppler can also be used, but it's difficult especially in obese patients or if the abdomen is gassy. CT can sometimes be used as a choice over angiography, because it's less invasive. However, angiography has the advantage of having therapeutic use)

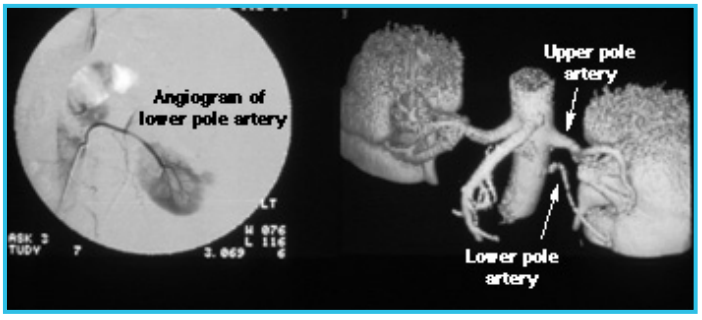
- There are many variations of the renal vasculature.
- Renal arteries branch from the abdominal aorta laterally between L1 and L2, below the origin of the superior mesenteric artery.
- The right renal artery passes posterior to the IVC.
- There may be more than one renal artery (on one or both sides) in 20-30% cases.
- Renal veins drain into inferior vena cava.
- Renal veins lie anterior to the arteries.
- Left renal vein is longer and passes anterior to the aorta before draining into the inferior vena cava.
- The left gonadal vein will drain into the left renal vein while the right gonadal vein drains directly into the inferior vena cava.
- Common variants include retroaortic and circumaortic left renal veins.

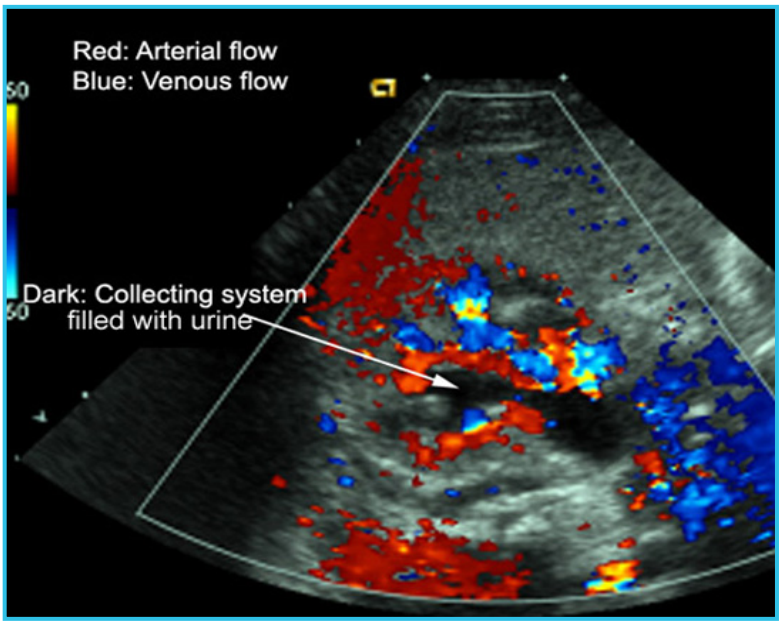


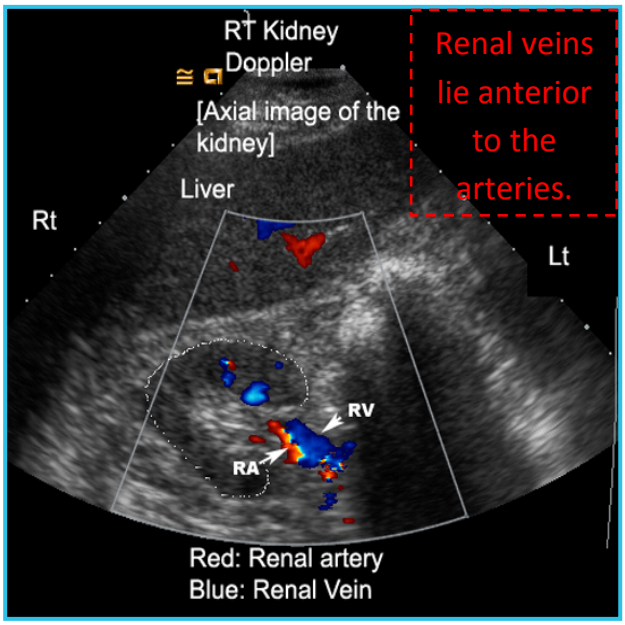
CTA: coronal



MRA – MR angio



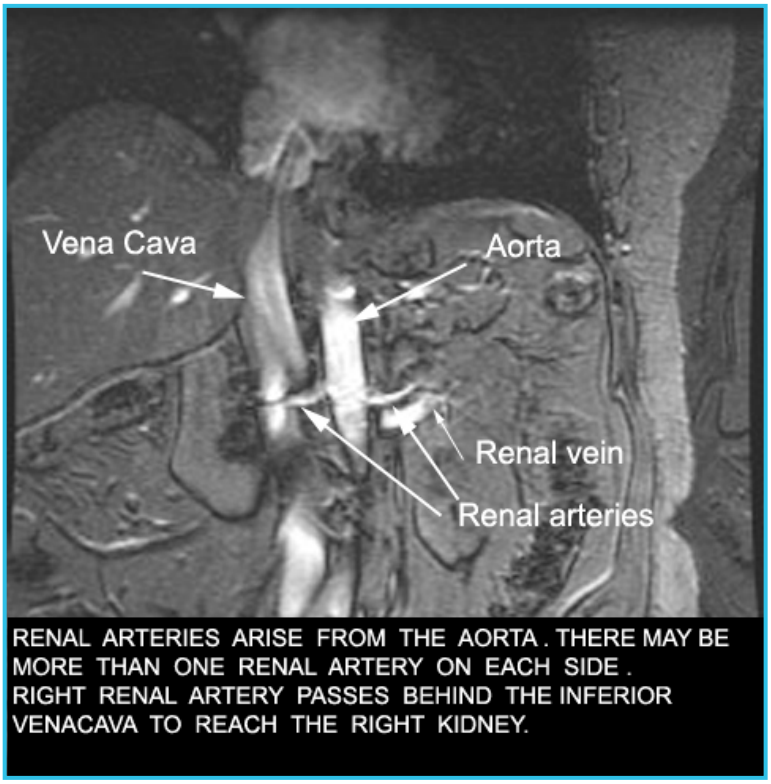


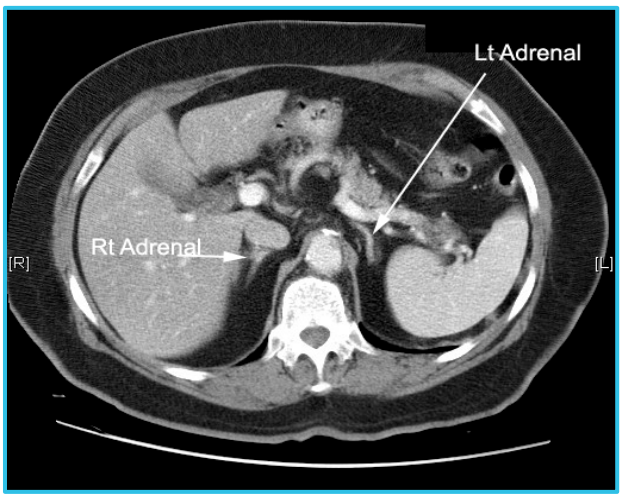


Renal veins lie anterior to the arteries.

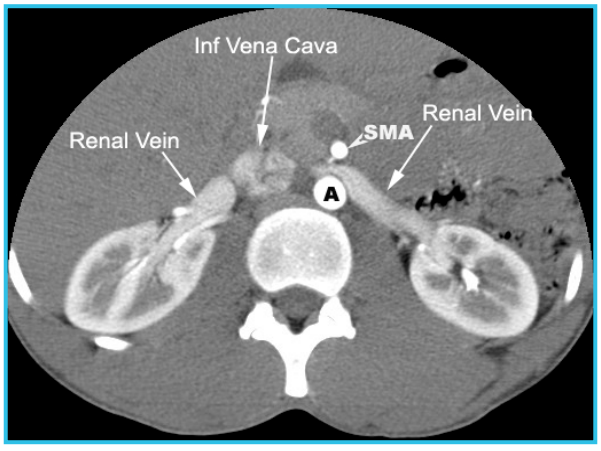
Red color doesn't not necessarily indicate an artery. So is the case with blue and veins.

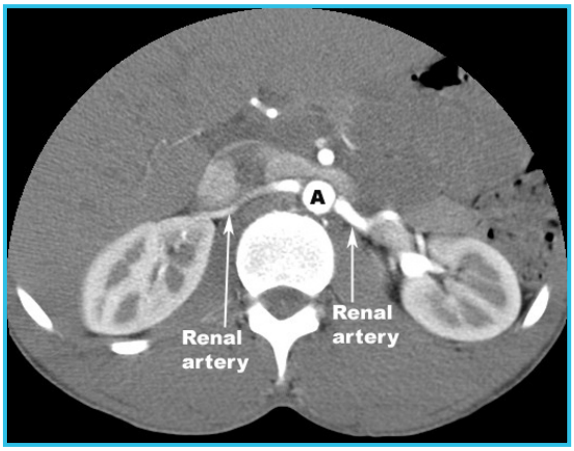
Actually, the color depends on the flow direction. Red is blood that is flowing towards the probe, and blue is flowing away.

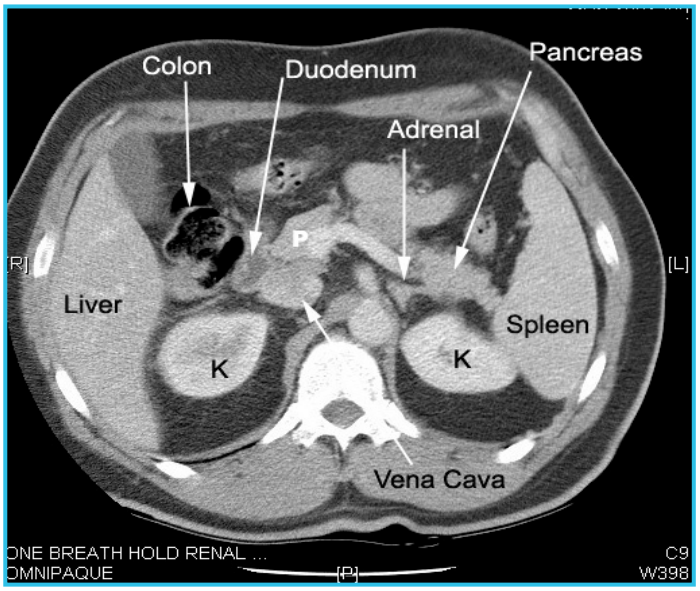


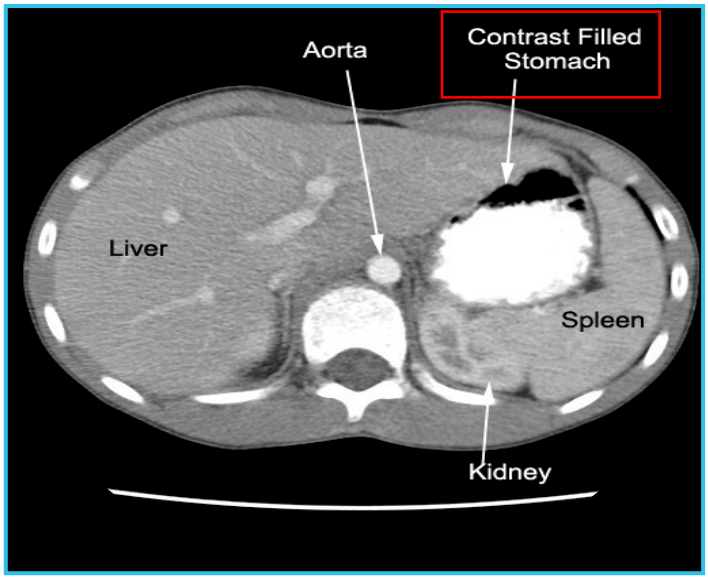


Adrenal Glands are superior to the Kidneys









Again, it is important to know the structures related to the kidney, and be able to identify them in the images.

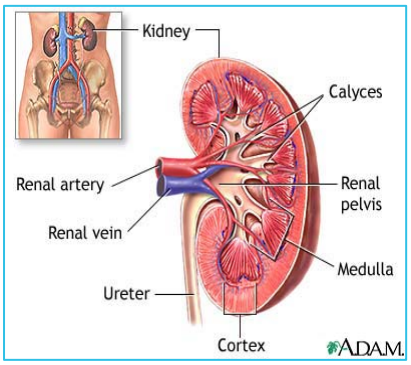
Superior to the kidneys: Adrenal glands.
Medial to the left kidney: Aorta
Antero-lateral to the left kidney: Spleen
Antero-lateral to the right kidney: Liver
Antero-medial to the right kidney: IVC

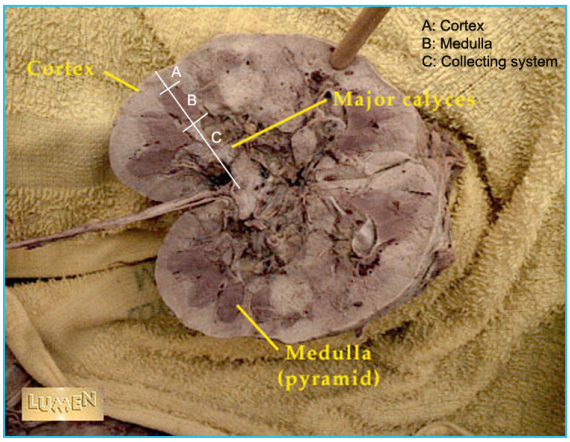
EXTRA

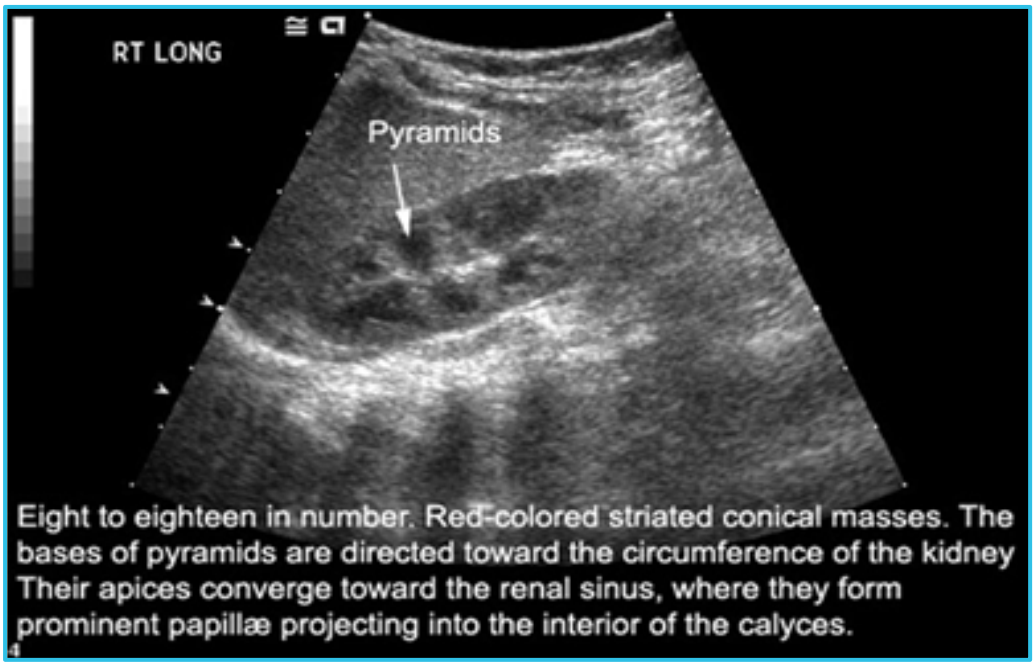
Relations	Right Kidney	Left Kidney
Anterior	*A small part of the superior pole, on its medial side: covered by the right suprarenal gland. *A large part of the rest of the upper part of the anterior surface is: against the liver and is separated from it by: a layer of peritoneum. *Medially: the descending part of the duodenum is retroperitoneal and contacts the kidney *The inferior pole of the kidney on its lateral side: the right colic flexure *The inferior pole of the kidney on its medial side: a segment of the intraperitoneal small intestine.	*A small part of the superior pole, on its medial side: covered by the left suprarenal gland. *The rest of the superior pole is covered by: the intraperitoneal stomach and spleen. *The middle part of the kidney is covered by: the retroperitoneal pancreas *The lower half of the kidney is covered laterally by: the left colic flexure and the beginning of the descending colon *The lower half of the kidney is covered medially by: the parts of the intraperitoneal jejunum.
Posterior	Common relations: *Diaphragm. *Costodiaphragmatic recess, of the pleura. *Psoas, quadratus lumborum, transversus abdominis muscles. *Subcostal (T12), ilio-hypogastric & ilio-inguinal nerves.	
	The right kidney is related to 12th rib and the last intercostal space	As the left kidney lies at higher level than the right, it is related to 11th & 12th ribs and the last intercostal space.

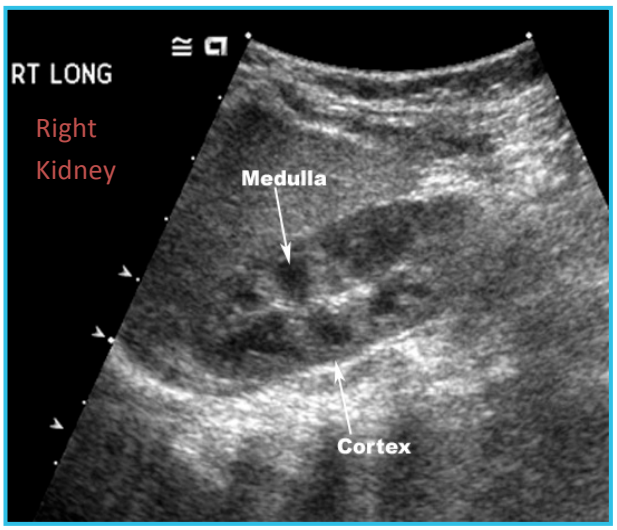
Renal structure:

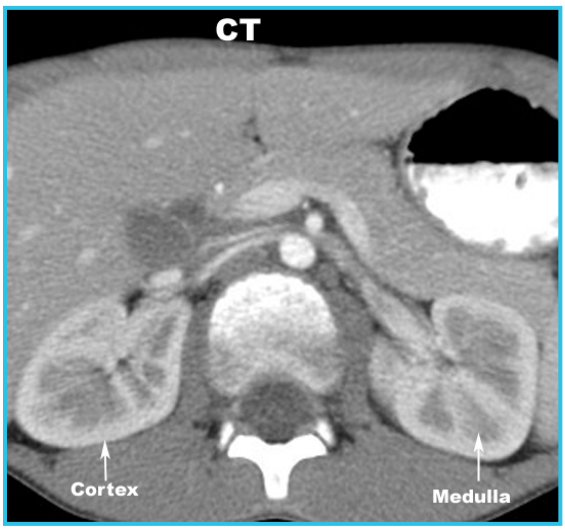
1) Thin capsule.
2) Renal cortex
   - Renal cortex consists of glomeruli and renal tubules.
   - Normal thickness is 2.5 cms.
3) Renal Medulla
   - Consists of multiple renal pyramids, which have their base to the periphery and their conical end directed towards the renal hilum.
   - Their tips are called papillae.
   - Each minor calyx receives 1-3 papillae.











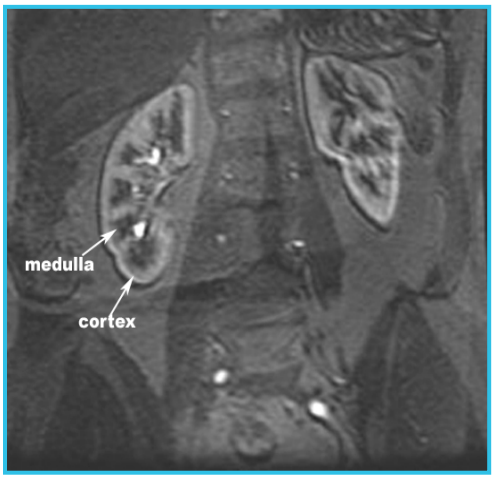
MRI:

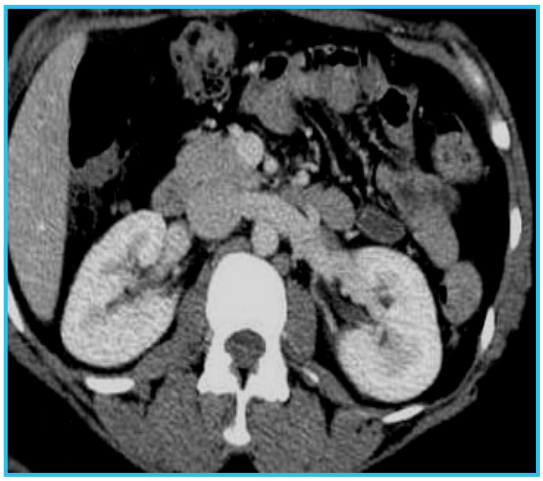
- Used selectively for specific indication.
- Excellent anatomic detail of kidneys.

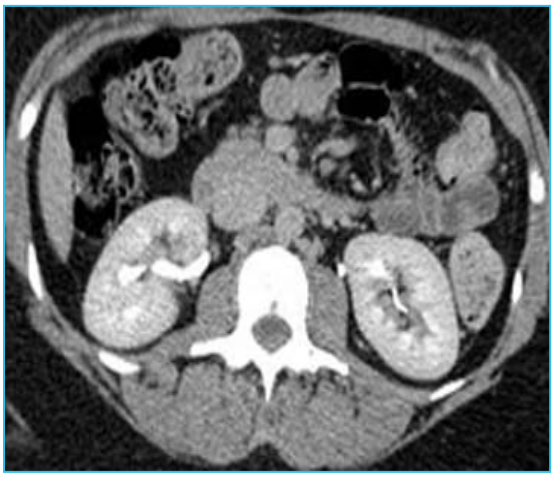
(Especially to detect small tumors)

- Safely performed in renal failure.
- No ionizing radiation.

In some MRI sequences:
Solid organs: grey. Fat:bright
(This gives good visulaization of the kidneys).

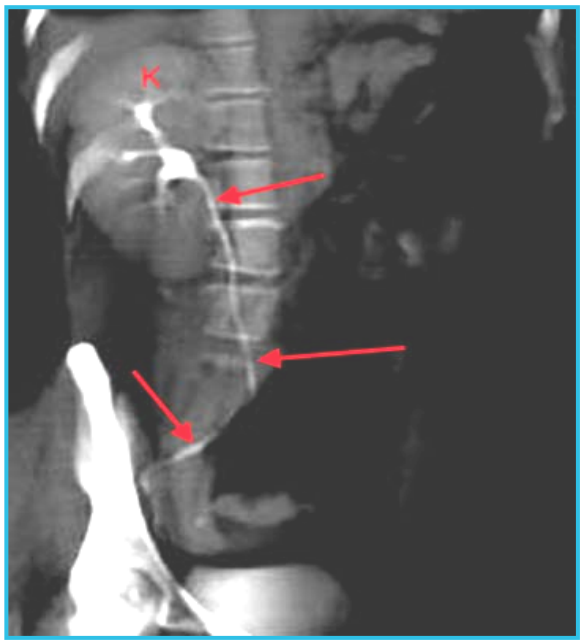




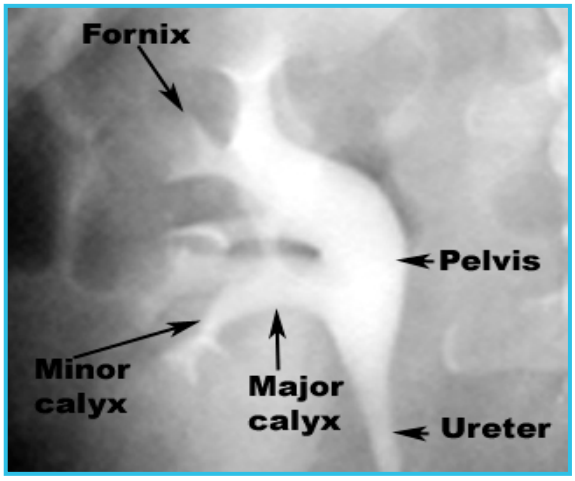


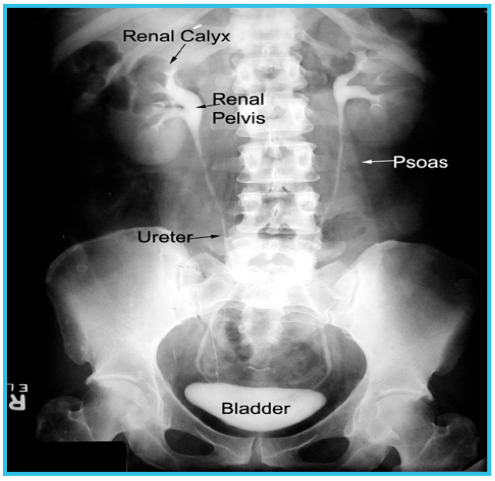
- Contrast enhanced CT scan (coronal) through the kidneys in nephrogram phase (showing corticomedullary differentiation).
- This is approximately 100 seconds following contrast administration and would show renal lesions well.

- Contrast enhanced CT scan through the kidneys in pyelogram phase (showing excretion of contrast into the collecting system).
- This is approximately 8 minutes following contrast administration and would show urothelial lesions well, such as transitional cell carcinoma, stones, and blood clots.



- 3D reconstructed image from CT scan of the abdomen and pelvis known as CT IVP.
- This exam is quickly replacing the conventional IV Urogram.
- 3D reconstruction is performed through the right kidney (K) and follows the normal ureter (arrows) all the way to the ureter's insertion into the bladder.





Renal Collecting System

1) Calyces:

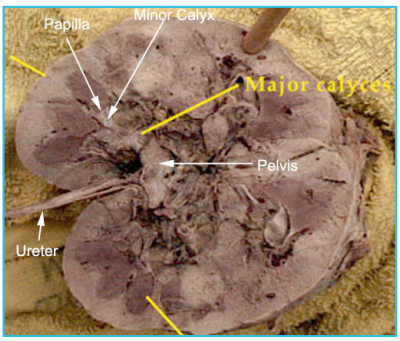
- Medulla sits in the fornix of the minor calyx.
- Fornix is sharp and concave.
- Papillae drain into minor calyces.
- Minor calyces coalesce to form 3 or 4 major calyces.
- Major calyces combine to form the pelvis.

2) Pelvis:

- Broad dilated part of the urine collecting system, located in the hilum.
- Renal pelvis drains into the ureter.

Ureters:

- 25-30 cm in length and 3 mm diameter. (It will be dialted in cases of obstruction)
- Course downwards from the most dependent portion of the pelvis to the midsacral region.
- Then turn posterolaterally and course in an arc downwards.
- Then inward and anteriorly to enter the trigone of the bladder on either side of the midline.



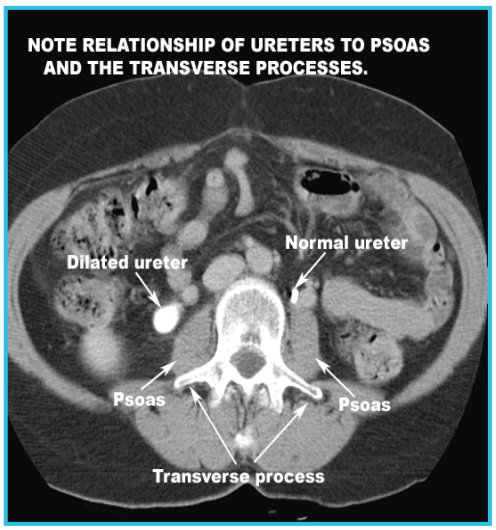
Three areas of normal narrowing:

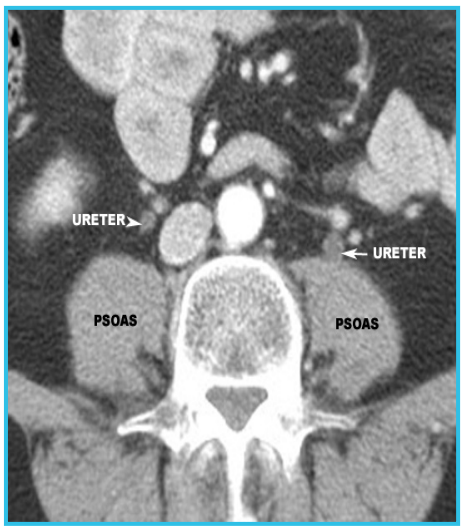
1) Ureteropelvic Junction.
2) Bifurcation of the iliac vessels.
3) Ureterovesicle Junction.

(Stones will most likely be in these areas)

Ureteral Vasculature:

- Blood is supplied by the ureteral branches of renal and testicular or ovarian arteries, and abdominal aorta.
- Renal and testicular or ovarian veins supply venous drainage.

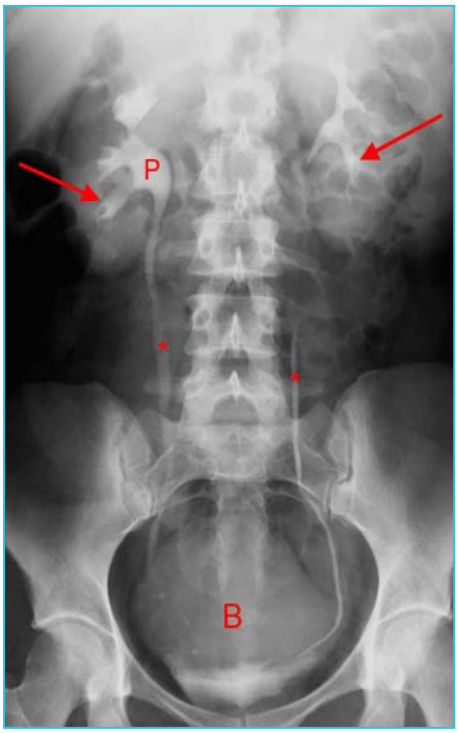


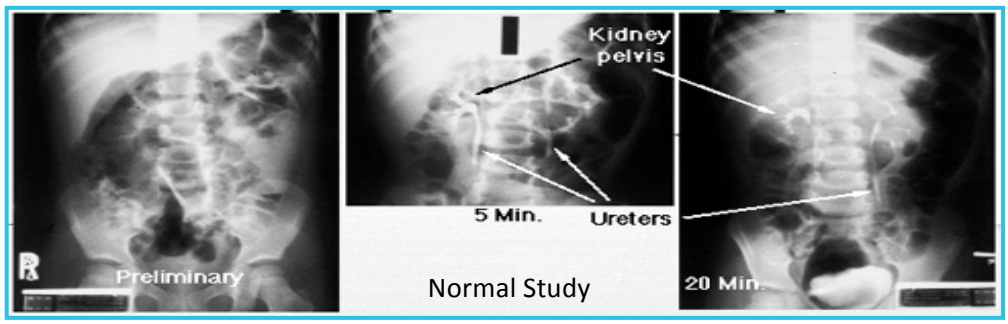


Intravenous pyelogram (IVP or IVU):

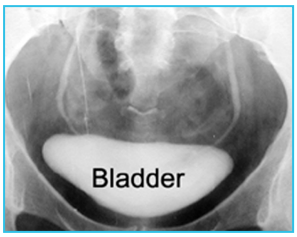
- Demonstrates renal, uretral, and bladder anatomy.
- Gross estimate of function.
- Ionizing radiation.
- Requires IV contrast.
- Patient prep.

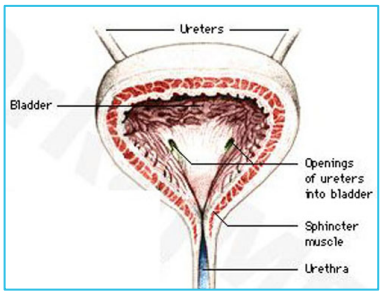
(Level of obstruction and how the system is dilated)





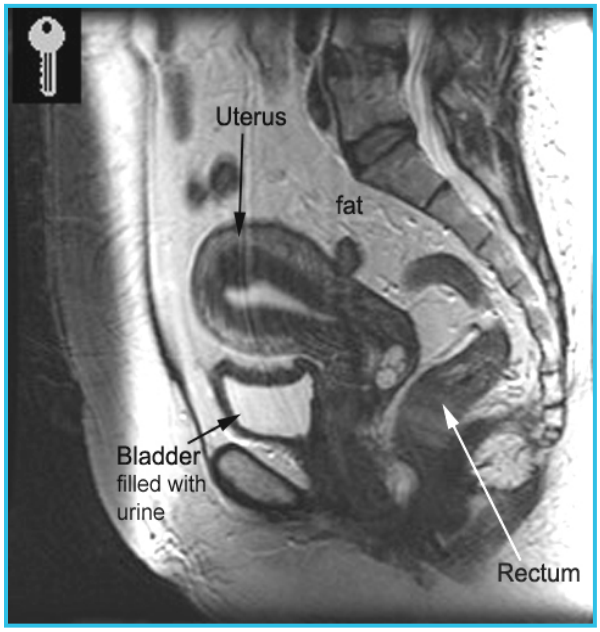
Urinary Bladder: (In the slides, but the doctor didn't mention these details)



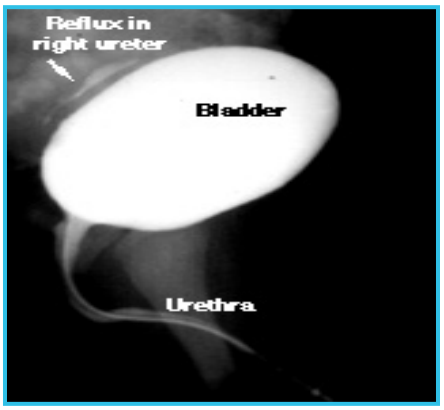


- Hollow muscular vesicle for storing urine temporarily.
- Bladder is higher in position in children and slightly higher in males than females.
- It is relatively larger in children than in adults.
- Size and shape vary considerably.
- Shape when empty: tetrahedral.
- Shape when full: transversely oval or round.
- When empty, it is completely within the pelvis.
- Inferior aspect projects 5-10 mm above the symphysis pubis.
- Separated from pubic bones by retropubic space.
- Floor is parallel to superior aspect of the pubic rami.
- Dome is rounded in male and flat or slightly concave in female.
- Neck of bladder - lies 3-4 cm behind lower part of symphysis pubis and rests on the prostate in the male.
- It has the urethral orifice.
- In females the peritoneum is reflected from the superior surface of the bladder to the anterior wall of the uterus at the junction between the body and cervix.
- The enclosed space is the vesicouterine pouch.
- In males the peritoneum is reflected from the bladder to the superior surfaces of the ductus deferens and seminal vesicles.
- Bladder is relatively free to move except at the neck which is fixed by the puboprostatic ligaments (males) and pubovesicle ligaments (females).
- Peritoneal reflection: Rectovesicle pouch in males, and vesicouterine and rectouterine pouch in females.

Examples of imaging modalities for the bladder:
X-Ray: stones.
CT-scan: masses.
Cystography: To see if there's any reflux –especially in trauma patients- from the bladder to the ureter.

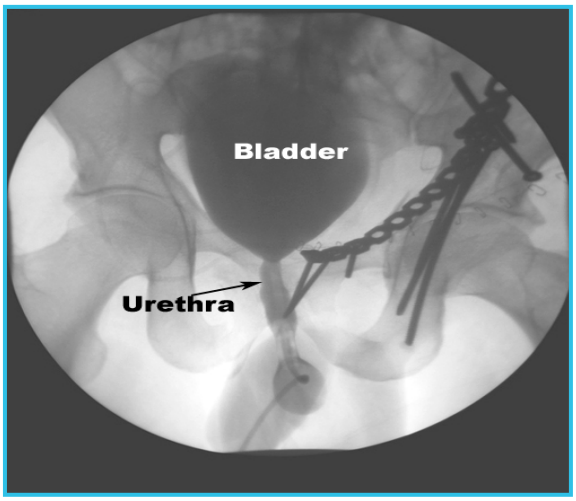


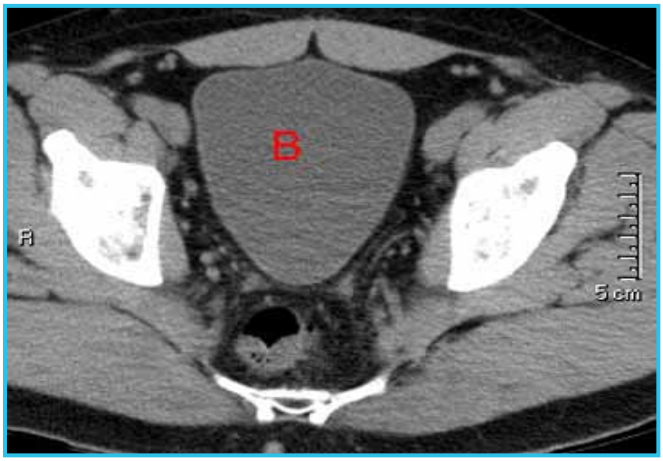
MRI of female pelvis



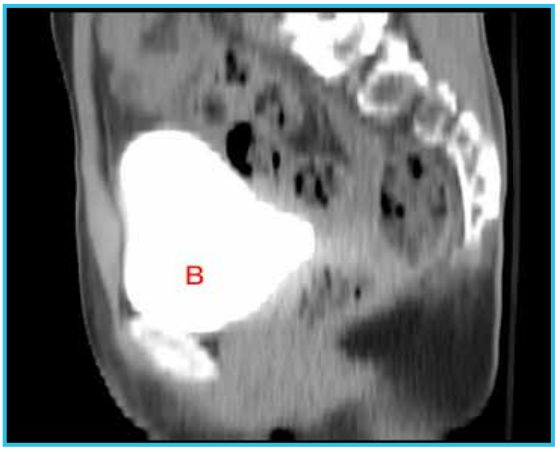
Voiding Cystourethrogram: assess bladder + urethra (best modality)

- A cystourethrogram is an X-ray test that takes pictures of your bladder and urethra while your bladder is full and while you are urinating. To find any rupture, stenosis or other abnormalities.
- Mostly done to children because they often present with UTI due to urine reflux.



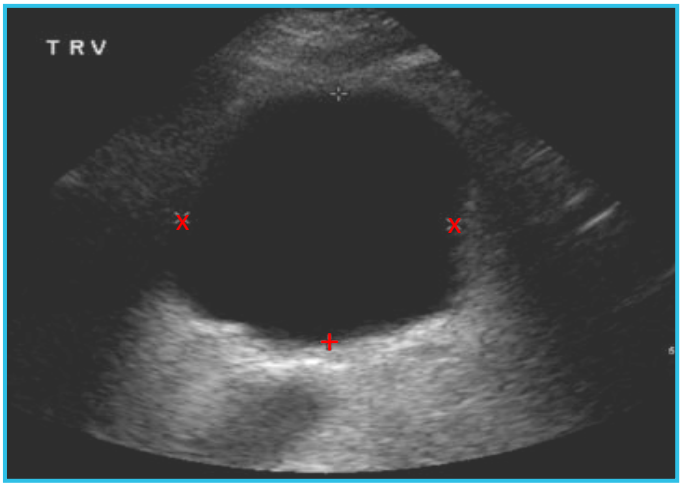


Unenhanced CT scan through a normal bladder (B) shows a normal fluid density structure. (Less than 10 Hounsfield units on CT density

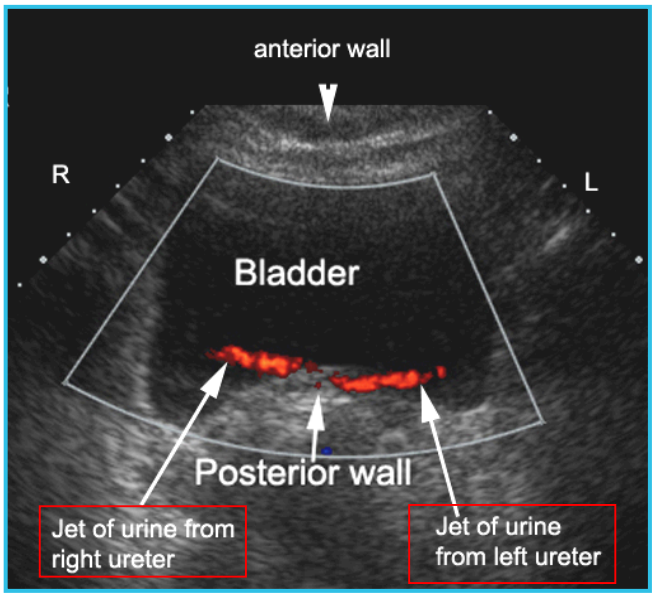


3D reconstructed image of a normal bladder in the sagittal plane following CT IVP.

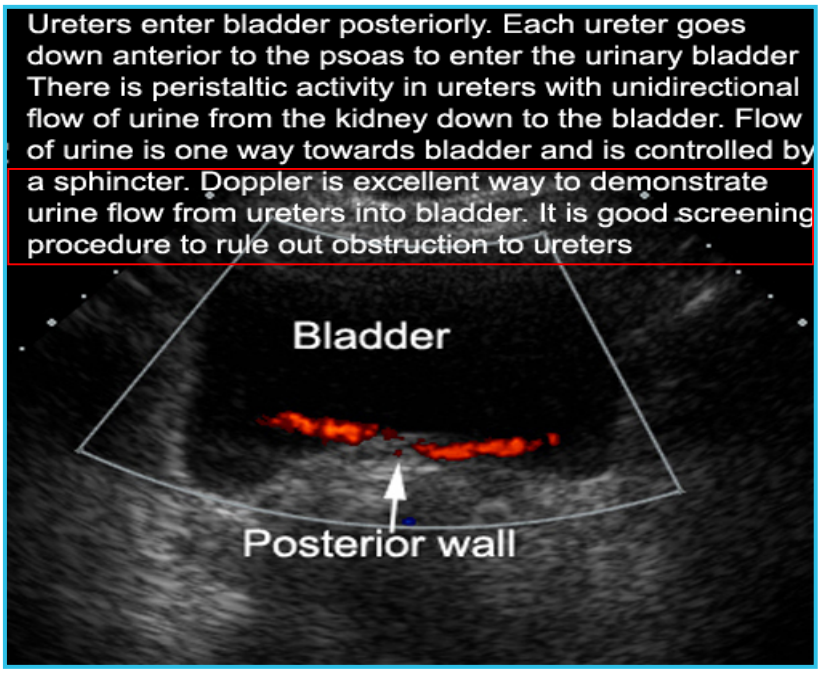
This is delayed image 10 minutes following IV contrast administration; excreted contrast fills an otherwise normal bladder. (B)



Transverse image through a normal bladder (calipers "x" and "+" outline the bladder wall) using ultrasound shows normal anechoic structure. (Anechoic = no echoes = black)



Urine can only be seen in Doppler if it's moving



	Uses/advantages	Disadvantages
X-ray	• Screening for urinary calculi (stones). • Diffuse abdomina pain. • Essential part of IVP.	
Ultrasound	• Best method to measure the size of the kidney • Excellent renal and bladder anatomy. • Can assess blood flow. • To differentiate between solid and cystic masses. • Can be used to evaluate the prostate or to guide biopsies.	• Poor urethral anatomy. • No functional information. (It's an anatomical modality).
CT	• Excellent anatomic details.	• Ionizing radiation → contraindicated in pregnancy.
MRI	• Excellent anatomic detail of kidneys. (Especially to detect small tumors) • Safely performed in renal failure. • Safe in pregnancy. (After the 1st trimester)	
Angiography	• Golden standard to evaluate renal vessels. (Vasculature) • Urinary tract hemorrhage. • Renal artery stenosis. (And hypertension) • Partial nephrectomy. (Therapeutic)	• Significant risk of complication. • Very expensive.
IVP/IVU	• Demonstrates renal, ureteral, and bladder anatomy. • Gross estimate of function.	• Ionizing radiation.