Radiology
Team 438

Radiological anatomy and investigations of urinary system

Lecture 7

Reviewed By
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Objectives

- To know the different types of modalities used in imaging the urinary tract.
- To know the anatomic location and normal size of structures of the urinary tract.
- To identify the kidneys, ureters, urinary bladder and urethra on different imaging modalities.

Color Index: Important | Doctor's Notes | Extra | Female slides | male slides

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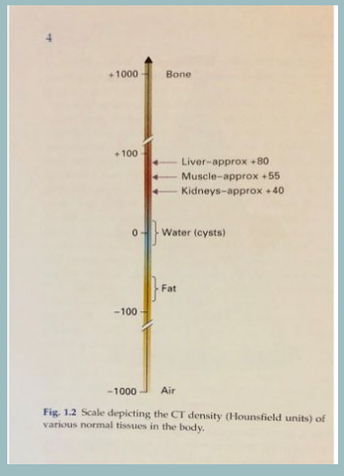
Urinary system

Kidneys | Ureters | Urinary bladder | Urethra

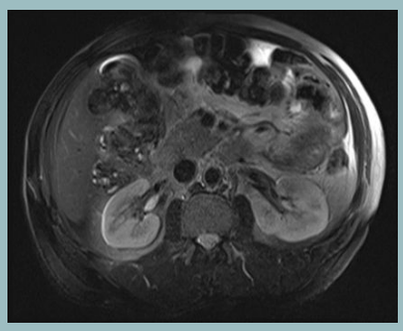
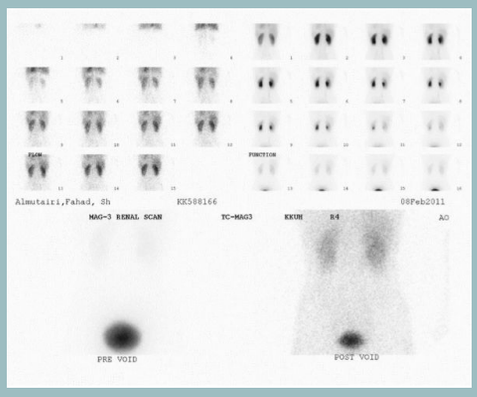
Imaging Modalities

Imaging Modality		Features
Plain X-Ray 	• First imaging modality • Cheap. • Useful for radio-opaque (white) stones. • x- ray is the basic modality in the beginning. • **"KUB" is X-ray of kidney, ureter, and bladder.** • Gives us quick diagnosis of renal colic (used in emergency department)	• Projectional image. • Image contrast determined by tissue density. • Good evaluation of radio-opaque stones.
Intravenous Urogram (IVU) 	• Conventional x-ray + IV contrast • Cheap. • Recently replaced by CT and MRI. • Useful for radio-opaque stones Contrast is injected through a vein then is mainly excreted via a kidneys and urinary system. It usually takes 7 to 8 minutes or even 10 in the elderly	• Projectional image. • Image contrast determined by tissue density and IV contrast. • Good evaluation of collecting system and radio-opaque stones.

Imaging Modalities

Imaging Modality		Features
Ultrasound 	• Uses High Frequency Sound Waves (No Radiation). • Contrast (the contrast is only because of different bodily structures) between tissue is determined by sound reflection. Best for soft tissue liver,spleen,kidney,bladder.	• Projectional imaging • Operator dependant. The person operating ultrasound decides to save images of what he thinks is significant. So maybe they miss saving something. While in CT and MRI images is taken for everything independently on operator. • Good resolution. • Used for stones , hydronephrosis,and focal lesions.
Computed Tomography   Fig. 1.2 Scale depicting the CT density (Hounsfield units) of various normal tissues in the body.	• Same basic principle of radiography. • More precise. • Costly. • +/- contrast.=risk • Useful for trauma, stone, tumor(with contrast) and infection. CT=100 x rays in spiral directions(helical) **CT densities in Hounsfield units:** • Bone has +1000 (Highest density) • Soft tissue 40-80 , according to which organ • Blood 40 • Water 0 • Fat -100 • Air -1000 (Lowest density)	• Cross sectional images. • Image contrast determined by tissue density +/- contrast. • Better evaluation of soft tissue. Usually CT of kidneys is without contrast (e.g. **we don't use contrast for assessing stones**)but mainly we add contrast to get more details and to assess the other pathologies because in CT without contrast,all tissues will have the same shade of grey

Imaging Modalities

Imaging Modality		Features
Magnetic Resonance Imaging 	• Better evaluation of soft tissue. • Uses magnetic field (No Radiation). • Expensive. • Useful for soft tissue pathology: tumor, infection Disadvantages: • Time consuming • Claustrophobic CT takes 5-8m MRI takes 30m at least	• Cross sectional images. • Image contrast determined by tissue properties. • Excellent for soft tissue evaluation. • Good for tumors
Nuclear Medicine (Scintigraphy) 	• Utilizes a gamma camera and radioactive isotopes.The radioactive source is the patient • Functional test. • Less expensive. • Useful for: obstruction and **split function** If we want to assess the function of each kidney (separately) we use nuclear medicine because it assess "split function" of each kidney separately (the normal kidney takes the radioactive material more than the failing kidney. The failing kidney -in renal failure- doesn't take the radioactive material).	• Projectional image. • Image contrast by tissue uptake and metabolism

indication for urography

Q)Where is the left kidney?
D (Don't forget in all radiology your left is the pictures right (opposite)…

except in nuclear medicine (also called scintigraphy) the right is also right (same side). We always say that nuclear medicine is used to assess function… here also CT with contrast is used to assess the function of renal system

Main indication for urography :

Indication of intravenous Urography or CT urography

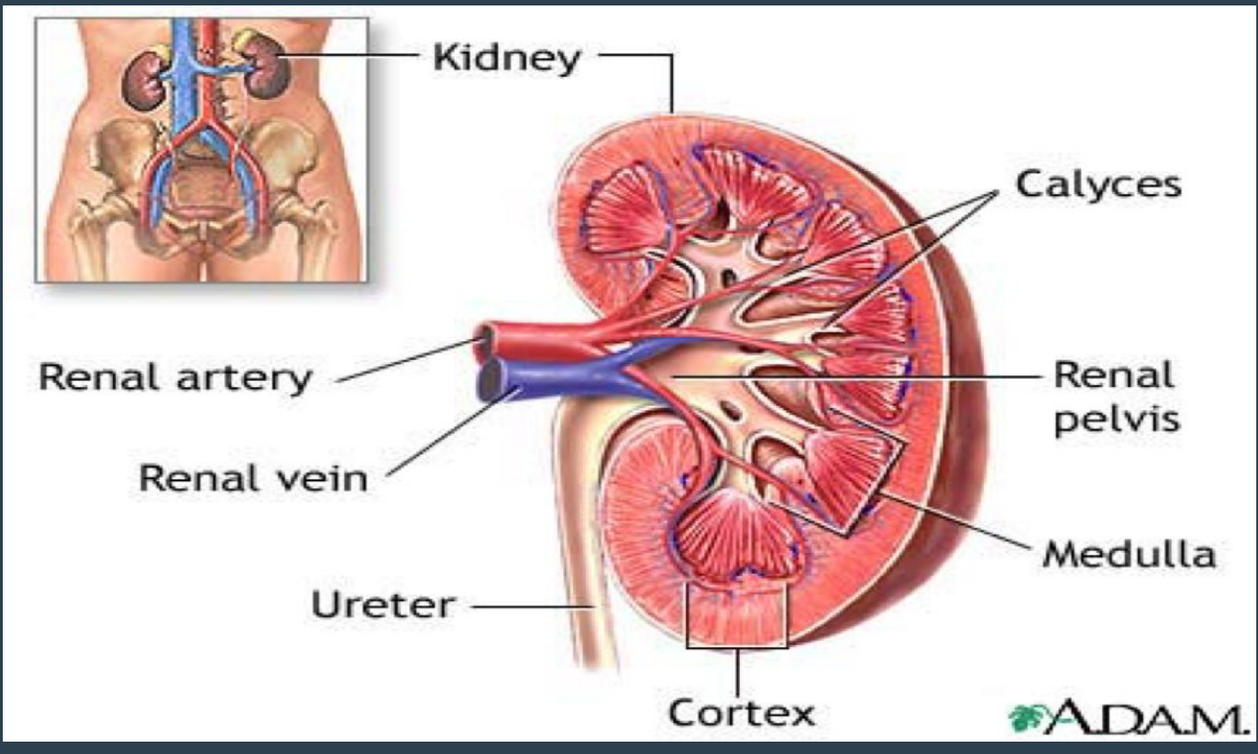
- Detailed demonstration of the pelviceal system and ureters are required.
- In suspected ureteral injury ex.following pelvic surgery or trauma. ex:C section they cut the ureter by mistake we will see hyperdense material
- Assessment of ureteric colic.we start with KUB and US then we do CT without contrast then CT with contrast

Indications of CT urography

- investigation of renal calculi.
- mainly, Investigation of haematuria.suspect tumor
- Characterization of renal mass.
- Staging and follow up of renal carcinoma.
- To delineate renal vascular anatomy .(e.g. suspected renal artery stenosis, prior live related kidney donation,to know the kidney is ok and not infarcted,atrophied or scarred).
- To diagnose / exclude renal trauma

Kidneys Anatomy :

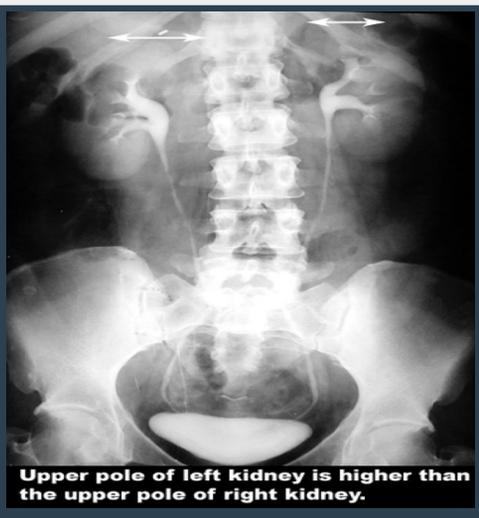
- Bean shaped structure.
- On either side of the lower thoracic and upper lumbar spine.
- Usual location – between (T11-L3). If you got confused where kidneys are in an image, look between T12-L1 where the renal arteries are.
- Right kidney is 2 cm lower than the left kidney. because of the liver
- Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles.
- Lower pole is 2-3 cm anterior to the upper pole. so we have to put the US probe in the right anatomical position in order to get a good sagittal view of the kidney, also while inserting a catheter it's important to know the right anatomical location of the kidney.
- Normal size: in adults 10-12 cm.
- Kidneys are visualized on the X-Ray due to presence of perirenal fat.
- They (The kidneys) are contained within the renal capsule and surrounded by perirenal fat = normal contrast and enclosed within the Gerota's fascia.
- Perirenal hemorrhage, pus and urine are contained within the fascia and detected on CT and US. Ex perirenal hematoma,perirenal urinoma

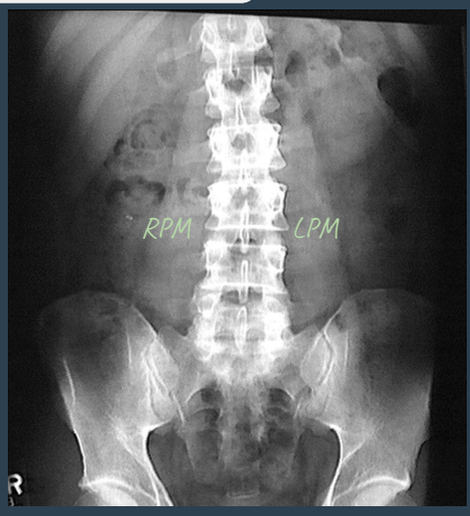


Conditions associated with enlarged kidneys Important		
	Diagnosis	Imaging
Always Unilateral	Compensatory hypertrophy.	Opposite kidney small or absent
May be Unilateral or bilateral	Bifid collecting* system Upper pole goes to seperate renal pelvis and lower pole goes to another seperate pelvis and even sometimes there is double ureter causing hypertrophy	Diagnosis obvious from abnormalities of collecting system
	Renal mass	Mass is seen
	Hydronephrosis** collection of urine in kidney caused by obstruction	Visible distension of the renal collecting system
	Lymphomatous infiltration	May show obvious masses; the kidneys may, however, be large but otherwise unremarkable
Always bilateral	Renal vein thrombosis.	No Doppler signal is visible in the renal vein and thrombus may be evident.
	Polycystic disease	Characteristic imaging appearance
	Acute glomerulonephritis	Non specific enlargement
	Amyloidosis	Non specific enlargement (rare)

Conditions associated with small kidneys Important		
	Diagnosis	Imaging
Unilateral but may be bilateral	Chronic pyelonephritis	Focal scars and dilated calices
	Tuberculosis	
	Obstructive atrophy	Dilatation of all calices with uniform loss of Renal parenchyma
	Renal artery stenosis or occlusion	Outline may be smooth or scarred, but the calices appear normal
	Hypoplasia	Very rare; kidneys may be smooth or irregular in outline with fewer calices may be clubbed
Always bilateral	Radiation nephritis	Small in size but no distinguishing features
	Chronic glomerulonephritis of many types	Usually no distinguishing features. In all the conditions the kidney may be small with smooth outlines and normal pelvicaliceal systemse
	Hypertensive nephropathy	
	Diabetes mellitus	
	Collagen vascular disease	
	Analgesic nephropathy	Calices often abnormal

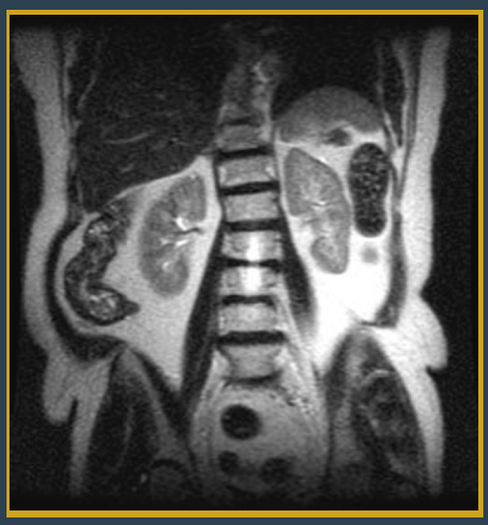
kidney



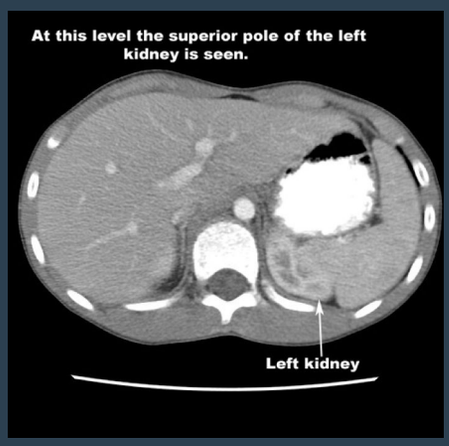


We don't usually see ureters in X-ray unless we are using contrast

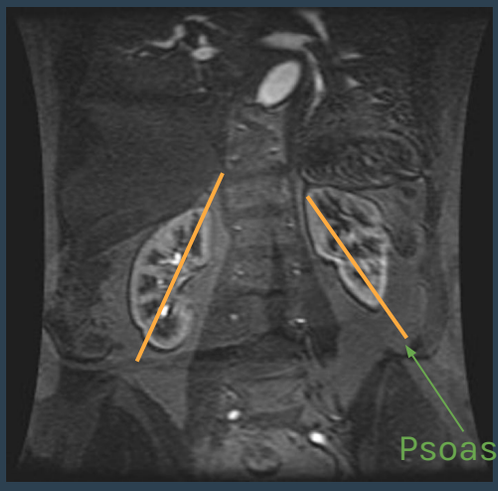
Kidneys are retroperitoneal organs and may be obscured by bowel loops, gas, fecal matter
Left and right psoas muscle



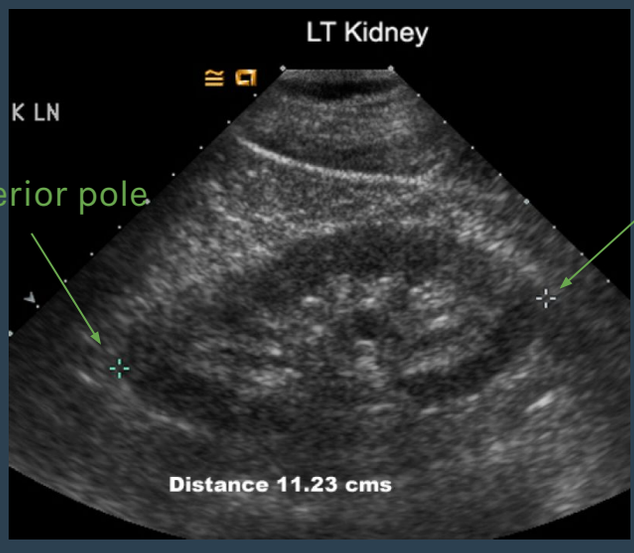
Coronal MRI showing Left Kidney is higher than Right Kidney



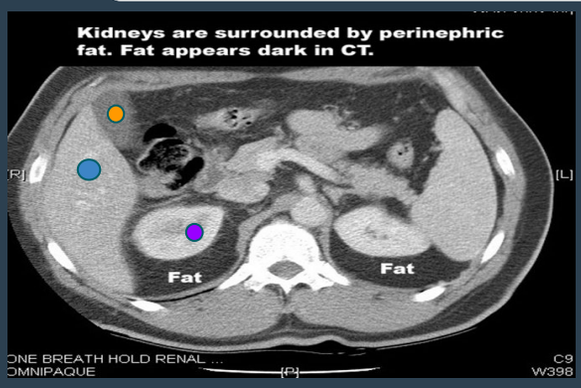
CT Scan showing left kidney higher than right
Remember that right kidney is lower in level that left kidney (because of liver)
so in CT don't quickly think of an absent kidney!
Maybe it's just the level of the image



Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles

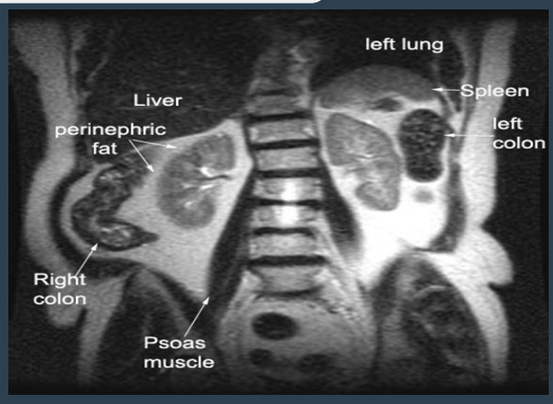


Ultrasound is the best method to measure the size of the Kidney and the structure



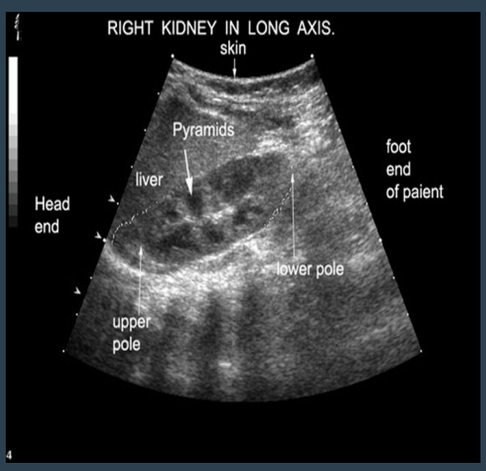
This image shows CT with contrast.

- liver appears hyperdense
- gallbladder appears hypodense
- we can visualize the kidney borders because of the difference in densities between the kidney and the perirenal fat.



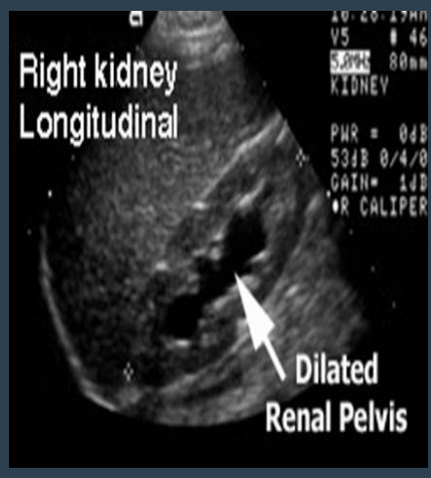
MRI: Fat is bright in T2 (natural contrast)

Ultrasound of the kidney:



sagittal Ultrasound of Right Kidney.upper pole is always on your left

Normal study
Collapse collecting system=normal no obstruction or dilation

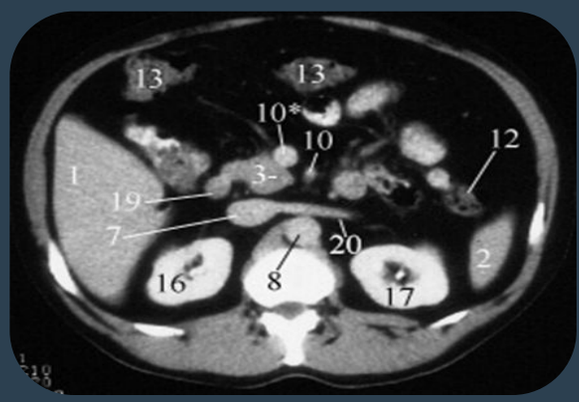


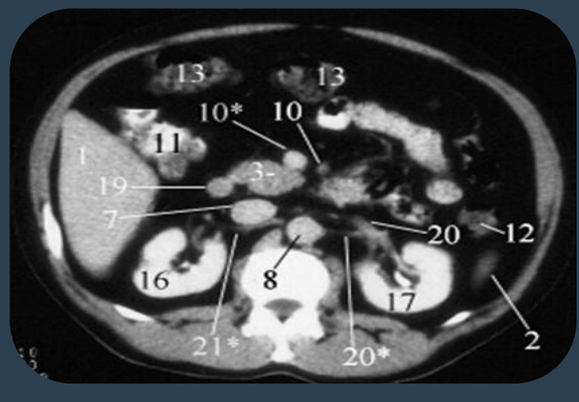
Dilated Renal Pelvis

CT Scan of the kidney:

VERY Important!

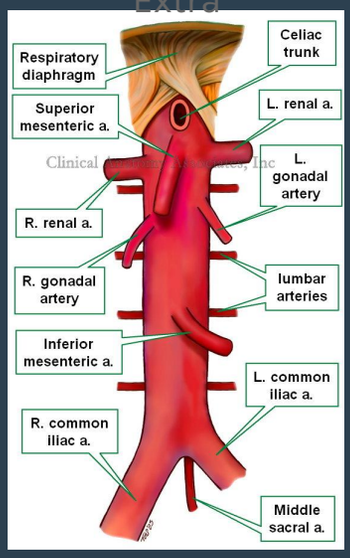
1-Liver.
2-inferior part of the Spleen.
3- Pancreas.
7-IVC.
8-Aorta.
10-superior mesenteric artery
11-Bowel.
12-Descending colon.
13-Transverse colon.
16-Right kidney.
17-Left kidney.
19-mesenteric vein
20-Renal vein.





Renal Vasculature: IMPORTANT

Extra

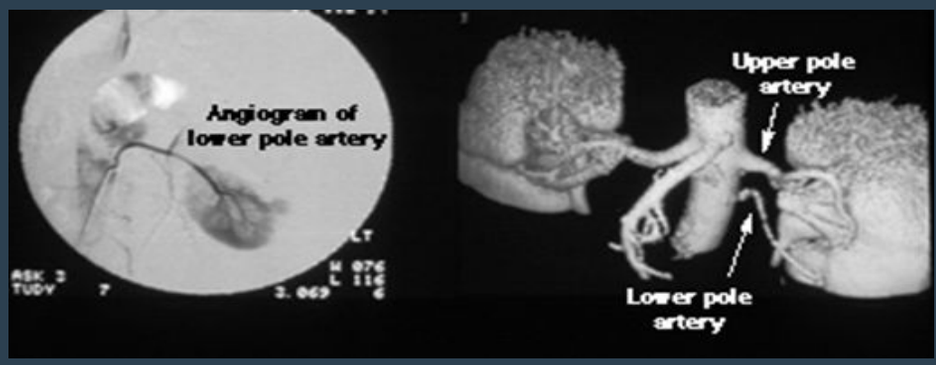


- Renal arteries branch from the abdominal aorta laterally between L1 and L2, below the origin of the superior mesenteric artery.
- The right renal artery passes posterior to the IVC.
- There may be more than one renal artery (on one or both sides) in 20-30% cases.which we call accessory's arteries
- Renal veins drain directly 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 to left renal vein while the right gonadal vein drains directly into the inferior vena cava
- Since left gonadal vein drains into left renal vein, more hydrostatic pressure is put on left renal vein and that may cause a condition called varicocele in males While in females may cause pelvic congestions.
- Gonadal vein in males is testicular or spermatic vein while in females it is ovarian vein.
- (important)To Remember the main branches of abdominal aorta (from up to down): celiac trunk and its branches (left gastric artery,splenic artery,common hepatic artery which gives us proper hepatic artery and gastroduodenal artery), then superior mesenteric artery then renal arteries then inferior mesenteric artery
    - So renal artery is located between the superior and inferior mesenteric.

Renal angiography

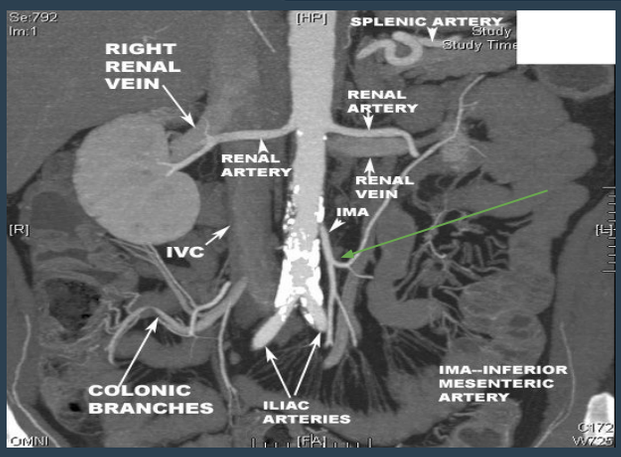
- It's important to know the anatomy because sometimes there is an accessory renal artery (extra artery) we see that mostly connected with the lower pole of kidney.
- *Why it is important to know if there is an extra renal artery?* Because if you were planning to do a nephrectomy to this patient and you don't know about this extra artery then hematoma might happen and then the patient may die (so they make this reconstructive CT before surgery)

Normal Supply Of Both Kidneys each By Single Renal Artery



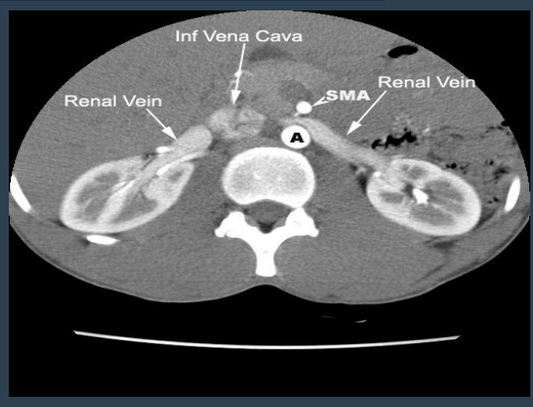
Left Kidney Supplied By Two Renal Arteries=accessory renal artery in lower pole,

kidney

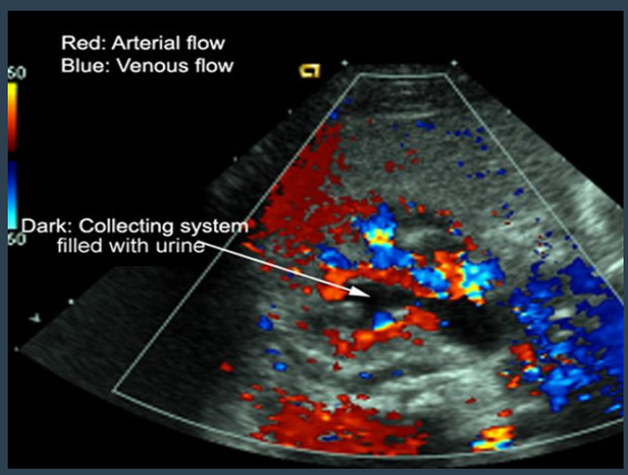


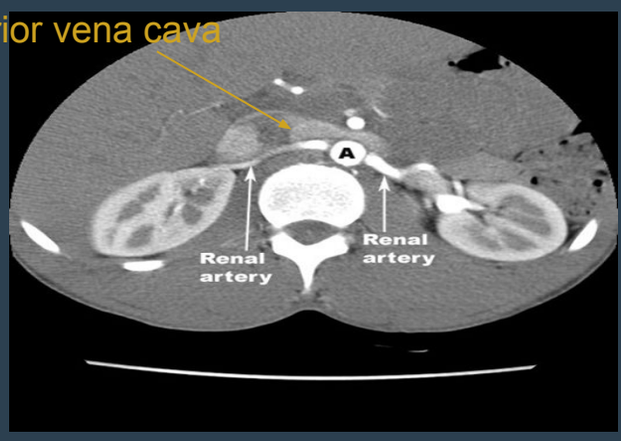
Coronal CT reformat

Coronal reconstruction of CT with IV contrast… here we see calcification of aorta.Why we see the artery more dense?We call this arterial phase because the contrast is now in the arteries



Left Renal Vein Passes Anterior to the Abdominal Aorta and posterior to superior mesenteric artery (SMA), sometimes left renal vein is compressed between superior mesenteric artery and abdominal aorta which causes left renal vein stenosis **(nutcracker syndrome) causing renal congestion and hematuria**



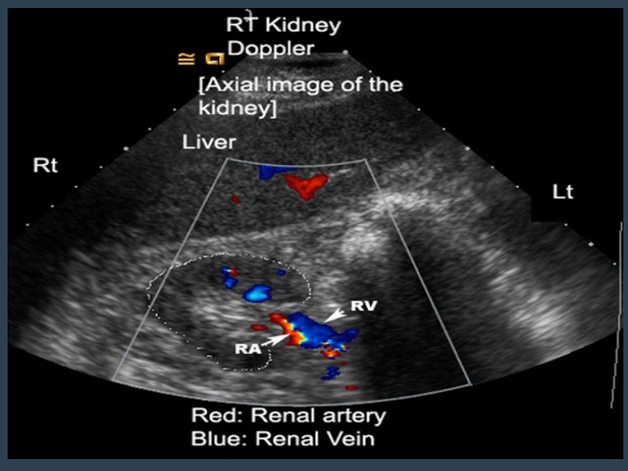


In doppler we see high flow of blood in arteries and veins but we don't see urine because urine is not high in flow (not quick) so with doppler the urine appears black while blood in arteries and veins appear colored.so their is hydronephrosis

When you want to image arteries or veins with contrast remember it's all about the timing.

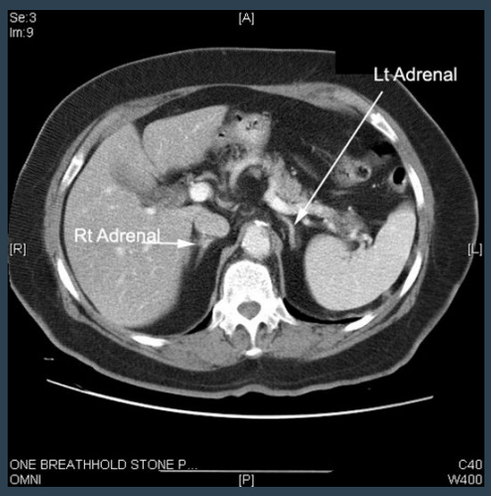
Here we don't see contrast in renal veins because of the time when the image was taken. If you want to image with contrast you will inject it to a vein (e.g. in hand of patient)

1) within few seconds, the contrast will reach the heart via vena cava
2) then become pumped into aorta and different major arteries in the body (after 20-30 seconds of injecting contrast it reaches arteries)
3) wait for the blood to be exchanged within the capillaries which will go back to veins again. This is called venous phase which takes 70s.
4) then there is the nephrogenic phase which is 70-80s to visualize the cortex of the kidneys

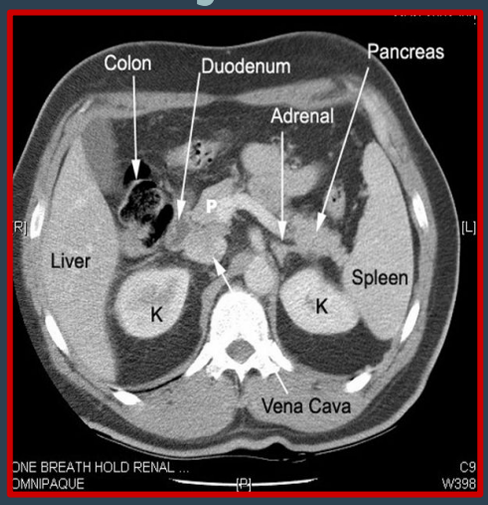


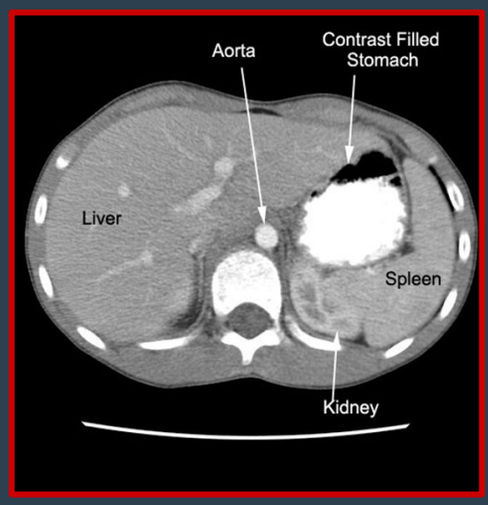
Doppler study: Renal Veins Lie Anterior to the Arteries Always the arteries are deeper than veins

Relations of the kidney :



Adrenal Glands are superior to the Kidneys





It's important to know the basic structures ex:liver,pancreas,aorta,IVC,spleen,question may come as labeling along with the labeling pictures on page 9

Renal Structure:

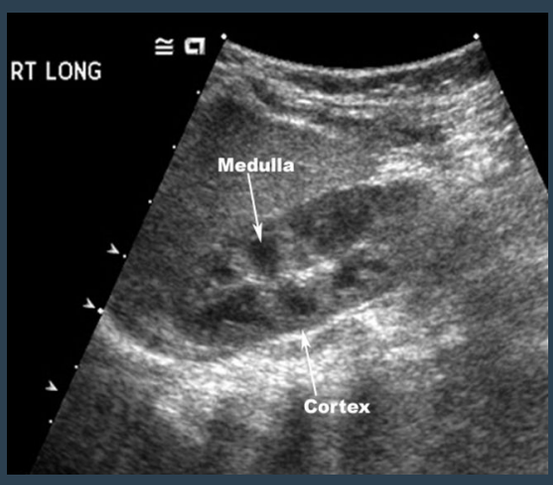
Cortex

- Renal cortex consists of glomeruli and renal tubules.
- Normal thickness is 2.5 cm. When the thickness is less than 1cm that means there is cortical thinning which can give us an early indication of renal failure,so determining the thickness by US can help us determine the function of the kidney

Medulla

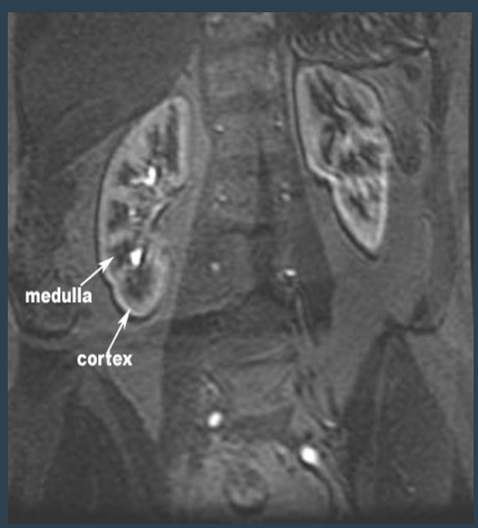
- Consists of multiple renal pyramids.

Normal kidney showing hyperdense cortex and hypodense pyramids of the medulla

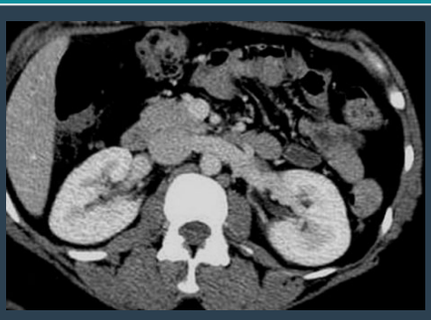


Ultrasound of Right Kidney showing Normal hyperechoic cortex and collecting system and hypoechoic pyramids of the medulla

If you can see collecting system there must be obstruction causing dilation, normally you should not see it on US



MRI OF Kidneys

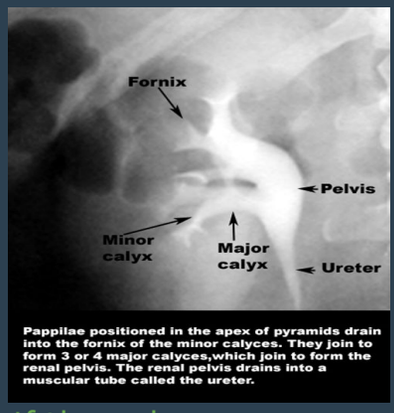
Nephrogram phase	Pyelogram phase	CT Urology
		
• Contrast enhanced CT scan through the kidneys in nephrogram phase (showing corticomedullary differentiation). • This is approximately 100 seconds following contrast administration and would show renal lesions well. • If the kidney isn't filtering well there will be thinning of the cortex for less than 2.5 cm (remember that nephrons -responsible of filtration- are present in renal cortex). • Cortex appears more whitish than medulla.	• Contrast enhanced CT scan through the kidneys in **pyelogram phase** also called excretory 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, blood clots. It will be seen as a **filling defect**	• 3D coronal reconstructed image from CT scan of the abdomen and pelvis known as CT urography. • **Nowadays, this exam is quickly replacing the conventional IVU.** • 3D reconstruction is performed through the right kidney (K) and follows the normal ureter (arrows) all the way to the ureter insertion into the bladder.

Renal Collecting System:

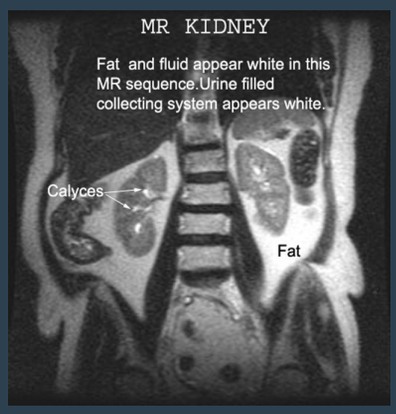
Calyces
- Medulla sits in the fornix of the minor calyx.
- Papillae drain into minor calyces.
- Minor calyces coalesce to form 3 or 4 major calyces.
- Major calyces combine to form the pelvis.

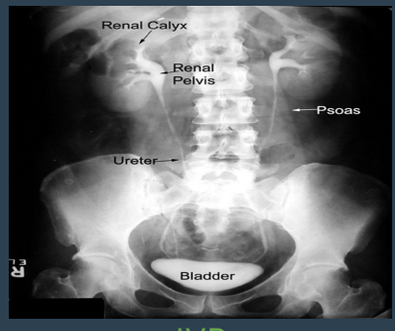
Pelvis
- Broad dilated part of the urine collecting system, located in the hilum
- Renal pelvis drains into the ureter"

(Ureteropelvic junction is the most common place for stones)

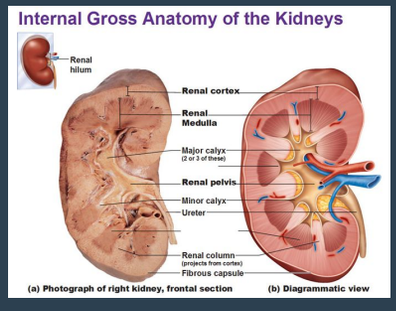


If the calyx are convex that means their is obstruction





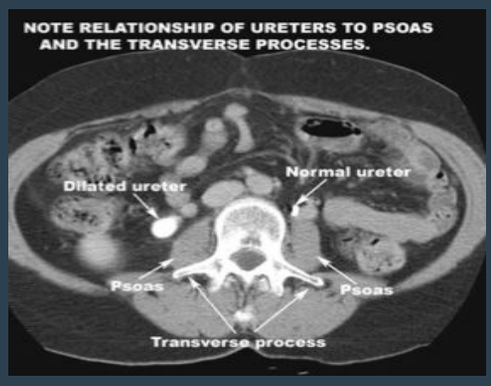
IVP



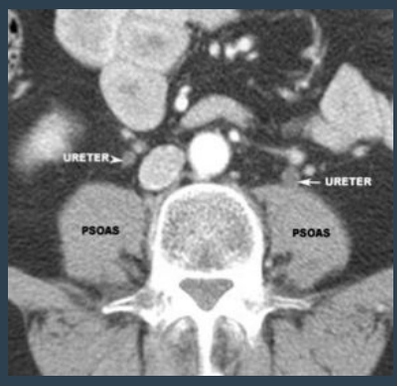
Urinary bladder

Ureters:

● 25-30 cm in length and 3 mm diameter. If ureters' diameter is wider than 3mm then it might be dilated because of a stone or tumor obstructing down
-to image the ureter we never use US. we use CT with contrast
● **Three areas of normal narrowing:**
1)Ureteropelvic Junction.start point
2)Bifurcation of the iliac vessels.
3)Ureterovesical Junction.end point
(When there is stone usually it impacts stuck) in these areas.



CT urography with contrast in excretory phase showing dilated ureter so if we scroll down we will probably see tumor or stone.Since this image show contrast inside ureters then this is **excretory phase**



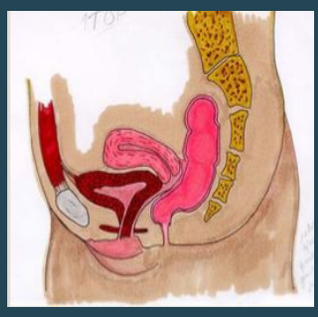
Shows CT in arterial phase you see contrast in aorta but no contrast in ureter so poor assessment of the ureter

Urinary bladder:

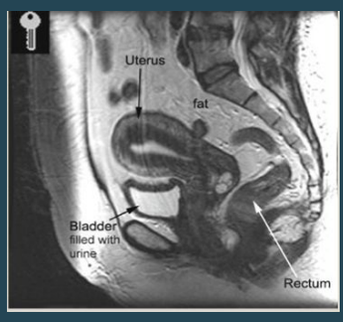
- Size and shape vary considerably
- When empty, it is completely within the pelvis.
- Dome is rounded in male and flat or slightly concave in female because of the uterus
- Bladder is relatively free to move except at the neck which is fixed by the puboprostatic ligaments (males) and pubovesical ligaments (females).
- Peritoneal reflection - Rectovesical pouch in males and vesicouterine and rectouterine pouch in females.one reflection in males and two in females

Anatomy of M&F pelvis showing the urinary bladder sagittal section

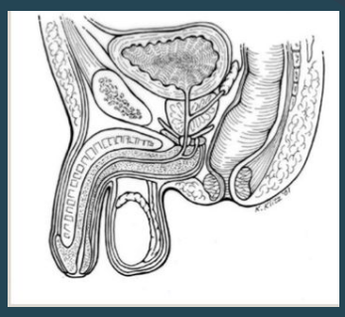
You should know the relation between the rectum,uterus,bladder



Female



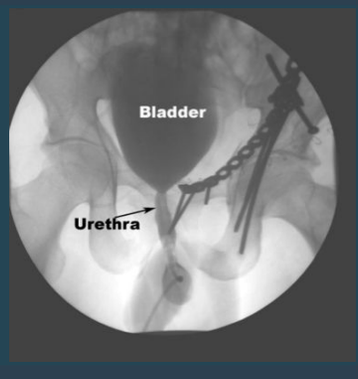
Female



male

Voiding Cystourethrogram

We inject contrast through urethra into the bladder to see if there is reflux to the ureter which is abnormal indicating vesicoureteral reflux



Urinary bladder cont..

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

Why the bladder is hypodense here? because of urine.

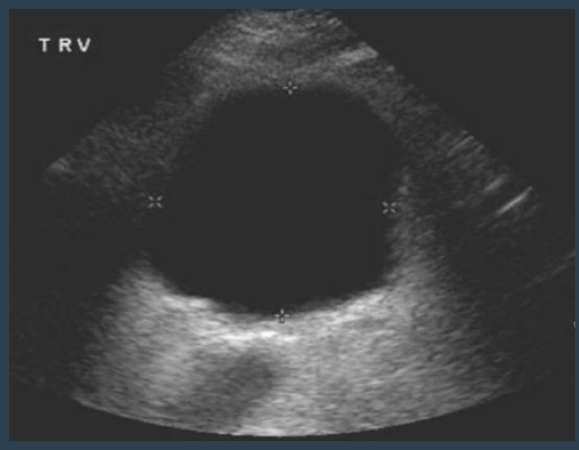
- 3D reconstructed sagittal image of a normal bladder in the sagittal plane following CT urography.
- This is delayed image 10 minutes following IV contrast administration, excreted contrast fills an otherwise normal bladder (B)

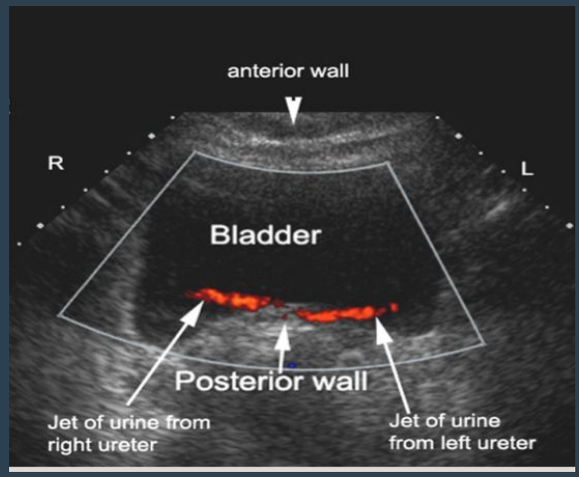
Bladder with filled contrast=late excretory phase(10s after IV contrast injection)very good for assessing urinary bladder tumors

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

We do ultrasound for bladder to see if there is any pathology. Sometimes if we suspect presence of stones we use doppler to see the flow (when ureters want to void urine into bladder they contract. As a result, urine flows through ureters into bladder quickly, if one ureter is obstructed by stones we see difference in flow between the two sides).

Normally we see two urethras jets,if we see one that indicates obstruction





Prostate gland

Prostate gland:

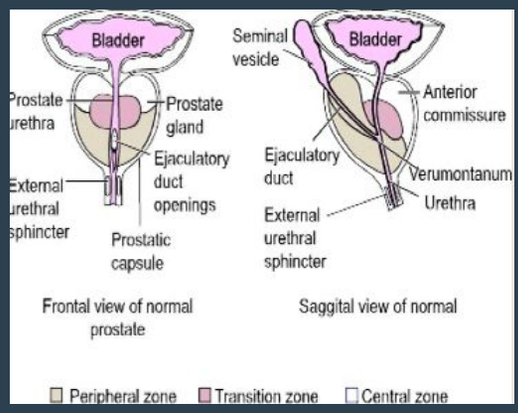
- Largest accessory gland of male reproductive system.
- Lies around the first part of the urethra at the base of the bladder (Tr=Transitional) 4 cm x 3 cm (height) x 2 cm (AP) in size.
- Surrounded by dense fibrous capsule.

- Anatomy of prostate gland:

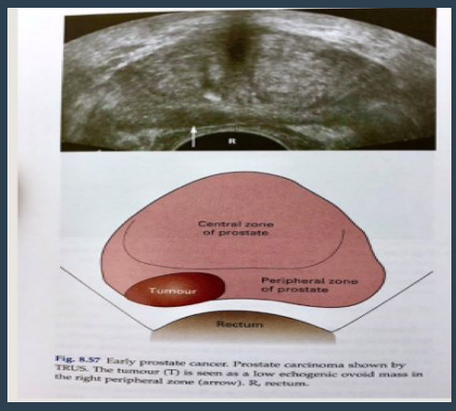
1. Base – closely related to neck of bladder.
2. Apex
3. Posterior surface
4. Anterior surface.
5. Anterolateral surfaces.

- Prostate gland can be divided into:

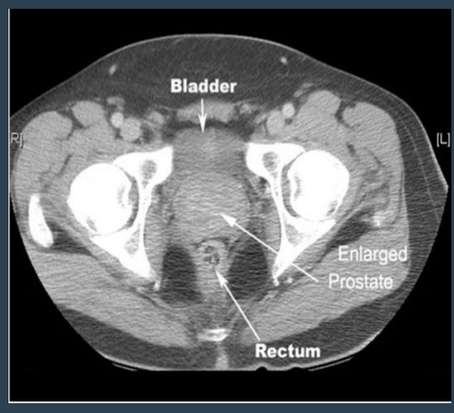
1. An inner gland – transition zone.
2. An outer gland – central and peripheral zones.



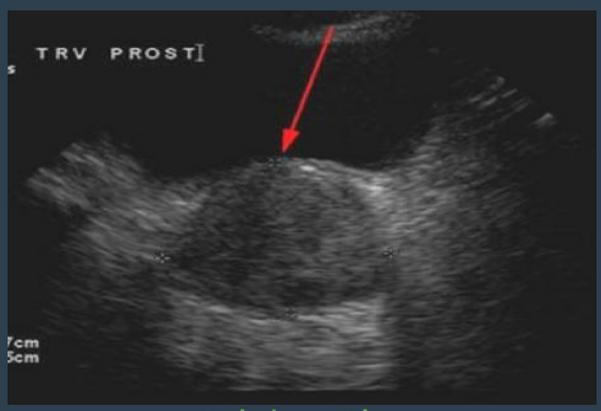
- **Transition zone** which lies in periurethral location is the site of **benign prostate hypertrophy** which can occlude the urethra.
- **Peripheral zone** is the primary **tumor** site in 70% patients.



Hypoechoic tumor in the periphery



Usually CT is not good for prostate and pelvic organs in general, MRI is better



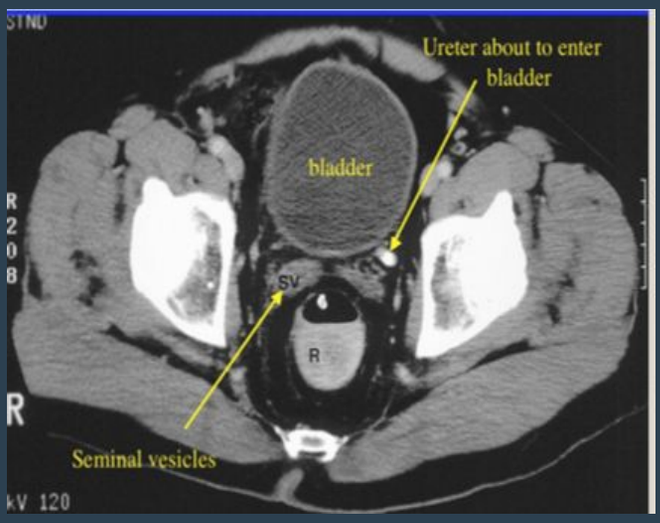
Axial section

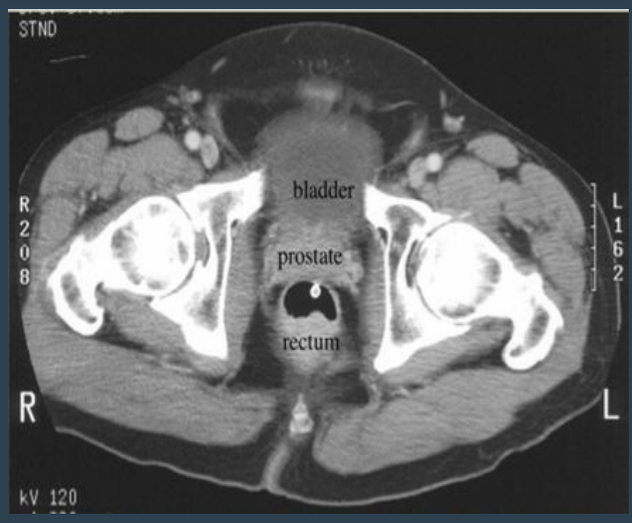
Sagittal section

We can measure the volume of the prostate and the best way is by endorectal US

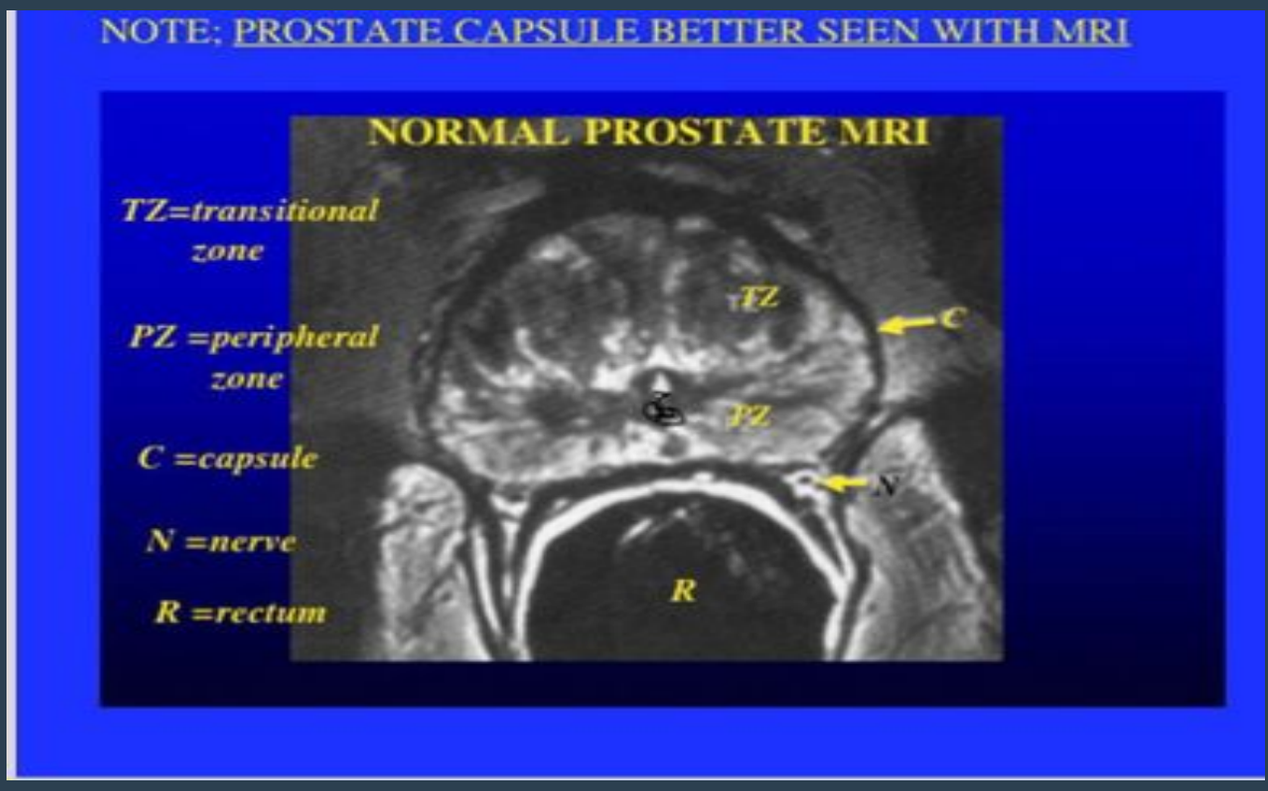
(An US for the bladder, and the red arrows indicates enlarged prostates.)

Prostate gland cont...





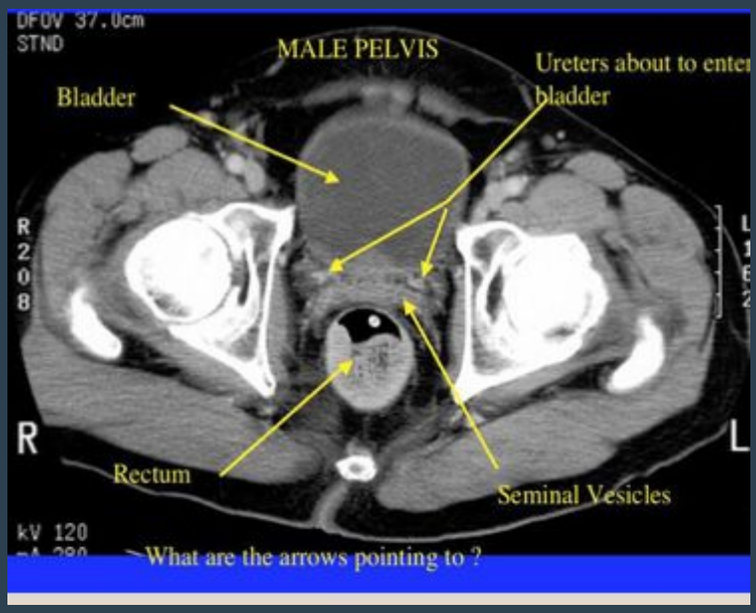
Prostate just anterior to the rectum easy to palpate on digital rectal exam

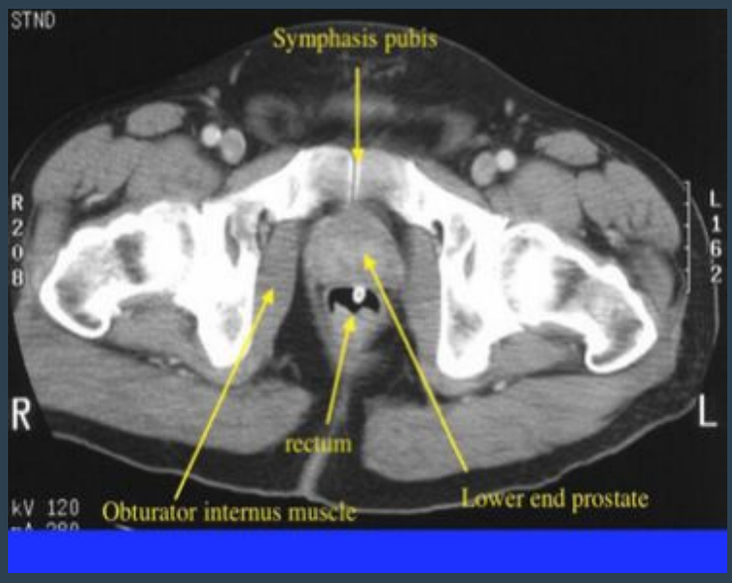


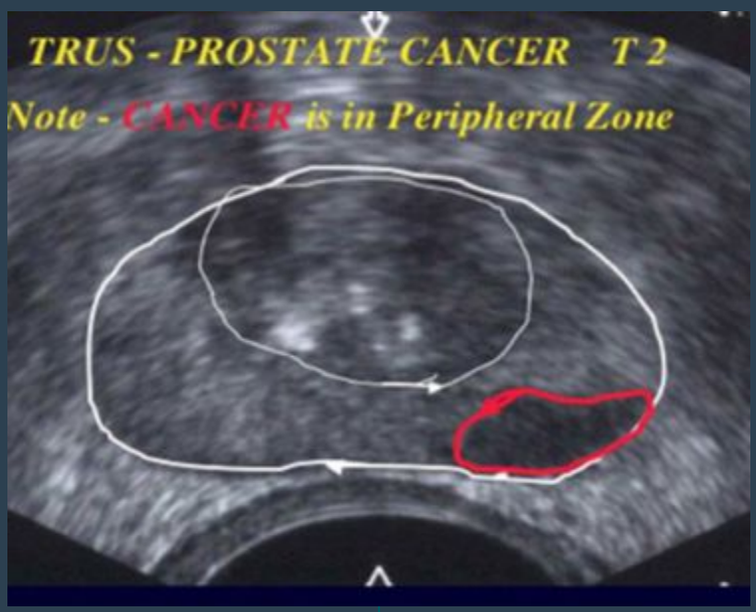
Best modalities:

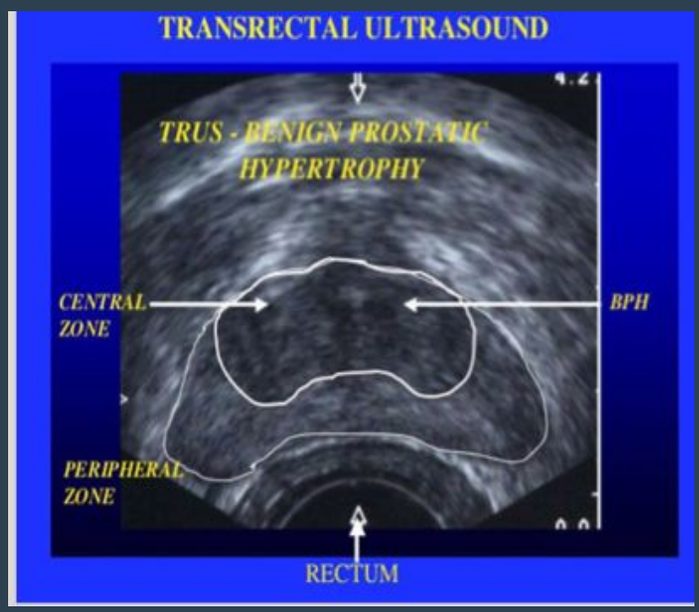
- for prostate gland=
  - transrectal ultrasound
  - then MRI **(Best modality)**
- For kidney= CT and US

Prostate gland cont..



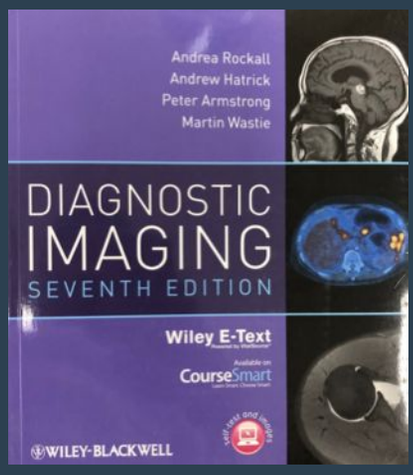




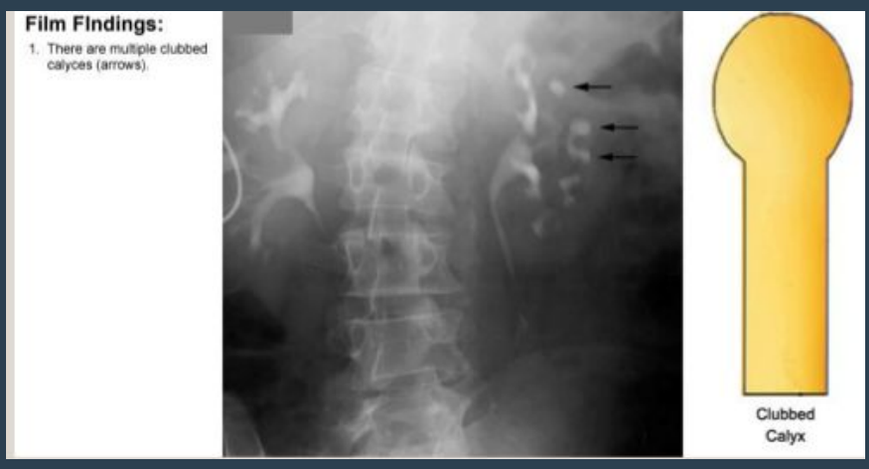


Hypoechoic seen in peripheral zones = tumor. We can take a biopsy using the same probe. After US we now should do MRI

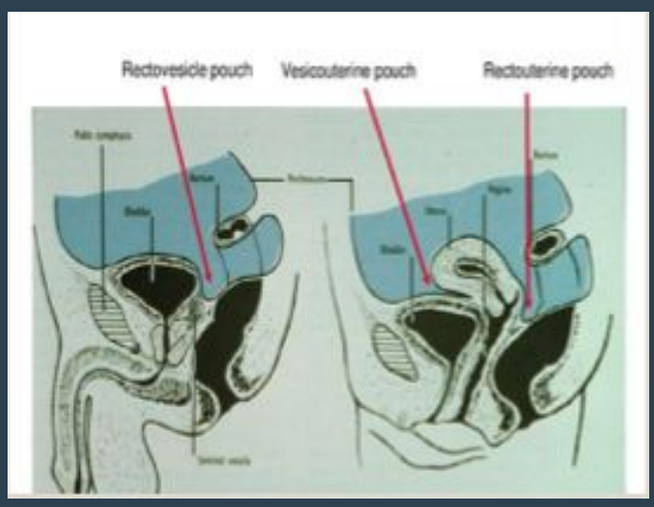
”mostly i bring the questions from the lecture but maybe i will add one question from the book”



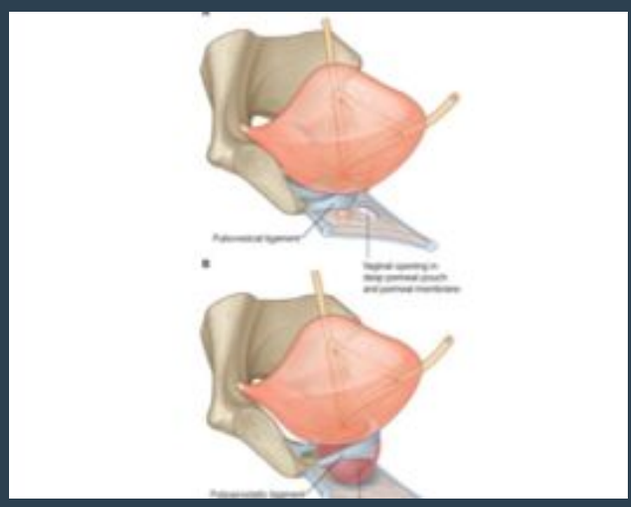
For better understanding:



if there is obstruction it will cause dilatation and calyces looks "clubbed like"



different pouches in males And females



different ligaments and pouches in males and females

Summary

Plain X ray	IVU	Ultrasound
• First imaging modality • Cheap. • Useful for radio-opaque (white) stones. x- ray is the basic modality in the beginning. "KUB" is X-ray of kidney, ureter, and bladder.	• Conventional x-ray + IV contrast • Cheap. • Useful for radio-opaque stones Contrast is injected through a vein then is mainly excreted via a kidneys and urinary system.	• Used for stones , hydronephrosis,and focal lesions. • Indicated in pregnancy • Contrast between tissue is determined by sound reflection. IMPORTANT: doesn't provide functional evaluation. it's good for anatomical evaluation.
Computer tomography	**MRI**	**Scintigraphy**
• More precise. • Costly. • +/- contrast. • Useful for trauma, stone, tumor and infection. Usually CT of kidneys is without contrast • Cross sectional images.. • Better evaluation of soft tissue. • It's the best modality for assessing Renal function+anatomy.	• Better evaluation of soft tissue. • Uses magnetic field (No Radiation). • Expensive. • Useful for soft tissue pathology: tumor, infection • Used for more specification. • We rarely use MRI for urinary system..	• Utilizes a gamma camera and radioactive isotopes. • Functional test. • Less expensive. • Useful for: obstruction and **split function** If we want to assess the function of each kidney (separately) we use nuclear medicine because it assess "split function" of each kidney separately

Summary

Conditions associated with enlarged kidneys

Always unilateral

1. Compensatory hypertrophy.

Always bilateral

1. Renal vein thrombosis
2. Polycystic disease
3. Acute glomerulonephritis
4. Amyloidosis

unilateral or bilateral

1. Bifid collecting system
2. Renal mass
3. Hydronephrosis
4. Lymphomatous infiltration

Conditions associated with small kidneys

Always bilateral

1. Radiation nephritis
2. Chronic glomerulonephritis of many types
3. Hypertensive nephropathy
4. Diabetes mellitus
5. Collagen vascular disease
6. Analgesic nephropathy

unilateral maybe bilateral

1. Chronic pyelonephritis
2. Tuberculosis
3. Obstructive atrophy
4. Renal artery stenosis or occlusion
5. Hypoplasia

quiz

1-Imaging Modality Used for stones , hydronephrosis,and focal lesions.

a. Plain X-Ray
b. Ultrasound
c. Computed Tomography
d. Intravenous Urogram(IVU)
e. Magnetic Resonance Imaging

2-one of the most common sites of renal stones is?

a. mid ureter
b. ureteropelvic junction
c. junction of mid-distal ureter
d. proximal ureter

3-Conditions associated with enlarged kidneys and always unilateral

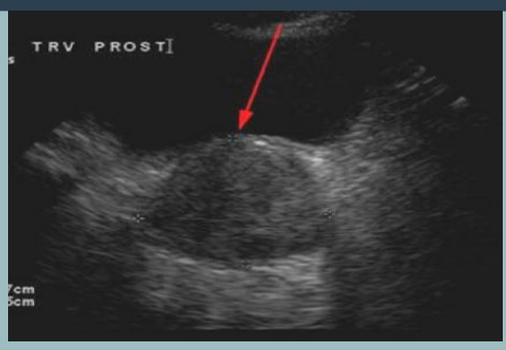
a. Renal mass
b. Compensatory hypertrophy.
c. Tuberculosis
d. Amyloidosis

4- which one is not a very good modality for prostate?

a. CT
b. MRI
c. US
d. All of the above are considered good

5-what does the red arrow indicate?

a. Posterior wall of the urinary bladder
b. Prostate that is enlarged
c. Normal male prostate
d. Anterior wall of urinary bladder



6-identify the abnormality circled in red and the modality used?

a. Tumor of the prostate,MRI
b. BPH,MRI
c. Tumor of the prostate,US
d. BPH,US

Switching from working on the dark theme to the light one

Answers
1)b
2)b
3)b
4) A
5)B
6)C