RADIOLOGY
TEAM 435

Radiological anatomy and investigation of urinary system

[Color index: Important | Notes | Extra]

[Editing file | Feedback | Share your notes | Shared notes]

Objectives:

1. To know the different types of modalities used in imaging the urinary tract .
2. To know the anatomic location and sizes of the structures of the urinary tract .
3. To identify the kidneys, ureters, urinary bladder and urethra on different imaging modalities .

Resources:

- 435 Slides
- 434 Team
- 435 Notes

Done by:

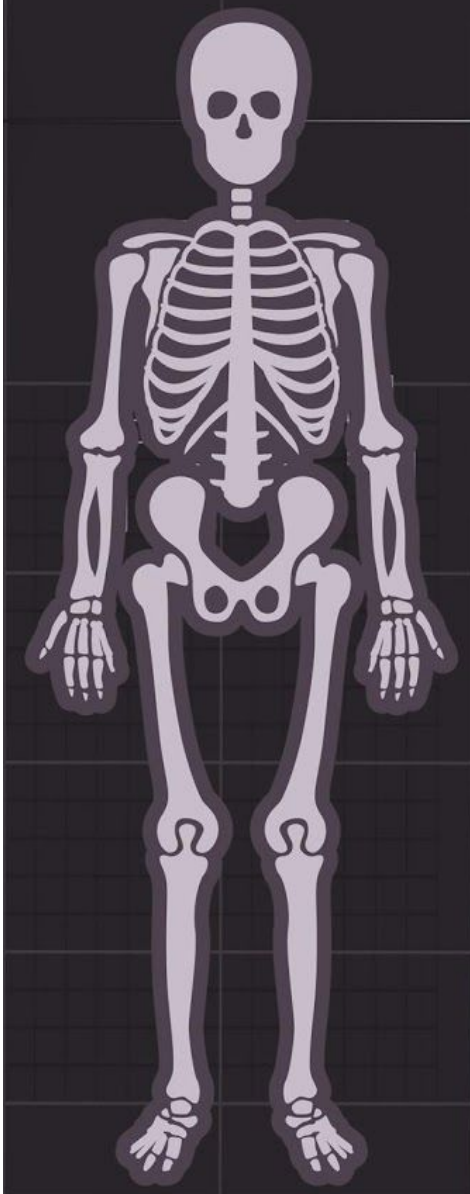
- Ahmed Alrweli

Team Leader:

- Amjad Alduhaish
- Mohammed Alsahil

revised by:

- Ahmad alyahya
- Luluh Alzeghayeer



Urinary System Investigation

❖ What is medical imaging?

A medical specialty that employs the use of imaging to both **diagnose** and **treat** diseases within the human body. Two principle parts:

1) Diagnostic radiology .
2) Interventional radiology. ex, Varicocele embolization, biopsies, draining abscess & collection

Radiological Modalities					
Plain X-Ray (KUB)[1]	**Intravenous Urogram (IVU)[2]**	**CT** Contrast or without	**Nuclear Medicine (aka=scintigraphy)[3]**	**MRI[4]**	**Ultrasound[5]**
Ionizing Radiation			Minimal Ionizing radiation	Non-Ionizing Radiation	

1) Plain X-Ray, KUB (Kidney Ureter Bladder)

- First imaging modality
- Cheap
- Useful for radio-opaque stones
- Nowadays they don't use it too much, When we suspect stones ideally we do CT without contrast but some ER physician's order plain x-ray.

❖ **Image features :**

1. Projectional image = bidirectional image (2D).
2. Image contrast determined by tissue density.
   there're two contrasts:
   air (least dense/black) & bone (most dense/bright)
3. Good evaluation for radio-opaque stones .

2) Intravenous Urogram (IVU) / intravenous pyelogram (IVP)

- Conventional x-ray (KUB) + IV contrast
- "contrast usually Iohexol" > contains iodine
- Cheap
- Provides functional and anatomical information.
- Recently replaced by CT and MRI rarely used nowadays.
- **The best urological imaging modality is CT urography**

❖ **Image features :**

1. Projectional image = 2D
2. Image contrast determined by tissue density and IV contrast.
3. Good evaluation of collecting system and radio-opaque stones.

if we see a stone "yellow circle", will be no contrast, what should we expect?
Hydronephrosis = dilation of the renal pelvis and calyces,

[1] KUB = Kidney Ureter Bladder , this's basic and first to do in renal colic or when you suspect renal stone.
[2] Nowadays IVU replaced by CT urography (Bc in CT everything is clear & the obstruction can be due to other causes rather than stones)
[3] scintigraphy > Mainly for function
[4] MRI > uses for specific cases
[5] US > Mainly to see structure of kidney, but we can't see ureters in US

3) Ultrasound

- Uses high frequency sound waves (NO RADIATION)
- Contrast between tissue is determined by sound reflection. density of collecting system is much higher than parenchymal tissue

*So how do expect bones to appear in US?

Bone will reflect all sound wave so we don't see it, and if there's a calcium stone, we see its shadow also bright white structures in center hyperechoic "brighter" , Because medulla density is higher than cortex.

if there's air, how will it appear !?

air does not reflect waves, so US is not good. in condition like Emphysematous pyelonephritis & Emphysematous pyelitis

❖ **Image features:**

1. Operator dependent. (unlike other Imaging modalities where the machine does everything)
2. Good resolution. & 2D
3. Used for stones, hydronephrosis, and focal lesions

4) CT Scan

- Same basic principle of radiography(the x-ray field)
- More precise. multiple fields of x-rays
- expensive
- +/- contrast (- : stone, +: anything other than stone e.g., masses)

- Useful for trauma "will see laceration[6]", stone, tumor and infection .

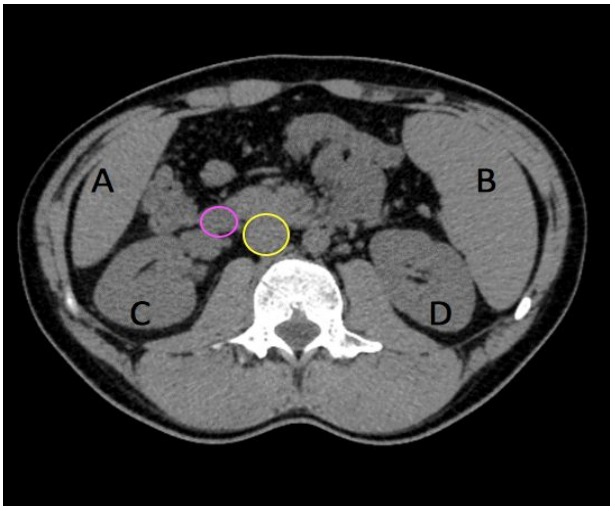
Nowadays, we don't say spiral CT; all CTs are spiral. And all CT images have high resolution.

Contraindications of CT w. contrast: Renal failure and hypersensitivity to contrast. how can you ask about them ? RF: Clearance of creatinine if less than 30 will not inject contrast .

❖ **Image features:**

1. Cross sectional images. This CT image is without contrast.
2. Image contrast determined by tissue density +/- contrast.
3. Better evaluation of soft tissue.

• NOTE: In US and CT look for dilatation of minor calyx "appears flat or concave"and pelvis, do not look to the defect because dilatation means obstruction.



Where is the Left kidney?

D

A = Inferior cut of the liver

B = Spleen

C= Right Kidney

Yellow circle = abdominal aorta

Pink circle = IVC > remember it's on the right side compared to aorta ^^

if you're interested in identifying more structures see this Pic ^^

[6] rupture, tear

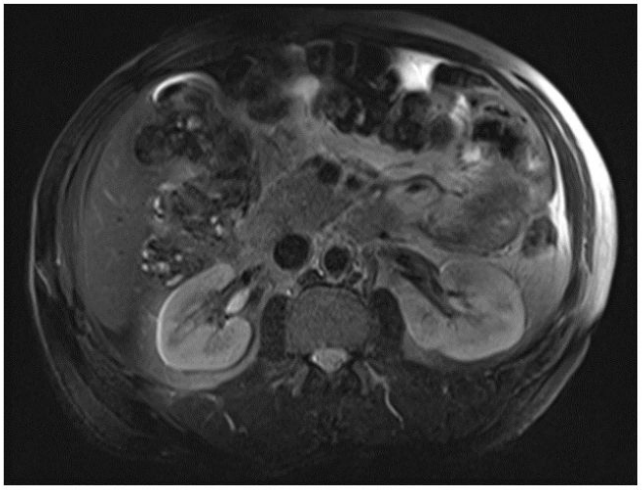
5) MRI

- Better evaluation of soft tissue. When the CT doesn't provide enough information, order MRI. But usually CT is enough to assess kidney.
- Uses magnetic field (NO RADIATION).
- Expensive.
- Useful for soft tissue pathology: tumor, infection.
- CI of MRI: Pacemaker or any metal device, claustrophobia.

❖ **Image features:**

1. Cross sectional images.
2. Image contrast determined by tissue properties.
3. Excellent for soft tissue evaluation

(If there's a renal cyst or tumor and we want more specification we do MRI)

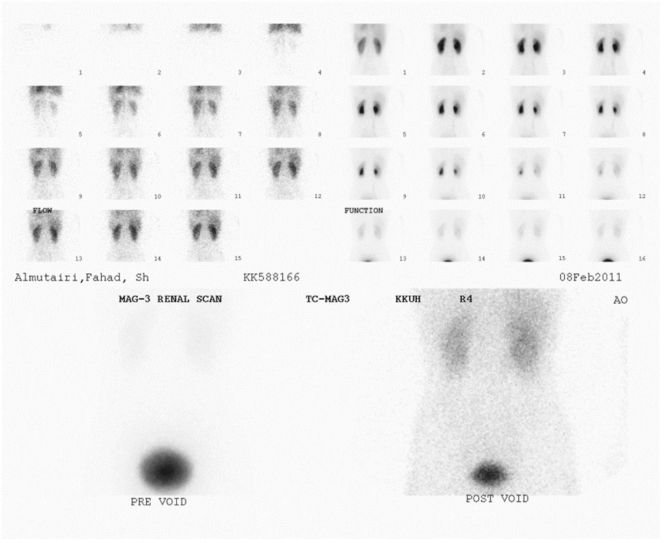


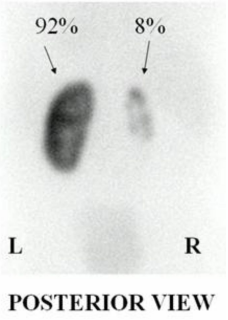
6) Nuclear Medicine (scintigraphy)

- Utilizes a gamma camera and radioactive isotopes
- **Functional test** (to evaluate kidney functions). The best functional test but it's not the only one; CT urography assess function also.
- Less expensive.
- Useful for: obstruction and split function[7] [8].

❖ **Image features:**

1. Projectional image.
2. Image contrast by tissue uptake and metabolism of radio-isotopes scan[9].





X-ray, IVP, CT, US, MRI > always ur left is right of the patient ^^
except Nuclear medicine > same side of ur hand

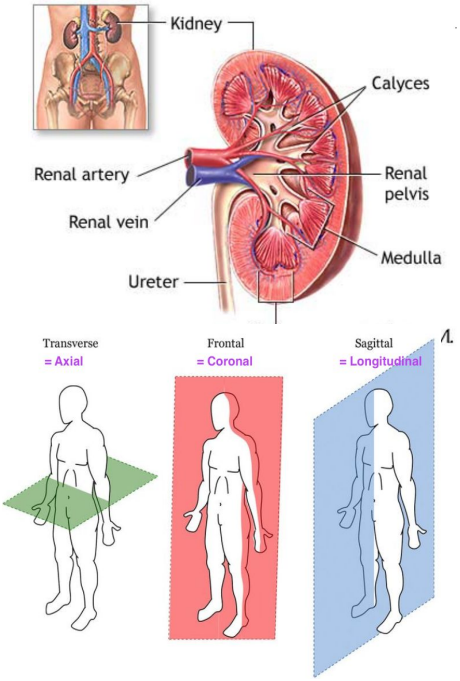
[7] means to know which kidney is functioning better than the other, it's gives us specific numbers/percentage
[8] also called renogram or renal perfusion study
[9] A radioactive material called a radioisotope, or radionuclide "tracer,

Anatomy

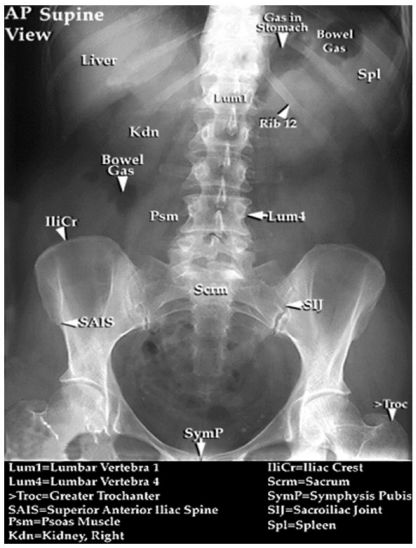
1- Kidneys 2 - Ureters 3- Urinary bladder 4- Urethra

• Kidneys:

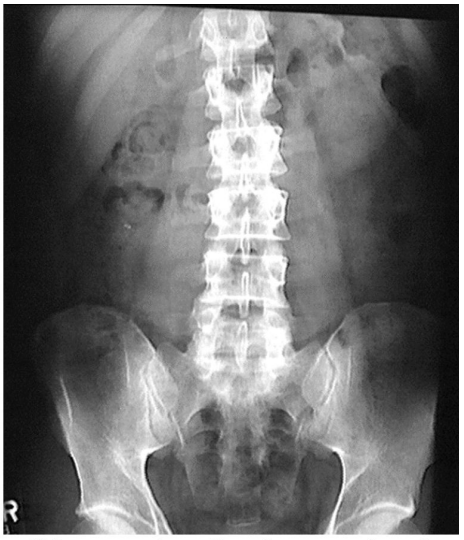
- Bean shaped structure.
- On either side of the lower thoracic and upper lumbar spine.
- Usual location – between (T11-L3) .
- Right kidney is 2 cm lower than the left kidney (Bc of liver effect).
- Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles.
- Lower pole is 2-3 cm anterior to the upper pole.
- Normal size : in adults 9-12 cm.
- Why is it important to know the normal size?
    1. Bilateral small kidneys > Chronic disease e.g. Glomerulonephritis
    2. Bilateral normal or large kidneys:
        - Polycystic Kidney Disease
        - Amyloidosis
        - DM
        - Acute Glomerulonephritis
    3. One is small, the other is large - consider:
        - Renal Artery Stenosis



Plain X-ray (KUB)



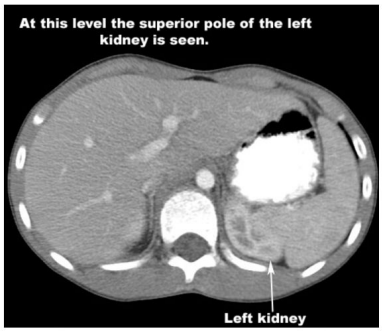
Useful when we suspect renal stone

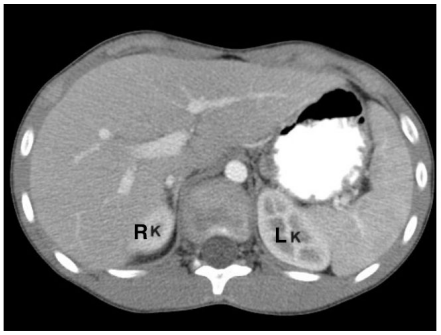


Kidneys are retroperitoneal organs and may be obscured/hidden by bowel loops

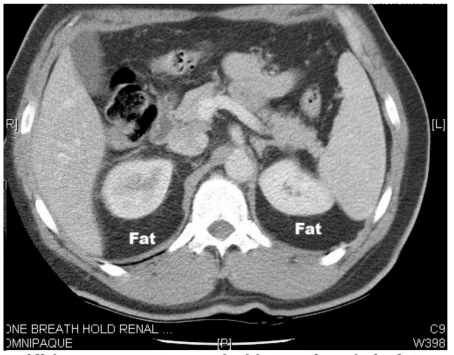
Upper pole of left kidney is higher than the upper pole of right kidney

CT





CT Scan showing left kidney higher than right;
Axial image of the upper pole of the left kidney we don't see the right kidney.
3 cuts inferior to see upper pole of right kidney .



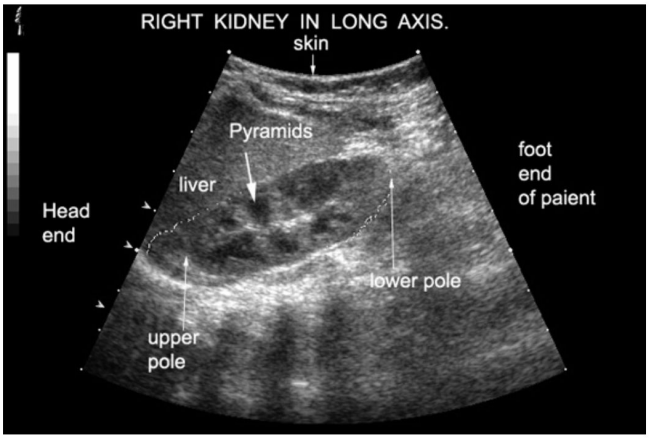
Kidneys are surrounded by perinephric fat.
Fat appears dark in CT

MRI

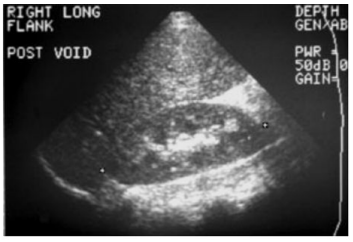
• MRI showing Left Kidney is higher than Right Kidney
• Around the kidney is the peri-renal fat.
• Fat is bright in T1 and T2 (the basic sequence of MRI).

Long axis of the kidneys is directed downward & outward, parallel to the lateral border of the psoas muscles. psoas muscle is important muscle connect skeleton to peripheral body.

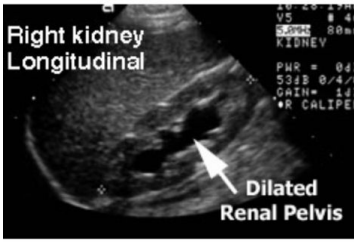
Ultrasound



US is the best method to measure the size of the Kidney.
It's longitudinal image. the left side of the image represent the upper "superior" pole and the right side is the lower "inferior" pole.
the perirenal fat in ultrasound is the white area around the cortex.



NORMAL STUDY



DILATED RENAL PELVIS

★ Kidneys are visualized on the X-Ray due to presence of perirenal fat which appears dark.
★ They 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 US** as perirenal hematoma or perirenal urinoma.

Perirenal **fat** is .....dark in: x-ray (KUB) & CT ,..... bright in; MRI & US

Q.1: Why do we see the Kidney clear in CT?
- Because of the contrast that is accumulated between the kidney and the fat surrounding it.

Q.2:How do we know if there's an infection (Pyelonephritis) ?
- We see fat stranding around kidney and differentiation will not be clear (fat will not be dark and clear, it will have white lines coming from kidney)

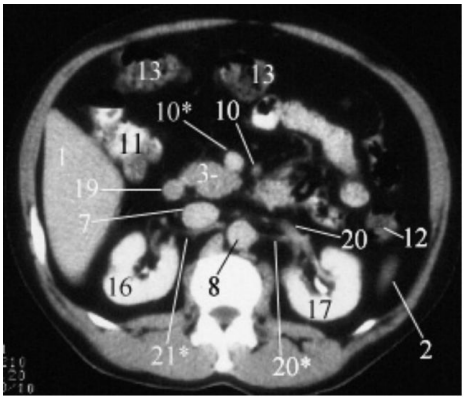
Q.3: What are the basic sequences of MRI?
- T1 and T2

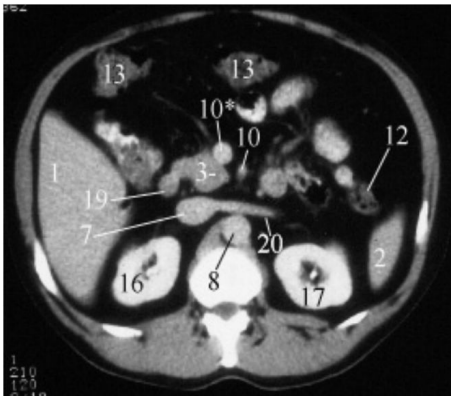
In MRI we see the kidneys because of perirenal fat which is bright white in T2 and T1.

Q.4: How can you differentiate between T1 sequence and T2 sequence?
- Fluid dark black (hyposignal) in T1 and bright white (Hypersignal) in T2

[10] (We see anechoic structure filled with urine so all is dark).

❖ Identify basic structures related to the kidneys on CT :

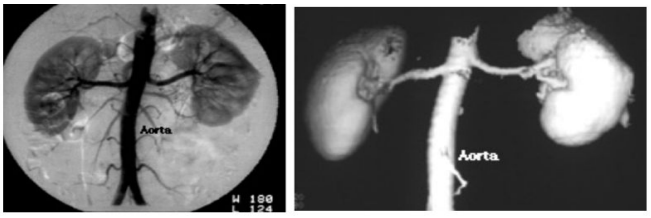




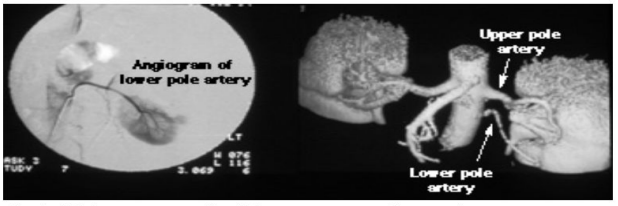
1- Liver 16- R.Kidney 7- IVC
2- Spleen 17- L.kidney 8- Aorta
3-Pancreas, 12- Descending colon, 13- Transverse colon, 20- Renal vein

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 (they may do nephrectomy and the forget about the **accessory renal artery** and the patient will be in severe hemorrhage).



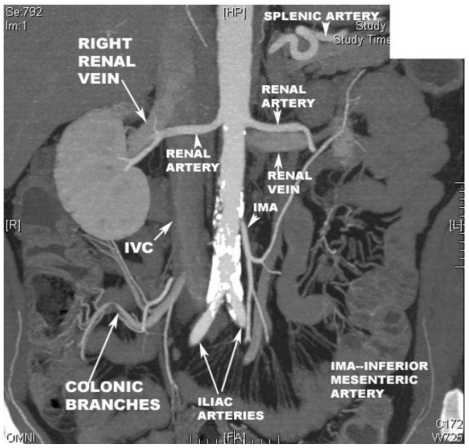
Normal supply of both kidneys by single renal artery



Left kidney supplied by two renal arteries.
Lower pole artery = accessory artery.

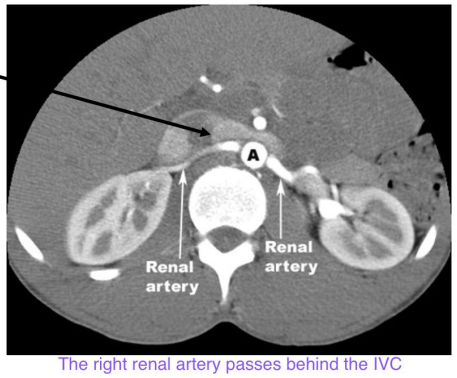
RENAL ANGIOGRAPHY:

- 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 to left renal vein[11] while the ***right*** gonadal vein drains directly into the ***inferior vena cava***.



Coronal CT reformat shows the right renal vein&artery, left renal vein and artery and IVC.
Calcification the whitish spots around aorta

IVC



The right renal artery passes behind the IVC

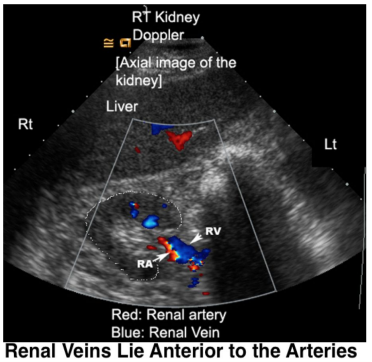
[11] it's so important in case of varicocele in male (= enlargement of the veins in Scrotum), So the pressure in LK higher than RK.

❖ Doppler US

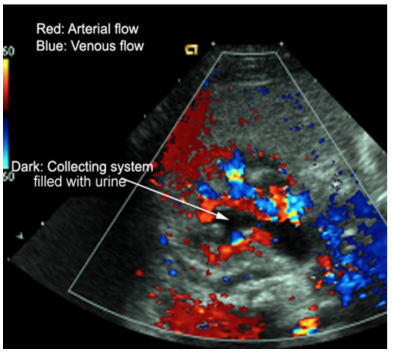
- Doppler US[12] is used to check the blood flow"velocity"in the renal arteries, if there is renal hypertension we will see renal artery stenosis. also after renal graft we can see if the blood flow is OK.

- **<u>How do we differentiate the renal vessels from collecting system?</u>**
  We put the color Doppler and we see no color signal in the collecting system, it always dark and this is important when we want to do nephrostomy (we make sure not to injure the vessels).
  nephrostomy = a catheter insert in the kidney to drain urine from it
  extra info.

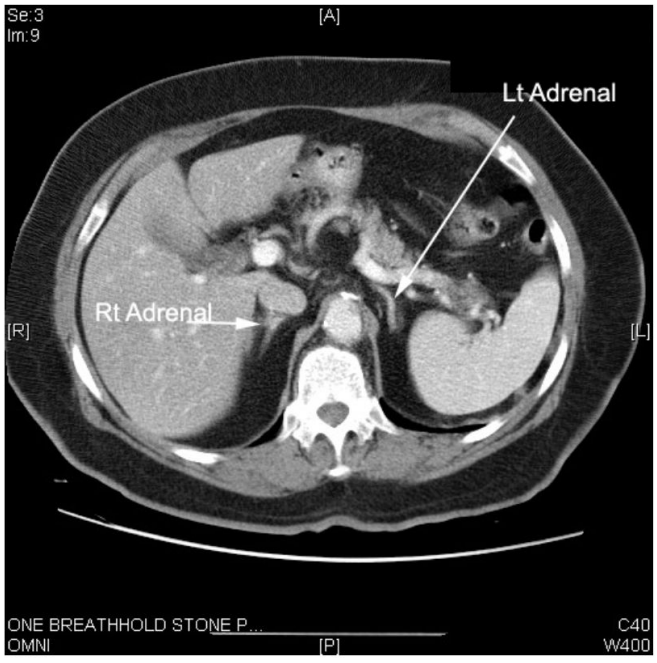
- **<u>Why do we see colored artery and veins and colorless collecting syatem, although in collecting system there is urine?</u>**
  Because of high velocity of blood.



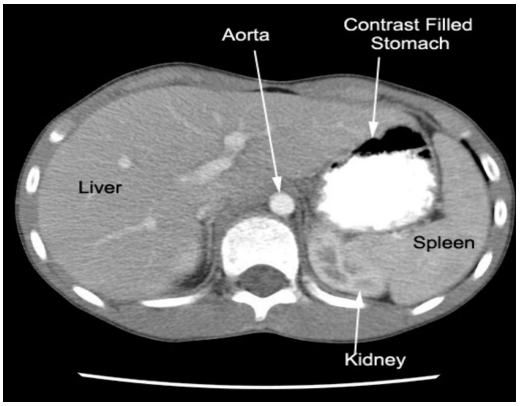
Renal Veins Lie Anterior to the Arteries

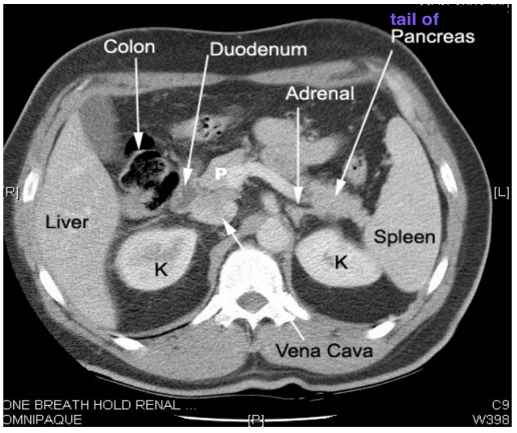


Relationships of the Kidneys



Adrenal Glands are superior to the Kidneys. they're "Y" shape structure.



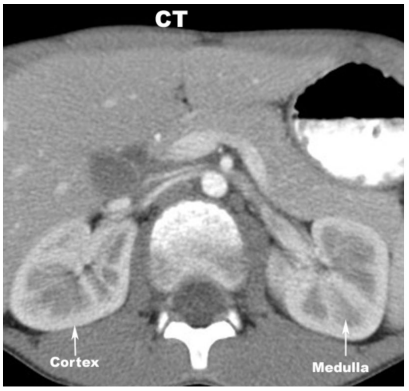


[12] only detect high flow

Renal Structure:

❖ Renal cortex :

- (consisting of glomeruli and renal tubules) filter urine from blood.
- Normal thickness 2.5 cm measured by US



❖ Medulla :

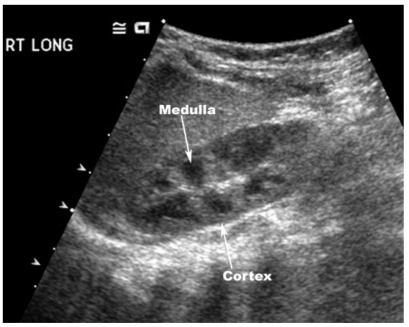
Consists of multiple renal pyramids.

Differentiation between medulla and cortex is Important to see masses

mainly in cortex.

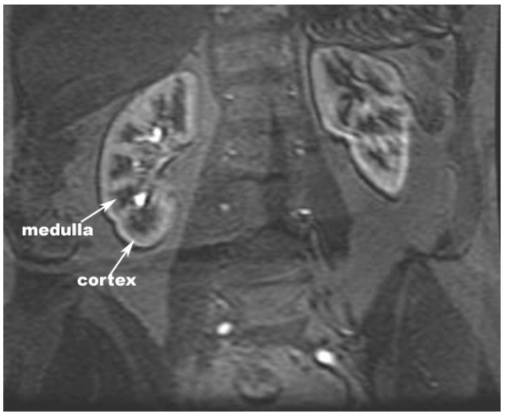
❖ Ultrasound of Right Kidney:

- The best modality to measure the thickness of cortex is US normally 2.5 cm.
- If you notice decreased cortex thickness (<2.5cm) by US, think of *renal failure.*



US showing cortex and medulla of right kidney.

❖ MRI:



CT (Nephrogram phase Vs. Pyelogram phase)

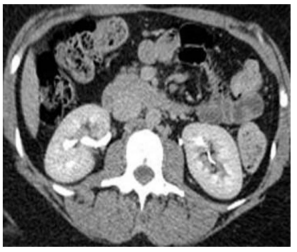
★ The IV contrast will appear first in the cortex, after that medulla, finally in the collecting system.

❖ Nephrogram phase:

- Contrast enhanced CT showing corticomedullary differentiation.
- This is approximately 100 seconds following contrast administration and it shows renal lesions well.

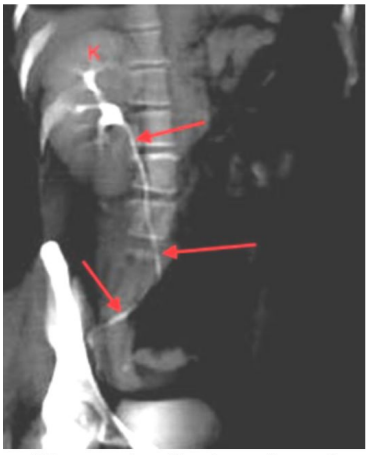
❖ Pyelogram phase

- Contrast enhanced CT showing excretion of contrast into the collecting system.
- This is approximately 8 minutes following contrast administration and shows urothelial lesions well, such as **transitional cell carcinoma**, stones, blood clots.



❖ CT urography:

- It is 3D reconstructed image from CT scan of the abdomen and pelvis.
- Nowadays, this exam is quickly replacing the conventional IVU
- CT urography is more favorable than IVU.
- In picture we see contrast all over the ureter.



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

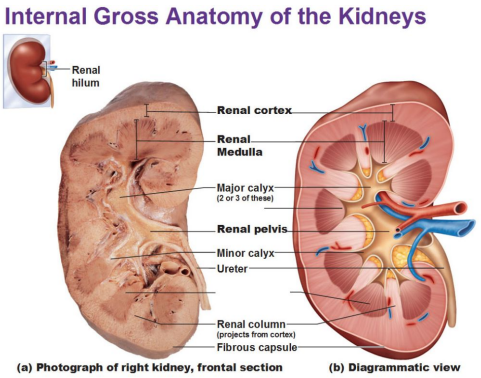
Renal cortex > Renal medulla > Minor calyces > Major calyces > Renal pelvis > Ureter.

❖ 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.

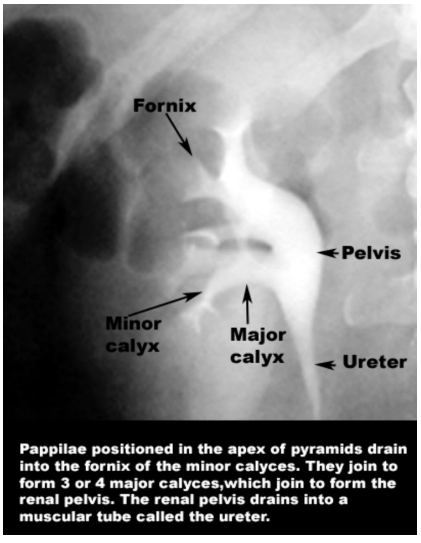
❖ Pelvis:

➔ broad dilated part of the urine collecting system, located in the hilum.
➔ renal pelvis drains into the ureter.

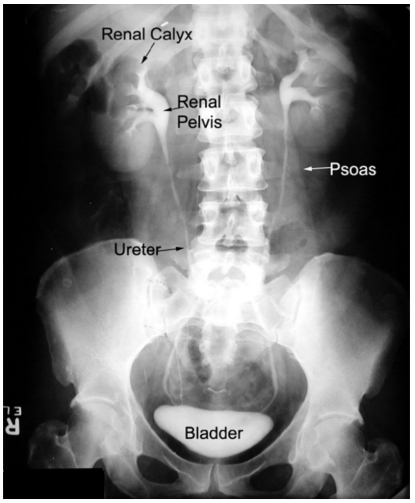


❖ IVP of collecting system:

You can see the calyces it is concave, if it was flat or convex then this indicate dilatation (obstruction).



Pappilae positioned in the apex of pyramids drain into the fornix of the minor calyces. They join to form 3 or 4 major calyces,which join to form the renal pelvis. The renal pelvis drains into a muscular tube called the ureter.



IVP, contrast reaches until bladder.

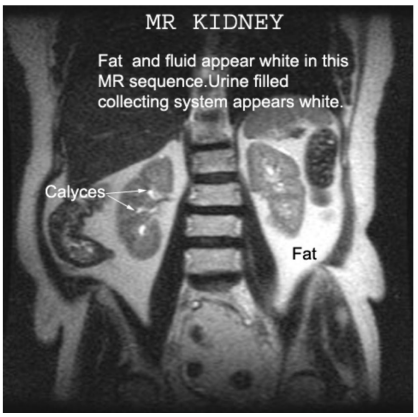
❖ MRI of the Kidney:

- Urine in calyces appears bright white “T2” as fat. so when there is dilation it will appear bigger and white.

- Why MRI at T2 not T1 ?

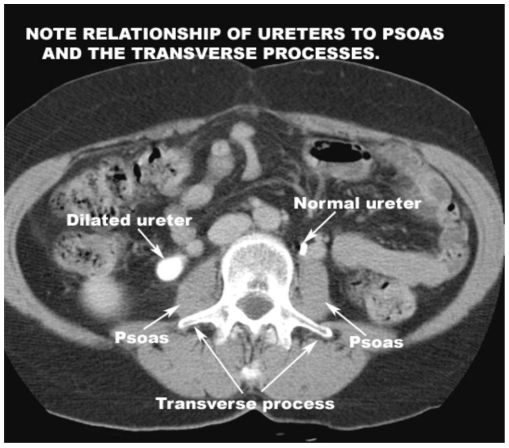
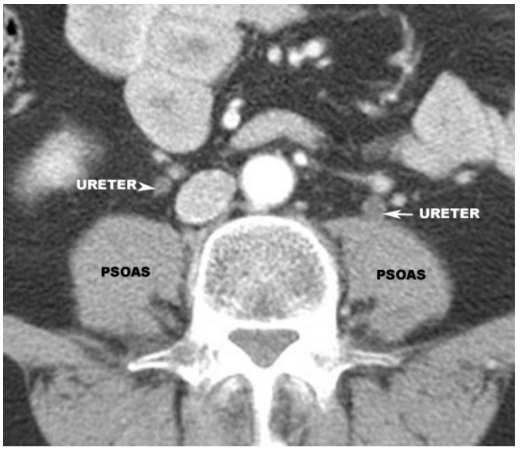
Cause fluid is white in T2.

mnemonics



Ureters

- 25-30 cm in length and 3 mm diameter.
- Three areas of normal narrowing:
  - Ureteropelvic Junction
  - Bifurcation of the iliac vessels
  - Ureterovesical Junction
- These areas are important to know because it’s the common site of stones (obstruction).

CT urography :	CT without contrast:
	
• Dilated ureter filled with contrast means there’s obstruction inferior to this dilatation. • Normal diameter of ureter is 3 mm if it’s more than this then its dilated. • if we are not able to see the contrast it means the stone is in this level. • Ureters related to psoas muscles.	• It’s difficult to find the ureter but we follow it from the pelvis downward until the bladder.

Urinary Bladder

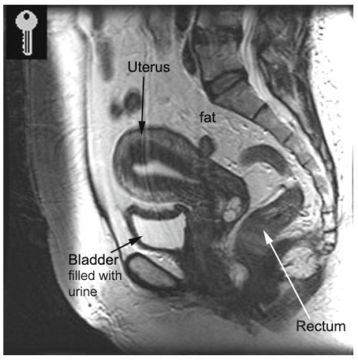
- Size and shape vary considerably.
- When empty, it is completely within the pelvis.
- Dome is rounded in male, flat or slightly concave in female due to the presence of uterus.
- Its capacity my reach to 400-600 cc.
- Bladder is relatively free to move **except at the neck which is fixed:**

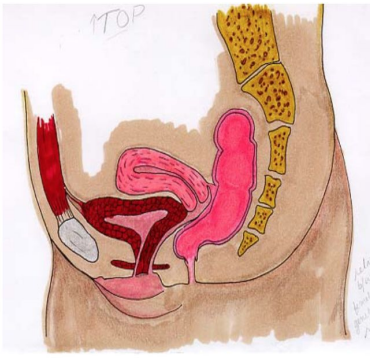
➔ Neck is fixed by **puboprostatic ligaments (males).**

➔ Neck is fixed by **pubovesicle ligaments (females).**

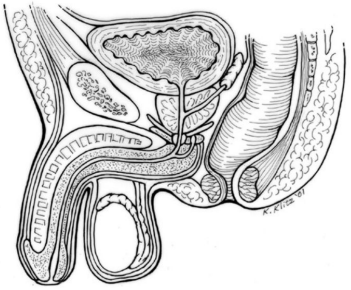
❖ Peritoneal reflection:

1. Rectovesical pouch in males.
2. vesicouterine and rectouterine pouch in females.





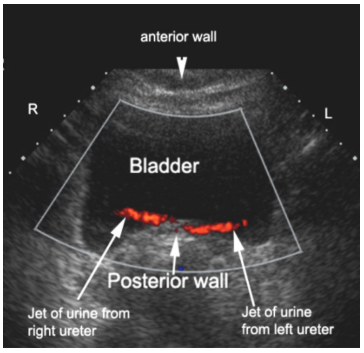
Anatomy of Female Pelvis showing the Urinary Bladder.
We can see vesicouterine and rectouterine pouches in MRI picture.



Anatomy of Male Pelvis showing the Urinary Bladder, Prostate and Seminal vesicle posterior to the bladder.

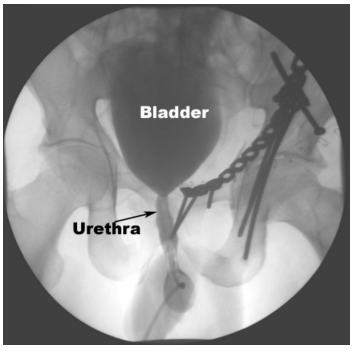
❖ US:

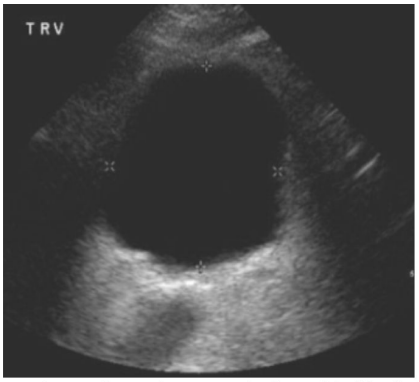
- US is excellent technique to investigate the bladder
- Always anechoic structure = dark (urine).
- When doing ultrasound for urinary system we ask the patient to drink a lot of water and not to urinate, because if bladder is empty we can't see anything, it should be full.
- If we want to verify there's no stones or occlusion, we do power Doppler.
- power Doppler detects the flow of urine in the bladder, so we can see the 2 ureteral jets (red parts) in the bladder, if we see that = this means that there is no obstruction along all the ureter.



❖ IVP :

Bladder with injected contrast through urethra.



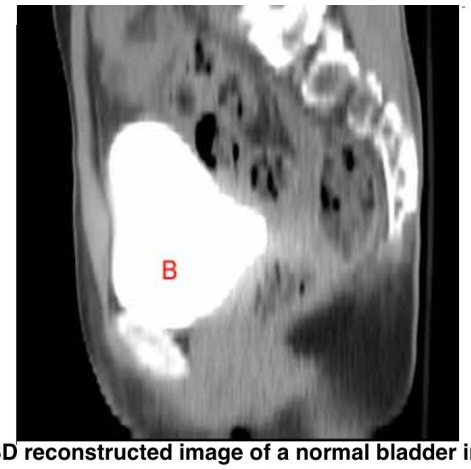


Transverse image through a normal urinary bladder (calipers "x" & "+" outline the bladder wall) using ultrasound.
• shows normal anechoic structure (anechoic = no echoes = black).
• To complete the exam we must ask the patient to void the urine to measure the volume of urine before and after .
• if there is obstruction we have to rule out prostate hypertrophy (Post voiding will be less).

❖ Unenhanced CT:

- Fluid appears hypodense.
- When assessing a mass it is preferable to use contrast and wait until the bladder is full to see filling defects or hyperdense mass.

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

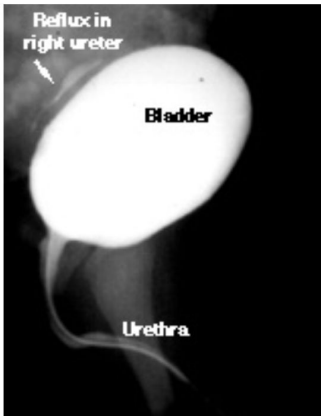


3D reconstructed image of a normal bladder in the sagittal plane following CT urography.
• This is delayed image 10 minutes following IV contrast administration, excreted contrast fills an otherwise normal bladder (B). No diverticula, no filling defects.
• If there is a tumor there will be filling defect.

❖ Voiding Cystourethrogram:

- It is an x-ray study of the bladder and urethra.
- Mainly done in pediatric age group, when we suspect reflux in ureter (Vesicoureteral reflux)
- It is done while the bladder is empty put catheter in urethra then we inject a contrast through the urethra and fill the entire bladder .
- after that we take fluoroscopy images to see if there's reflux.

- Some area are not white? We call it filling defect indicate tumor.
- Reflux to the ureter? Normally don't occur even if bladder is fully saturated by contrast, we can see it in neonate with congenital valve abnormality. The reflux have 4 grades for severity.

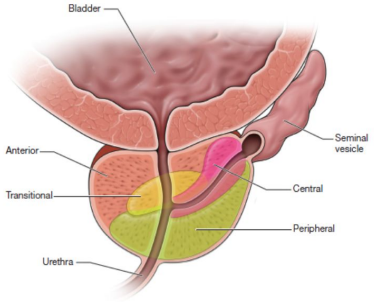


Prostate Gland

- Largest accessory gland of male reproductive system.
- Lies around the first part of the urethra at the base of the bladder.
- (Tr)[13] 4 cm x 3 cm (height) x 2 cm (AP) in size.
- Surrounded by dense fibrous capsule.
- Should be less than 25ml volume in healthy male. Elderly normally=reach 25cc

❖ It has :

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

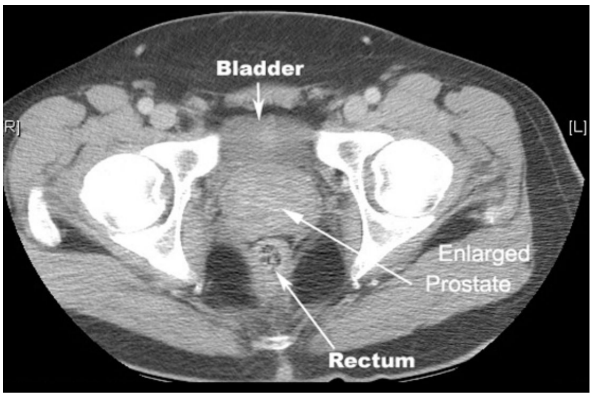


❖ Prostate gland can be divided into:

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

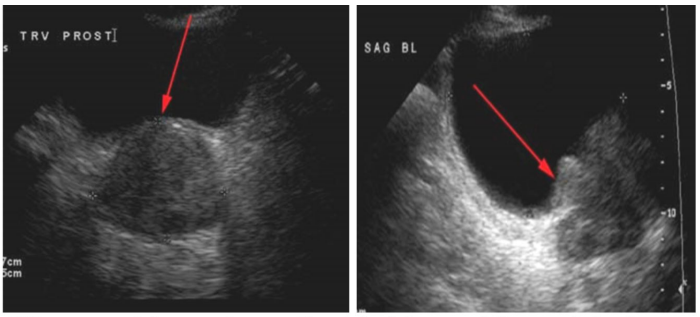
- Transition zone which lies in periurethral location is the site of benign prostate hypertrophy which can occlude the urethra.
- Peripheral zone is the primary tumor site in 70% patients. If elderly male patient complains of obstructive symptoms, consider BPH. But if he has no signs and only high PSA[14] think about tumor.
- Lower end of prostate is behind the symphysis pubis.

[13] transverse
[14] Prostate-Specific Antigen



CT showing enlarged prostate.

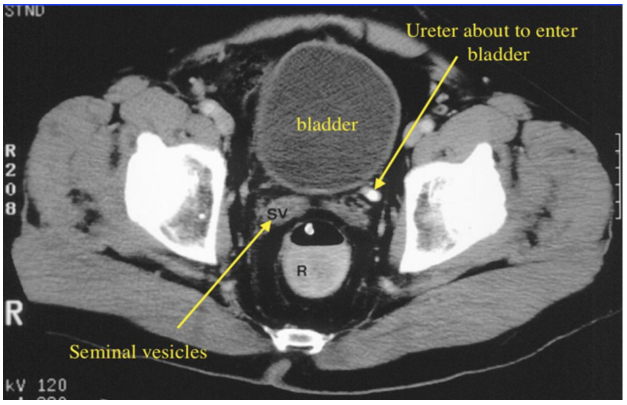
Axial section Longitudinal

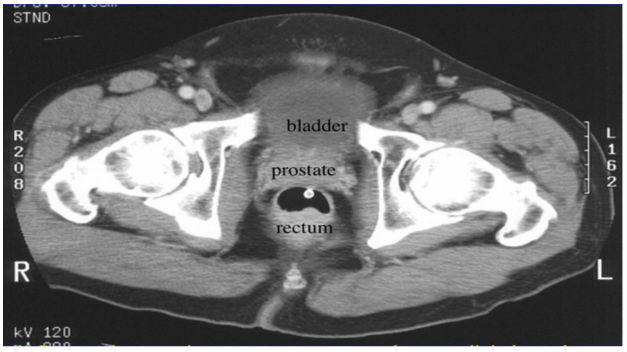


Ultrasound here shows the bladder and the pointed structure is the enlarged prostate
(Prostate bulging bladder)

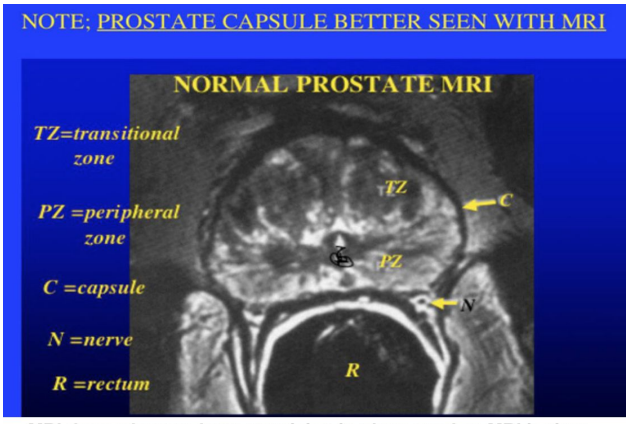
★ The best imaging for **Prostate** is **Endorectal Ultrasound**, after it is MRI

The next images are multiple cut sections in a CT
Note: you have to know the pointed structure.

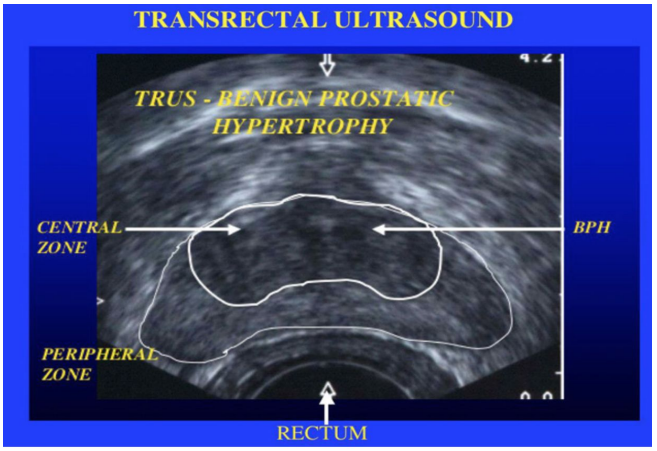




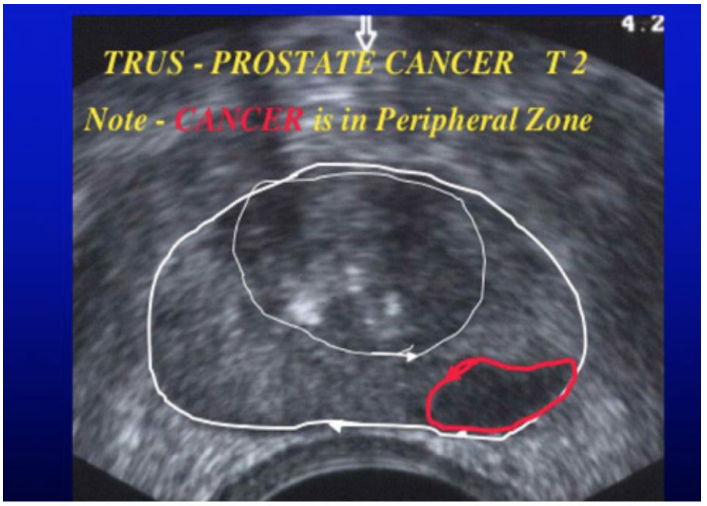
Prostate just anterior to rectum - easy to palpate on digital exam



MRI done when we have suspicion in ultrasound as MRI it gives more details about the prostate and soft tissues .



central zone which is hypoechoic = BPH



- hypoechoic seen in peripheral zones = tumor.
- so if we see that we have to do biopsy (the biopsy is taken using the same probe).
- We never use CT for the prostate, it is either US or MRI.