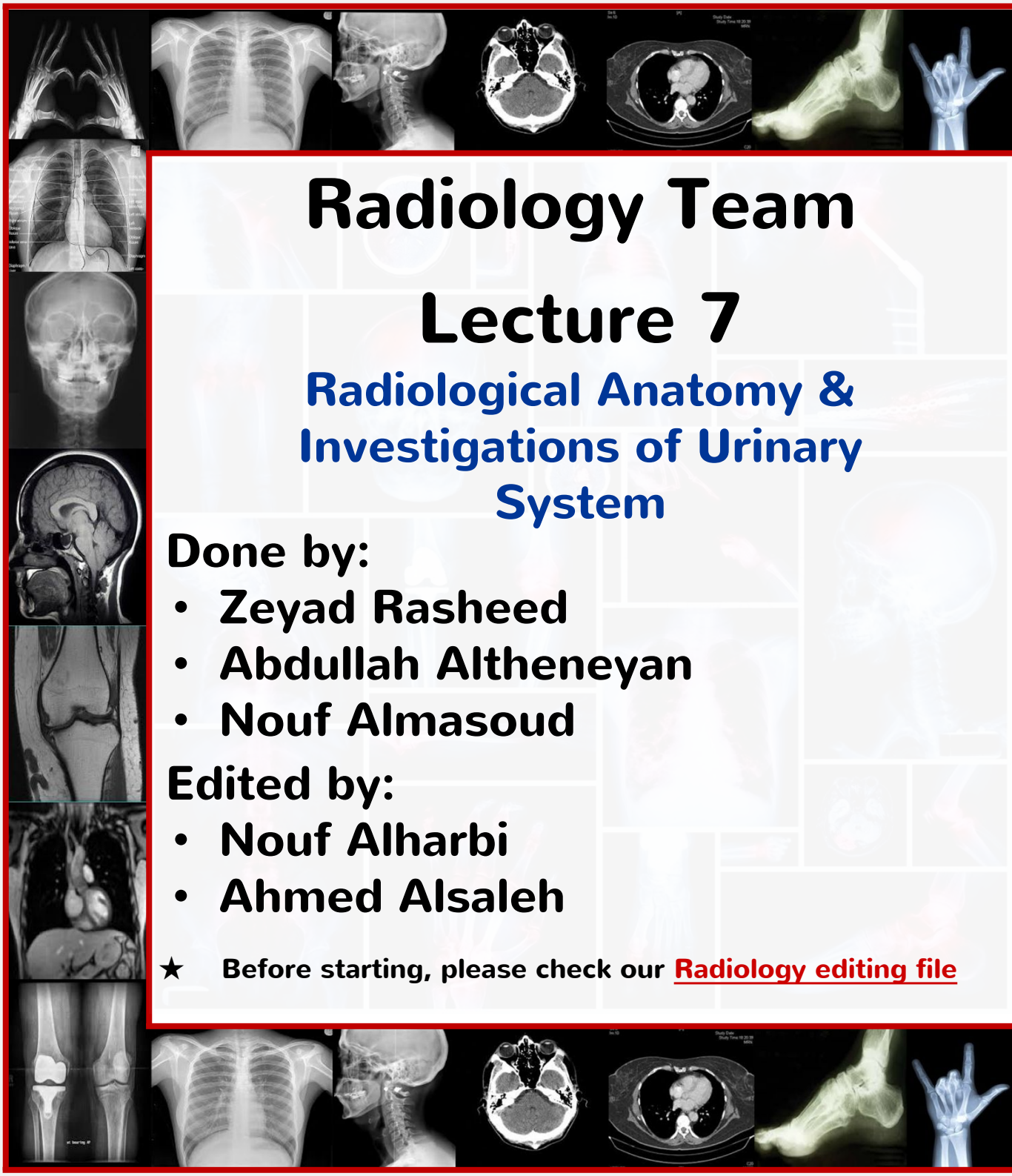


Radiology Team

Lecture 7

Radiological Anatomy & Investigations of Urinary System

Done by:

- Zeyad Rasheed
- Abdullah Altheneyan
- Nouf Almasoud

Edited by:

- Nouf Alharbi
- Ahmed Alsaleh

★ Before starting, please check our Radiology editing file

Color Index:

• Important • Doctor's notes • Explanations

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

Urinary System

Kidneys | Ureters | Urinary bladder | Urethra

Imaging Modalities

Plain X-Ray / KUB (means 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.

*So In case of Kidney stone either will investigate it by x-ray or CT.

- **Image features:**
- Projectional image = **bidirectional image "2D"**
- Image contrast determined by tissue density

"Hyper dense such as bone and calculus stone will be **bright white**, and very low density like air will be **dark black**".

- Good evaluation for radio-opaque stones

Intravenous Urogram (IVU) / intravenous pyelogram (IVP)

- Conventional x-ray + IV contrast (Same as plain x-ray but we give IV contrast)
- Cheap
- Recently replaced by CT and MRI WHY? Because in CT every thing is clear also the obstruction can be due to other causes rather than stones.
- IVU is rarely used nowadays.
- Useful for radio-opaque stones
- **The best urological imaging modality is CT urography**

- **Image features:**
- Projectional image = **bidirectional image "2D"**
- Image contrast determined by tissue density and **IV contrast**.
- Good evaluation of **collecting system** and radio-opaque stones
- **If there is a stone here what do you expect ?**

There will be **no contrast in the distal parts** "area below the stone" of ureter because of the obstructive stone + **dilatation of collecting system** and the area which is above the stone.(dilatation of pylo calyces system)

- **X-ray to know if there is obstruction or not**
- **CT to know the cause of obstruction**

Imaging Modalities

Ultrasound

- Use high frequency sound waves
- Contrast between tissue is determined by sound reflection.
- **Image features:**
- Operator dependent (in US, the images depend on the person who take the images unlike other Imaging Modalities where the machine does everything).
- Projectional image "2D".
- Good resolution
- Used for stones, hydronephrosis*, and focal lesions

- If there is a stone like calcium or gallbladder stone it gives shadow and it reflects sound waves so we see it as bright white structures
- Determined border, you can see the border between liver and kidney
- Why in center **hyper echoic** "brighter" ? Because medulla density is higher than cortex.

* Swelling of the kidney due to obstruction" usually represented medially". The best example to detect dilation "faster than CT"

CT Scan

- Same basic principle of radiography
- More precise
- Costly
- +/- contrast (if you highly suspect renal stones we do it without contrast because dilation and obstruction can easily be seen), contrast: if there is obstructing, mass..etc.
- Useful for trauma "will see laceration", stone, tumor and infection
- Nowadays there is nothing called spiral CT, all CTs are spiral and all CTs are high resolution
- **CI of CT:** Renal failure and hypersensitivity. how can you ask about them ?

RF: Clearance of creatinine if less than 30 will not inject contrast

- **Image features:**
- Cross sectional images
- Image contrast determined by tissue density +/- contrast
- Better evaluation of soft tissue
- This CT image is without contrast.

- **NOTE: In US and CT look for dilatation not the defect because dilatation means obstruction**

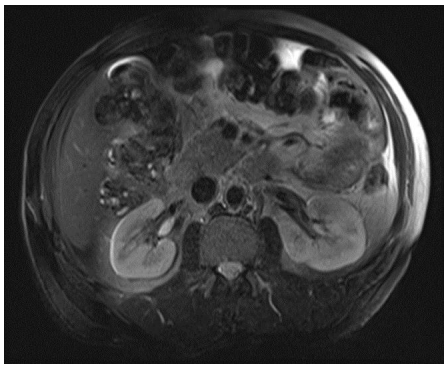
This image is CT without contrast. "We don't see too much" but can see:

- kidneys
- No dilatation of pyelocaliceal system
- No stones
- No fat stranding
- No infiltration

Imaging Modalities

MRI

- Better evaluation of soft tissue. Better than CT
- Expensive
- More specific
- Useful for soft tissue pathology: tumor, infection
- **CI of MRI:** Pacemaker or any metal device " not compatible" , claustrophobia..etc
- **Image features:**
- Cross sectional images
- Image contrast determined by tissue properties
- Excellent for soft tissue evaluation (If there's a renal cyst or tumor and we want more specification we do MRI)

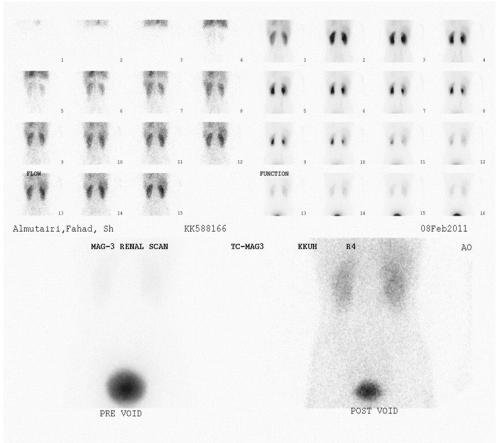


Nuclear Medicine (scintigraphy)

- Utilizes a gamma camera and radioactive isotopes
- **Functional test** (to evaluate kidney function)

The best functional test but it's not the only one; cause there is **CT urography** tell us about the function also. when we see contrast going from cortex to medulla to collecting system
To ureter to bladder.

- Less expensive
- Useful for: obstruction and split function
- **Image features:**
- Projectional image
- Image contrast by tissue uptake and metabolism
- If there's obstruction we see it without contrast.

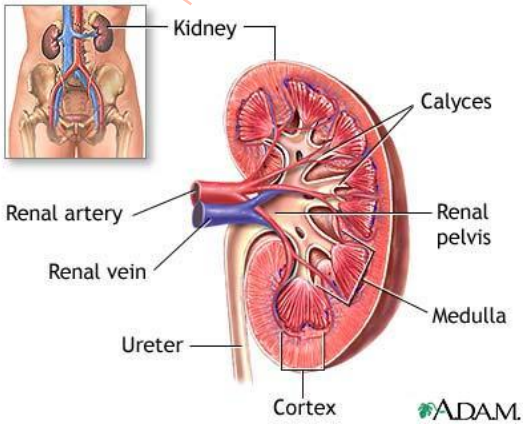


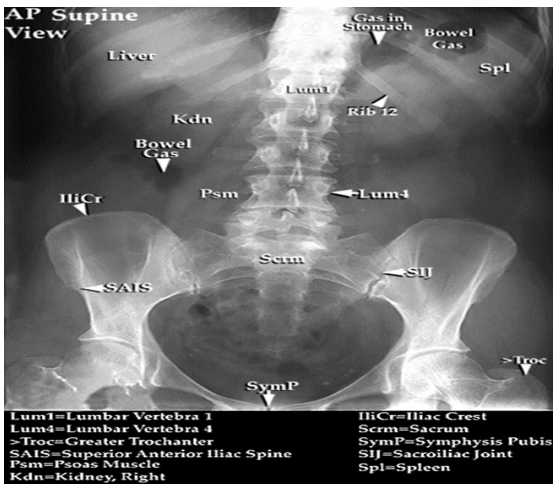
Anatomy

1-Kidneys:

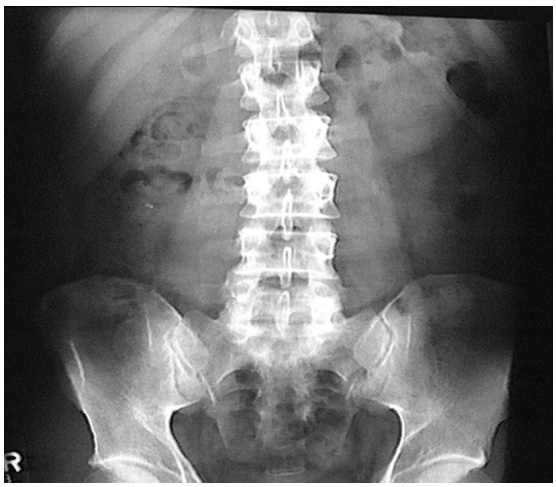
- Bean shaped structure
- On either side of the lower thoracic and upper lumbar spine
- Usual location – between (T11-L3)
- Right kidney is 2 cm lower than the left kidney (Because of liver effect)
- Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles
- Lower pole is 2-3 cm anterior to the upper pole
- Normal size : in adults 11-12 cm

Coronal section of the kidney: Cortex, medulla, major calyces, minor calyces and pelvis



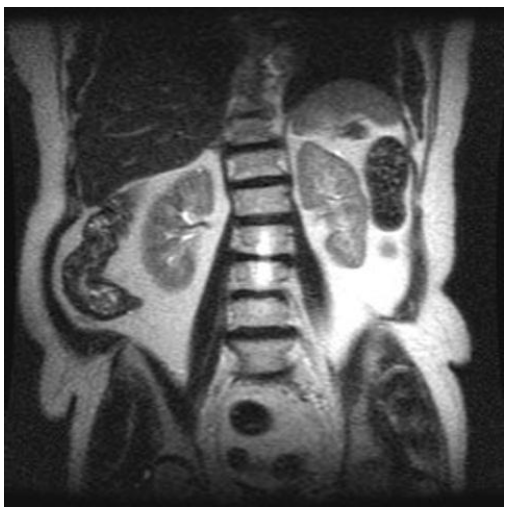


Plain X-Ray(KUB) of abdomen, Useful when we suspect renal stone



Why x-ray not recommended for kidneys?

Kidneys are retroperitoneal organs and may be obscured by bowel loops



MRI showing Left Kidney is higher than Right Kidney

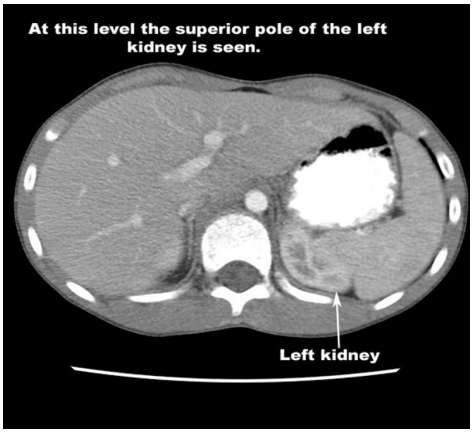
- Around the kidney is the perirenal fat
- **Fat is bright in T1 and T2** (the basic sequence of MRI)

❖ **CT Scan showing left kidney higher than right.**

Pic1: Axial image of the upper pole of the left kidney we don't see the right kidney.

Pic2 : 3 cuts inferior to see upper pole of right kidney

Pic1

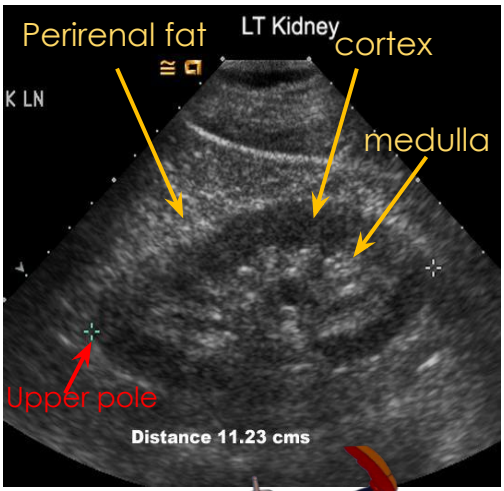


Pic2

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

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

- It is 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



Imagine this kidney as someone who's swim on his back and relaxing, So his head will be in this side of **upper pole** and his feet on the side of **lower pole** --> as Goofy over here ☺

Cont. Kidneys:

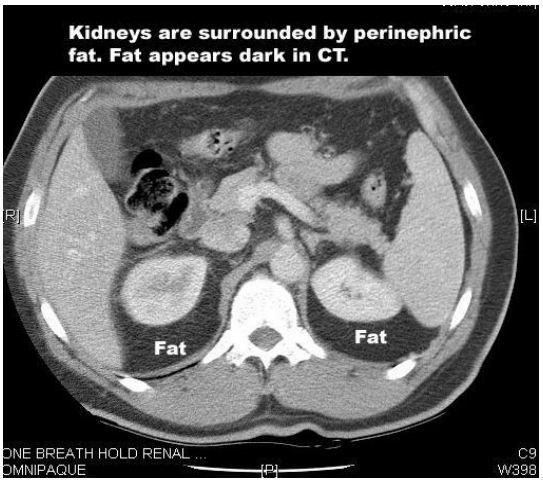
- Kidneys are visualized on the X-Ray due to presence of perirenal fat which is appear dark.
- They are contained within the renal capsule and surrounded by perirenal fat and enclosed within the Gerota's fascia
- Perirenal hemorrhage, pus and urine are contained within the fascia and detected on CT and US as perirenal hematoma or perirenal urinoma.

- **Why do we see the Kidney clear in CT?**

Because of the contrast that is accumulated between the kidney and the fat surrounding it.

- **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 as shown here it will have white lines coming from kidney)

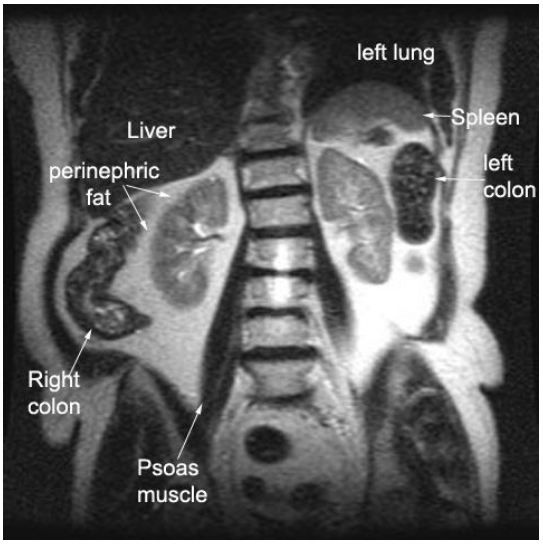


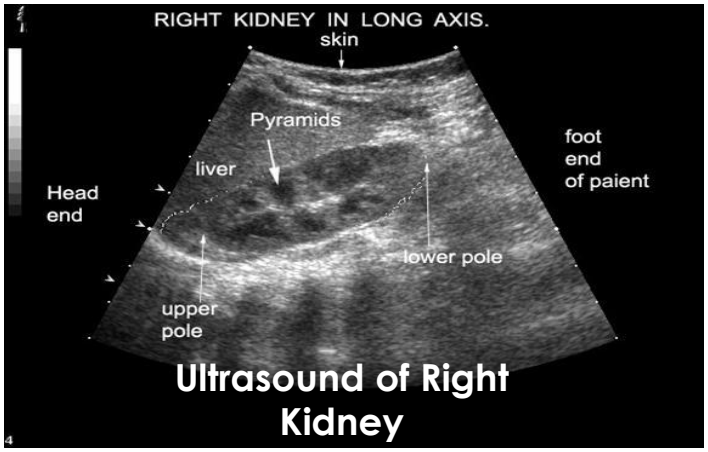
- **What are the basic sequences of MRI?**

T1 and T2

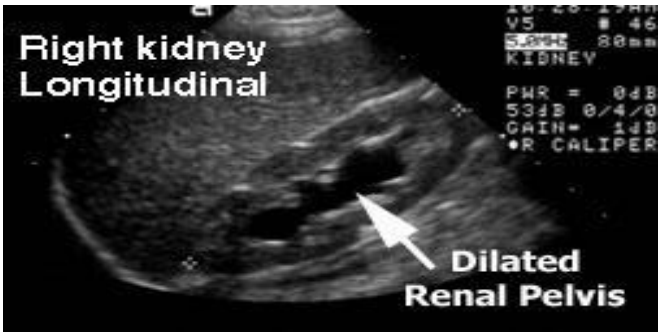
- **In MRI we see the kidneys because of perirenal fat which is bright white in T2 and T1.**
- **How can you differentiate between T1 sequence and T2 sequence?**

Fluid dark black (hyposignal) in T1 and bright white (Hypersignal) in T2.

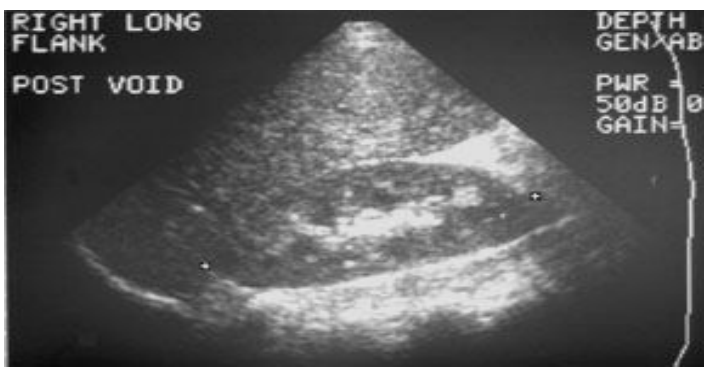




Ultrasound of Right Kidney

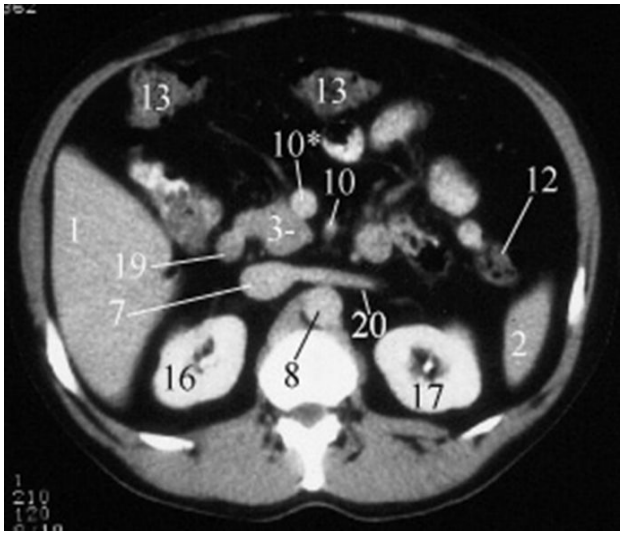


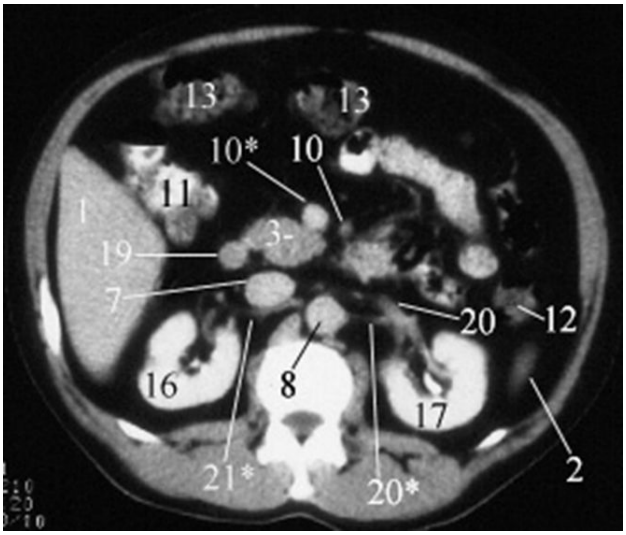
DILATED RENAL PELVIS* (We see anechoic structure filled with urine so all is dark).



US of Kidney (Normal study)

*Dilated renal pelvis: means there is obstruction anywhere in the ureter we have to look for it in CT Urography



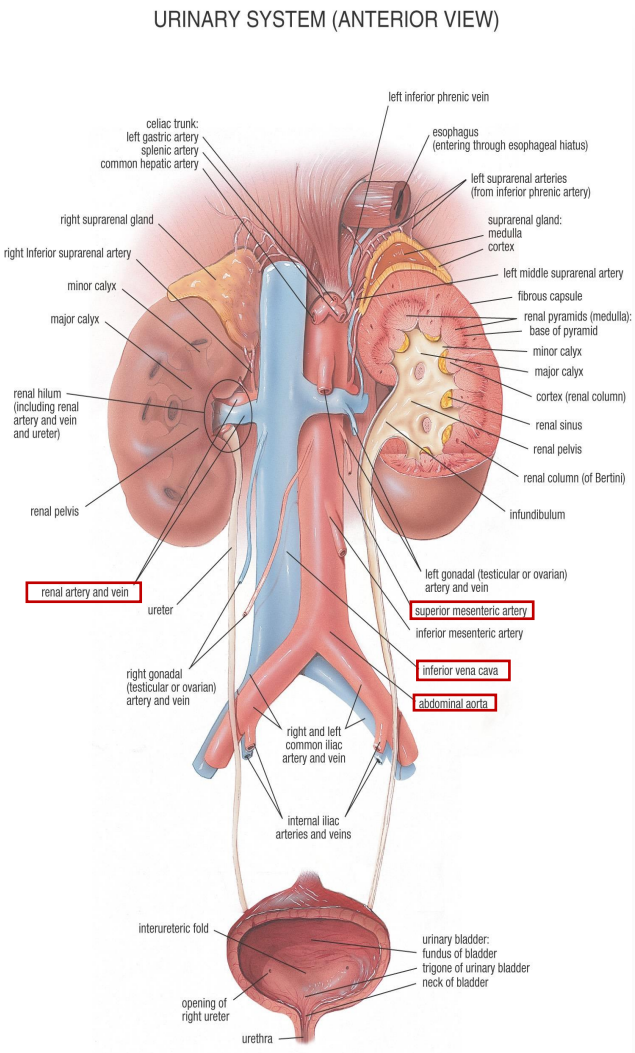


❖ **Structures he pointed at:**

1-Liver	13- Transverse colon
2-Spleen	16- Right kidney
3-Pancreas	17- Left kidney
7-IVC	12- Descending colon
8-Aorta	20- Renal vein

2-Renal Vasculature:

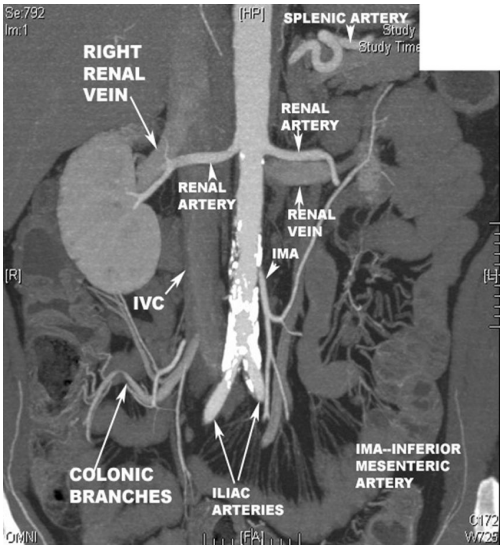
- Renal arteries branch from the abdominal aorta laterally between L1 and L2, below the origin of the superior mesenteric artery.
- The right renal artery passes posterior to the IVC
- There may be more than one renal artery (on one or both sides) in 20-30% cases (they may do nephrectomy and the forget about the accessory renal artery and the patient will be in severe hemorrhage)
- 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 while the right gonadal vein drains directly into the inferior vena cava



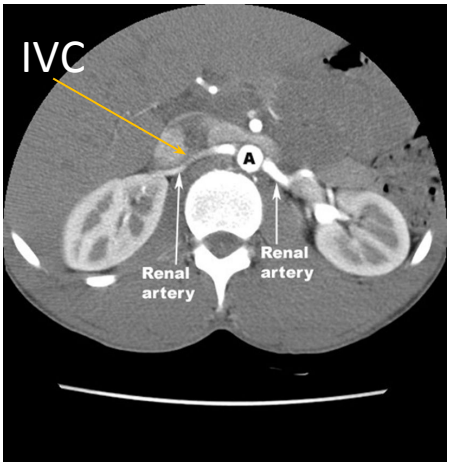
RENAL ANGIOGRAPHY SHOWS:

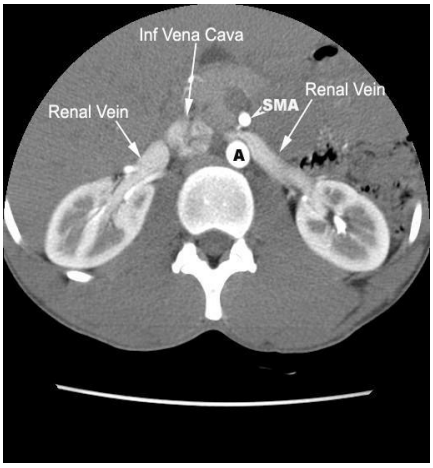
NORMAL SUPPLY OF BOTH KIDNEYS BY SINGLE RENAL ARTERY

LEFT KIDNEY SUPPLIED BY TWO RENAL ARTERIES Lower pole artery = accessory artery. mostly If there is other than principal arteries it's accessory

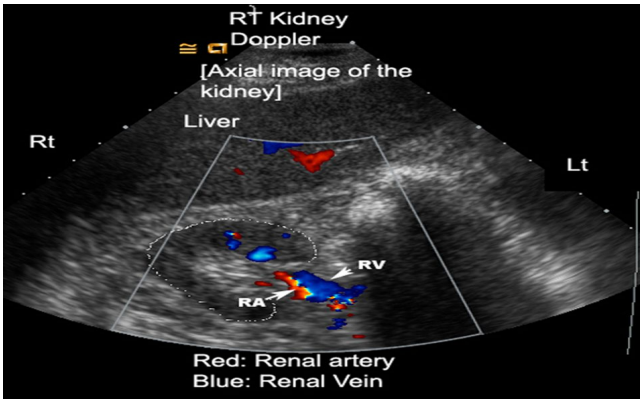


Coronal CT reformat shows the right renal vein and artery, left renal vein and artery and IVC.

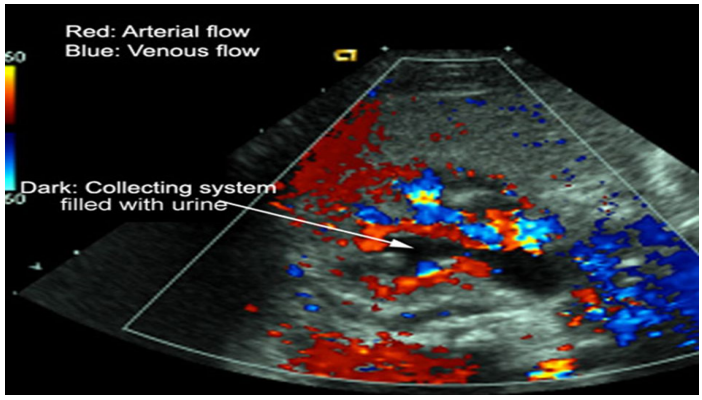




- The right renal artery passes behind the IVC
- The left renal vein passes anterior to abdominal aorta

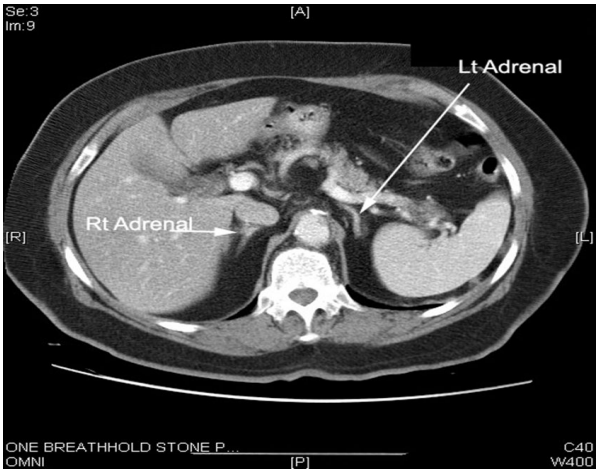


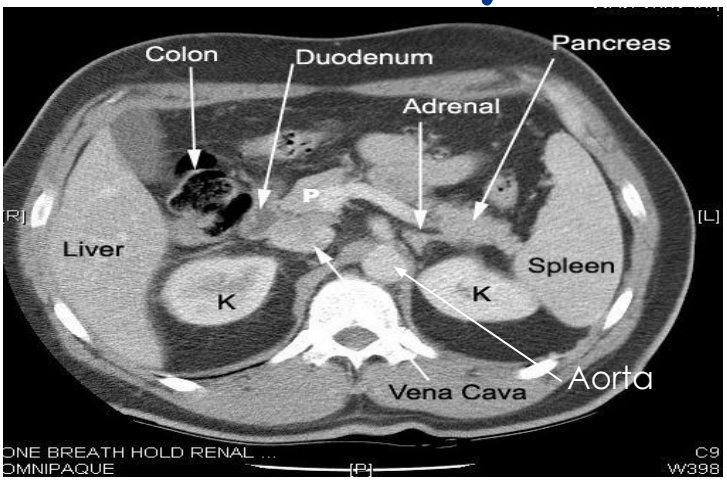
Doppler US shows Renal Veins Lie Anterior to the Arteries.
We do Doppler US to check the blood flow in the kidney, if there is renal hypertension we will see renal artery stenosis. also after renal graft we can see if the blood flow is OK



How do we differentiate the renal vessels from collecting system? 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 take care not to injure the vessels.
Why we see artery and veins colored although in collecting system there is urine? Because of high velocity of blood

Relationships of the Kidneys

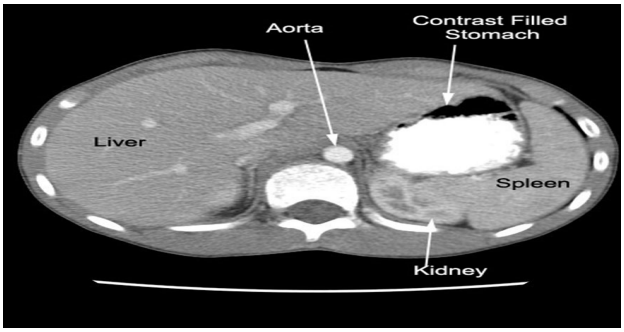




Adrenal Glands are superior to the Kidneys. they are "Y" shape structure.

Structures he pointed at:

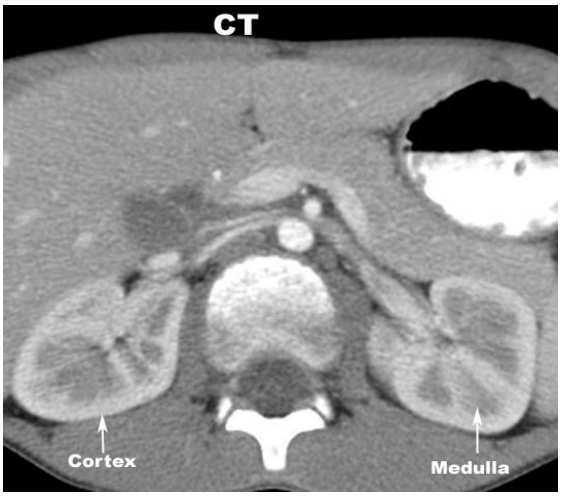
- Pancreas (tail)
- Adrenal
- Spleen
- Liver
- Colon
- Duodenum
- Perineal fat
- Aorta
- Stomach
- Upper pole of left kidney



Renal Structure:

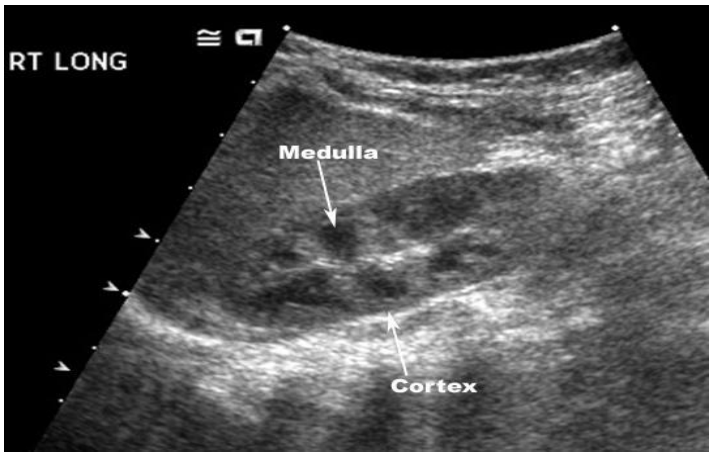
A **CT scan** showing the following:

- **Renal cortex** :
  - (consisting of glomeruli and renal tubules) filter urine from blood.
- Normal thickness 2.5 cm
- cortex thickness < 2cm = kidney failure
- We can measure the cortical thickness by **ultrasound.**
- **Medulla** :
- Consists of multiple renal pyramids

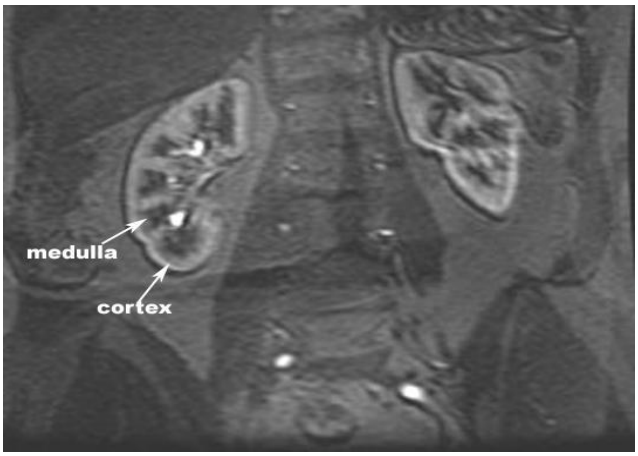


Differentiation between medulla and cortex is Important to see masses mainly in cortex.

Cont.. Renal structures:



Ultrasound of Right Kidney



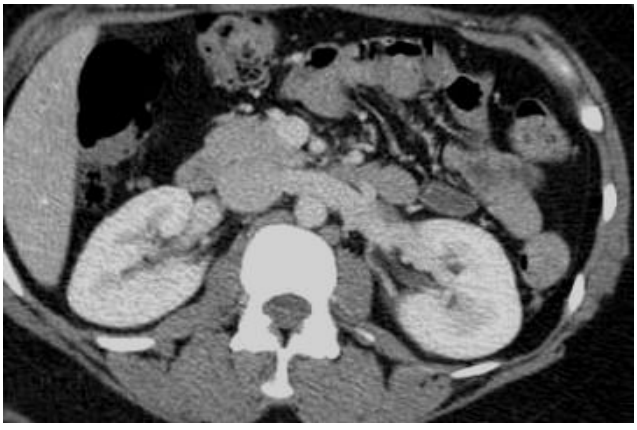
MRI of Kidneys

- Ultrasound showing cortex and medulla of right kidney.
- The best modality to measure the thickness of cortex is US normally 2.5 cm
- If we notice decrees in cortex thickness (<2.5cm)by US then this indicate renal failure.

MRI shows medulla and cortex

Nephrogram phase Vs. Pyelogram phase in CT

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

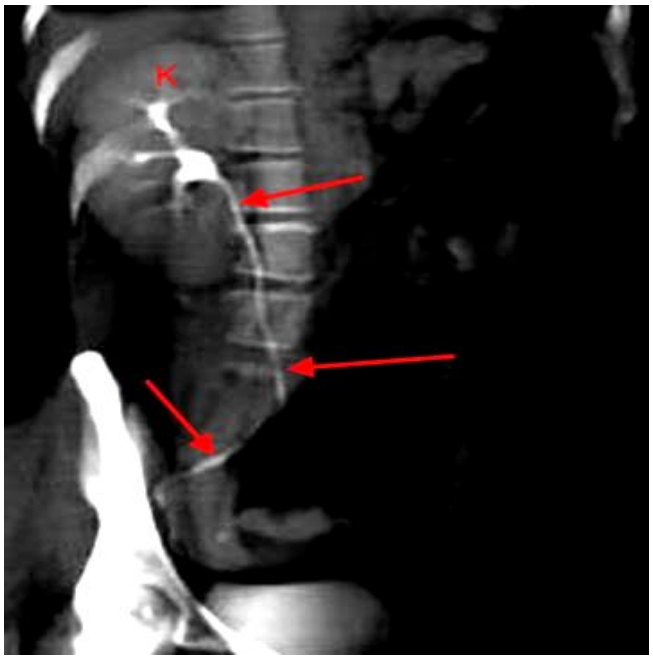


Contrast enhanced CT scan was taken in (Nephrogram phase):

- showing corticomedullary differentiation
- This is approximately **100 seconds** following contrast administration and would show **renal lesions** well

Contrast enhanced CT scan was taken 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, 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

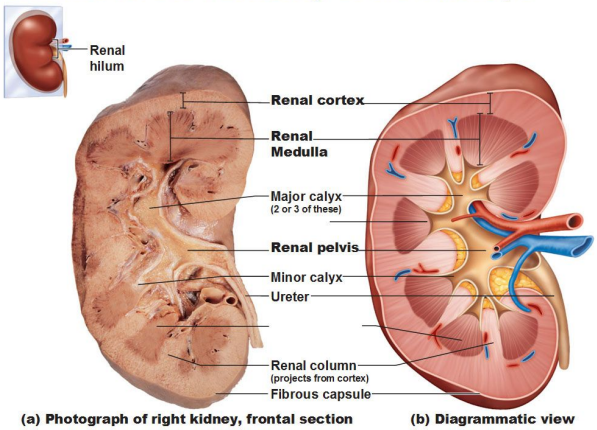
1-Calyces:

- 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

2-Pelvis:

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

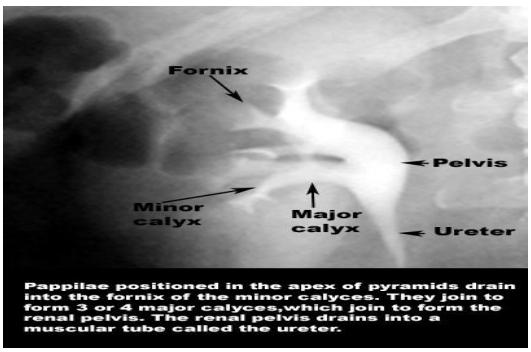
Internal Gross Anatomy of the Kidneys



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

IVP showing collecting system:

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



MRI of the Kidney:

- Urine in calyces appears bright white "T2" as fat. so when there is dilation it will appear bigger and white.
- MRI at T2, Why T2 ?Cause fluid is white

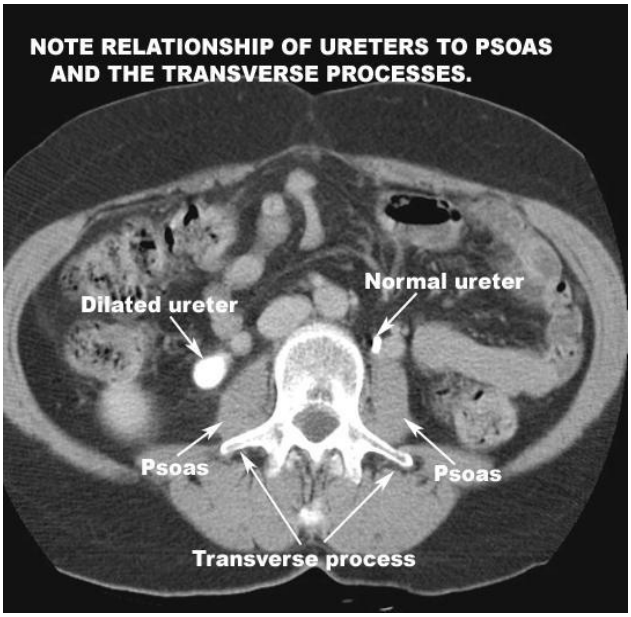
IVP, contrast reaches until bladder.

3- 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).

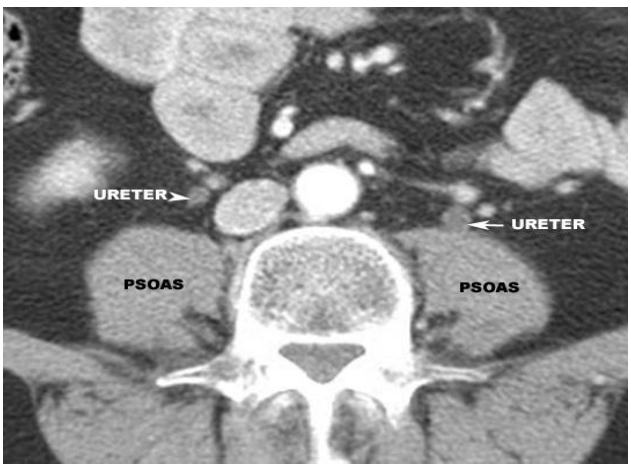
CT urography :

- Dilated ureter filled with contrast means there is obstruction inferior to this dilatation
- Normal diameter of ureter is 3 mm if its 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.



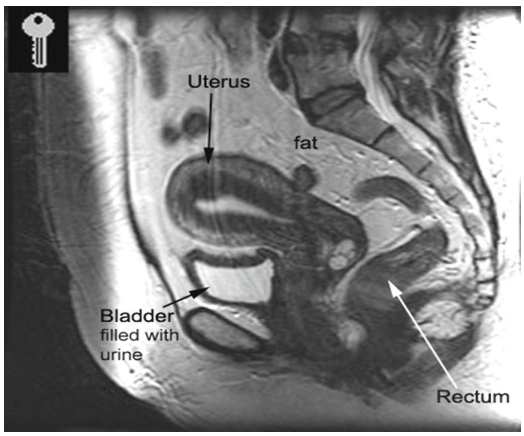
CT without contrast:

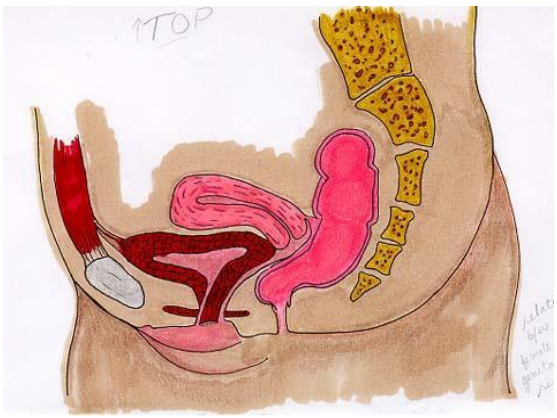
- It's difficult to find the ureter but we follow it from the pelvis downward until the bladder.



Urinary Bladder

- Size and shape vary considerably
- When empty, it is completely within the pelvis
- Dome is rounded in male and flat or slightly concave in female
- Its capacity my reach to 500-600 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:**
- Rectovesicle pouch in males
- vesicouterine and rectouterine pouch in females

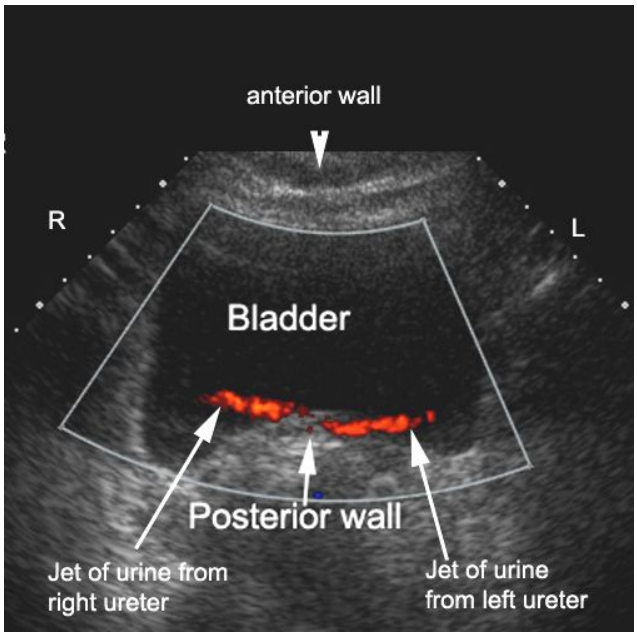


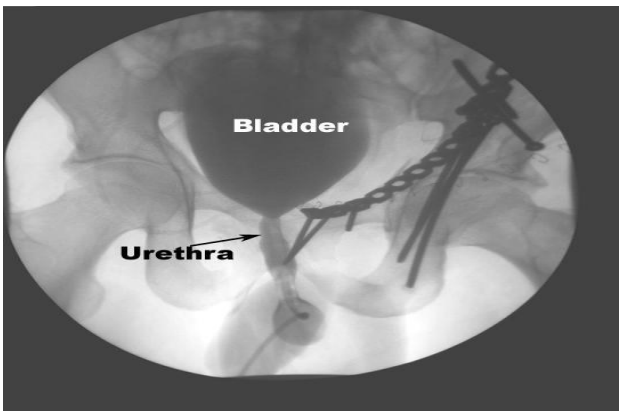


Anatomy of Female Pelvis showing the Urinary Bladder

- We can see vesicouterine and rectouterine pouches in MRI picture.

- 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**.



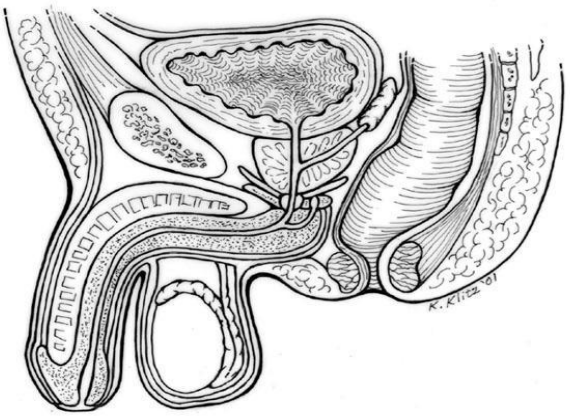


IVP

Bladder with injected contrast through urethra.

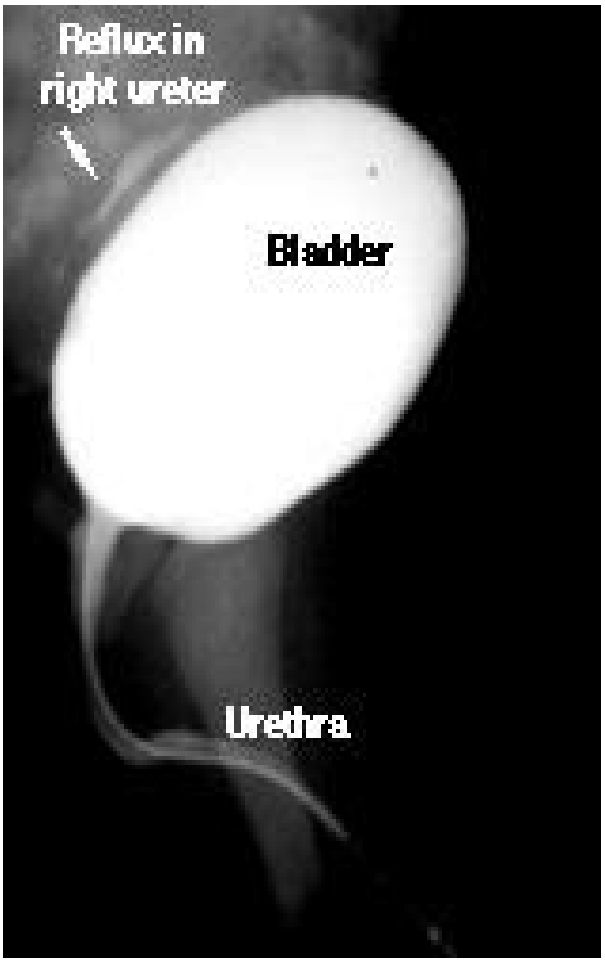
Anatomy of Male Pelvis showing the Urinary Bladder:

Prostate and Seminal vesical posterior to the bladder



Voiding Cystourethrogram:

- **What is it ?**
- It is an x-ray study of the bladder and urethra.
- Mainly done in pediatric age group, when we suspect reflux in ureter (Vesicoureteric 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

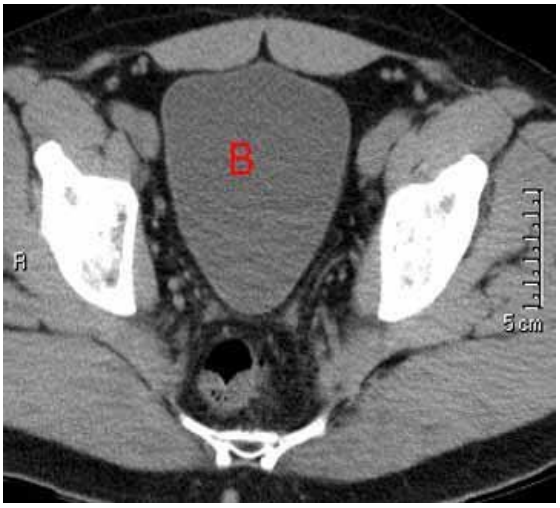
- **Reflux to the ureter?**

Normally don't occur even if bladder is fully saturated by contrast, we can see it in neonate with congenital valve abnormality. If reflux is present there are 4 grades.

Urinary Bladder

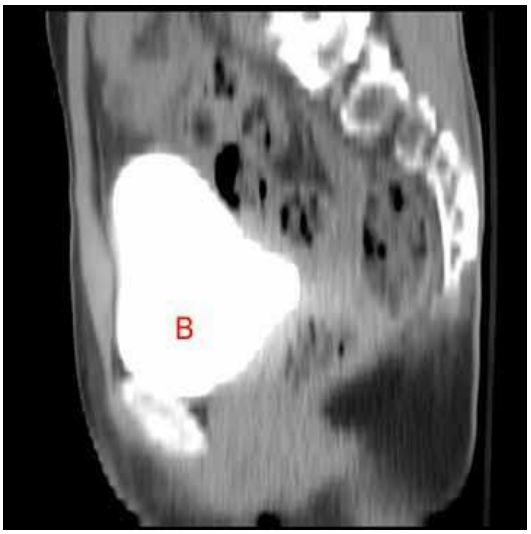
Unenhanced CT scan (without contrast) through a normal bladder(B) shows a normal fluid density structure (less than **10 Hounsfield units** on CT density scale).

- 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.



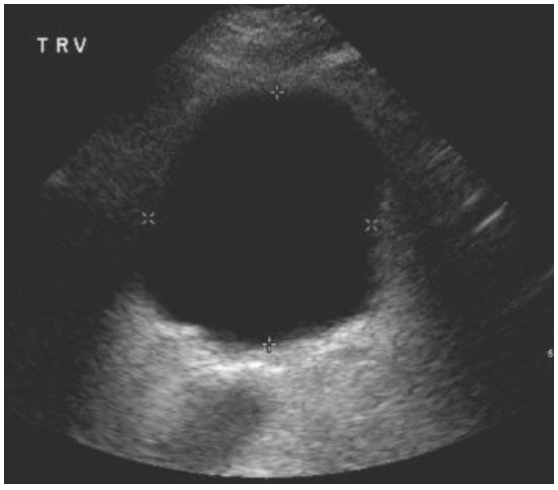
3D reconstructed image of a normal bladder in the sagittal plane following CT urography

- 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



Transverse image through a normal urinary bladder (calipers "x" and "+" 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)



Prostate Gland

- Largest accessory gland of male reproductive system.
- Lies around the first part of the urethra at the base of the bladder.
- (Tr) 4 cm x 3 cm (height) x 2 cm (AP) in size
- Surrounded by dense fibrous capsule
- It is less than 20 cc volume (more than 20 cc = hypertrophy) up to 25 cc still normal especially in elderly
- **It has :**
- Base – closely related to neck of bladder
- Apex
- Posterior surface
- Anterior surface
- Anterolateral surfaces
- **Prostate gland can be divided into:**

➢ An inner gland –transition zone

➢ An outer gland – central and peripheral zones

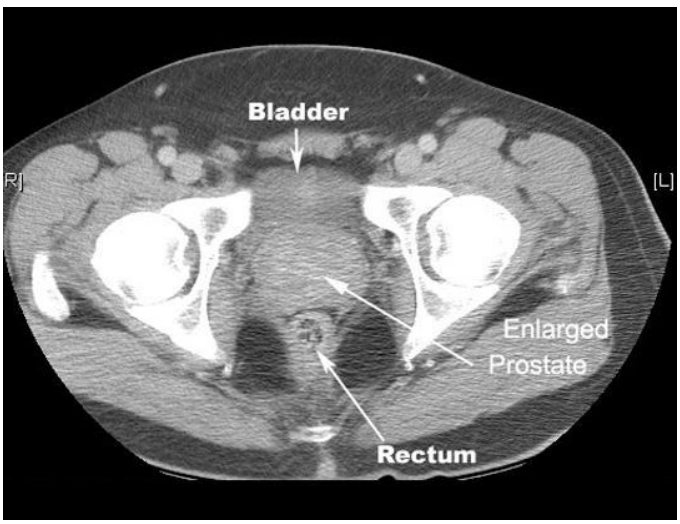
➢ **Transition zone** which lies in periurethral location is the site of benign **prostate hypertrophy** which can occlude the urethra

➢ **Peripheral zone is the primary tumor site in 70% patients**

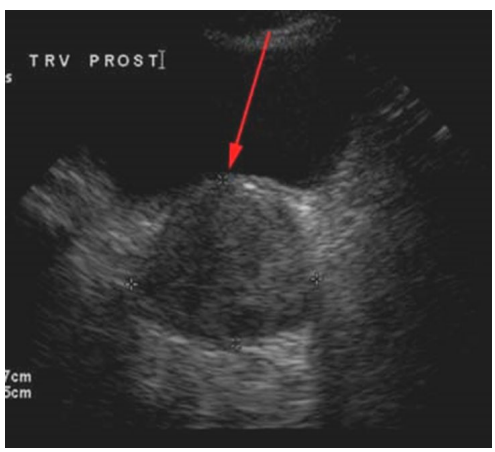
If elderly male patient said has obstruction think about BPH

But if he has no signs and only PSA high think about tumor

➢ transrectal ultrasound is the best imaging modality for prostate



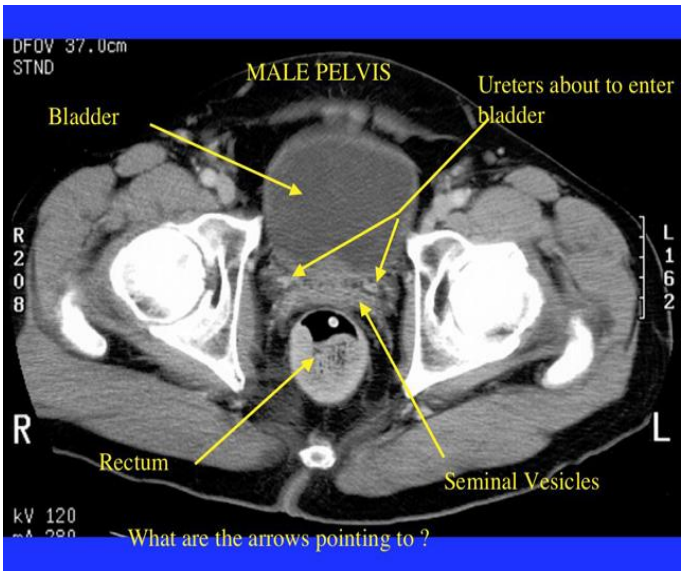
CT showing enlarged prostate

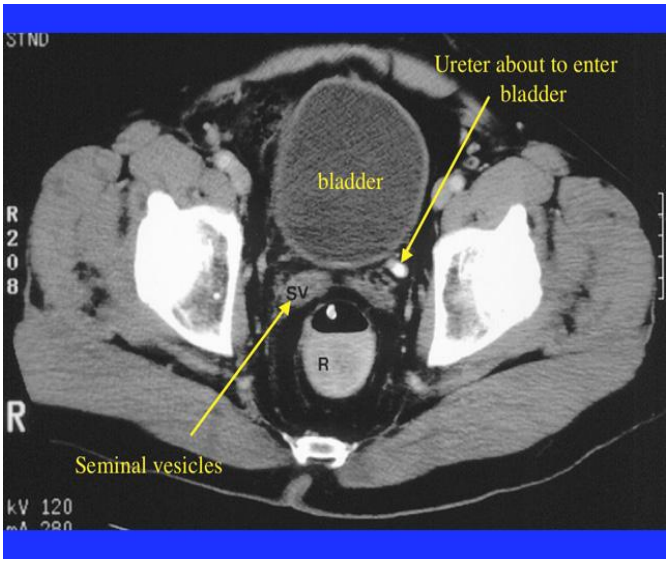


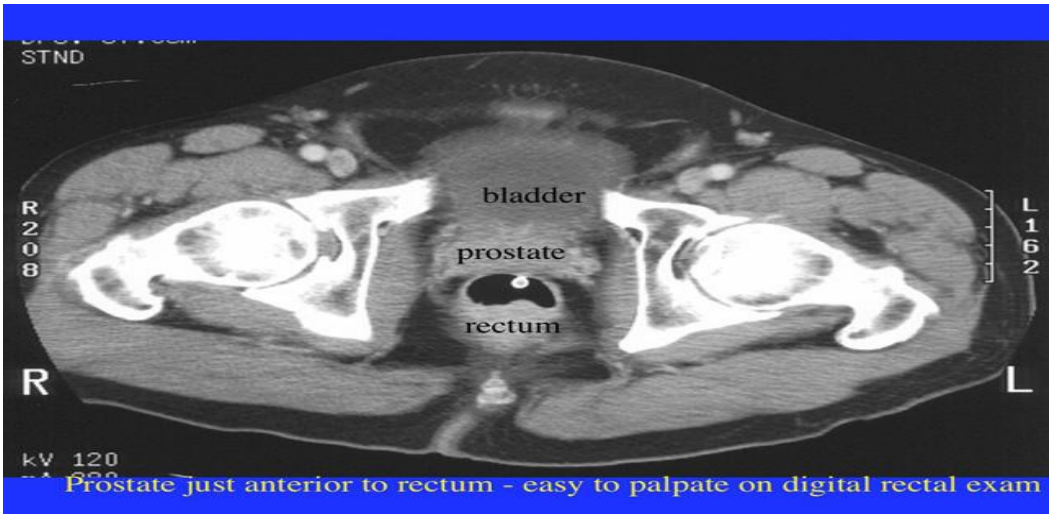
Ultrasound here shows the bladder and the pointed structure is the enlarged prostate more than 20 cc volume

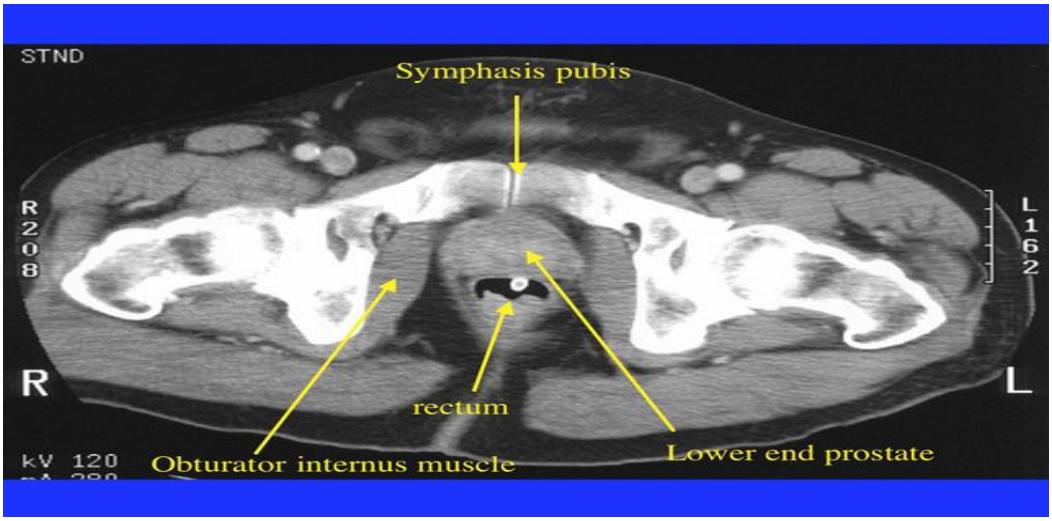
The next images is multiple cut sections in a CT…

Note: you have to know the pointed structure.

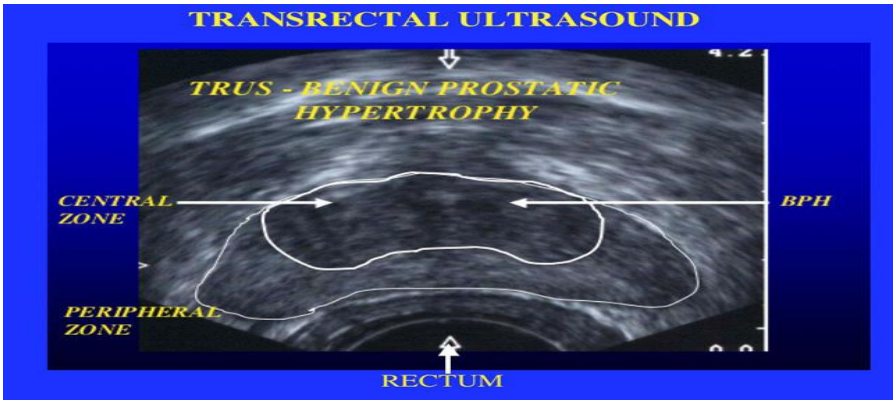




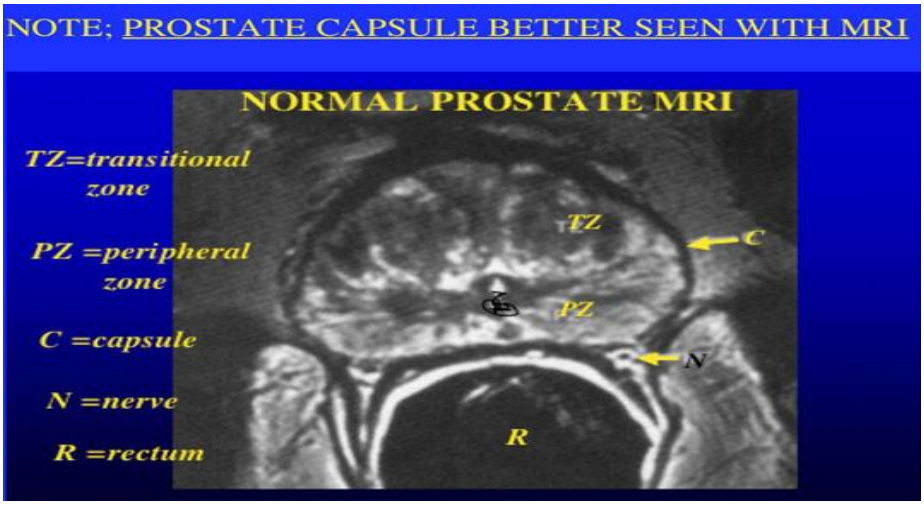




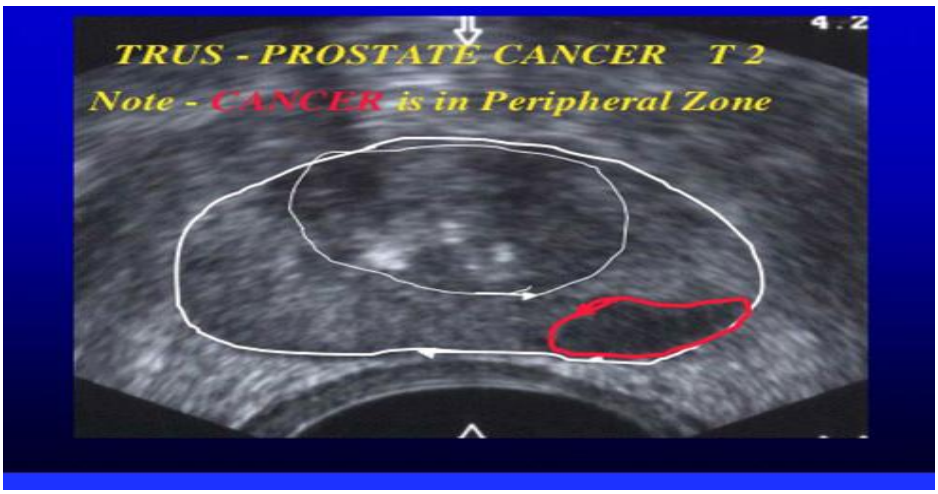
- Lower end of prostate behind the symphysis pubis



- central zone which is hypoechoic = BPH



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



- hypoechoic seen in peripheral zones = Cancer
- 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