Nephrology cycle - Lecture 8

Anatomy and investigations of Genitourinary system

Objectives

1. Introduction about medical imaging.
2. To know the anatomic location and normal size of structures of the urinary tract.
3. To know the different types of modalities used in imaging the urinary tract.
4. To identify the kidneys, ureters, urinary bladder and urethra on different imaging modalities.

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Color Coding

Important | Notes | Extra

[Editing File]

What is medical imaging ?

A medical specialty that employs the use of imaging to both diagnose and treat diseases within the human body.There are two main subspecialties in radiology: a- diagnostic radiology. b- intervention (invasive) radiology.

General note by the doctor:

The best modalities to assess:

Brain → MRI, CT

Bone → X-ray, CT

Lungs → X-ray, CT

Liver → US, CT with contrast, MRI

Urinary System

- Kidneys.
- Ureters.
- Urinary bladder.
- Urethra.

Imaging Modalities

- Plain X-Ray.
- Intravenous Urogram (IVU). Usually we don’t use it but for your knowledge
- US.
- CT.
- MRI.
- Scintigraphy.

Plain X-Ray

1. First imaging modality x- ray is the basic modality in the beginning. "KUB" is X-ray of kidney, ureter, and bladder.
2. Cheap.
3. Useful for radio-opaque (white) stones.

Image features of Plain X-Ray

- Projectional image.
- Image contrast determined by tissue density.
- Good evaluation of radio-opaque stones.

Intravenous Urogram (IVU) this is a fluoroscopy

1. Conventional x-ray + IV contrast Contrast is injected through a vein then is mainly excreted via kidneys and urinary system.
2. Cheap.
3. Recently replaced by CT and MRI.
4. Provides functional and anatomical information.

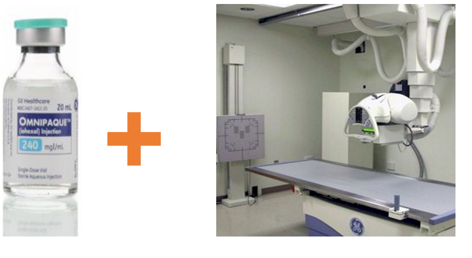


Image features Of Intravenous Urogram (IVU)

- Projectional image. **Projectional radiography** is a form of radiography that produces 2D images by x-ray radiation, and it refers to **Plain radiography**.
- Image contrast determined by tissue density and IV contrast.
- Good evaluation of collecting system and radio-opaque stones.

We may see dilated renal pelvis when there is obstruction in the ureters.

Ultrasound (US)

1. Uses High Frequency Sound Waves (No Radiation).
2. Contrast (the contrast because of different bodily structures) between tissue is determined by sound reflection.
   IMPORTANT: doesn't provide functional evaluation it's good for anatomical evaluation.

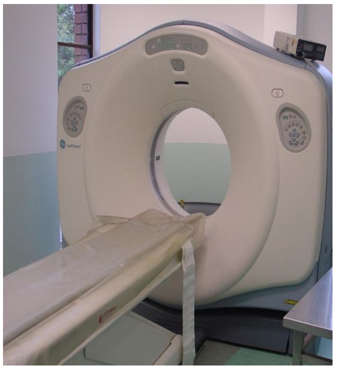
Image features of Ultrasound (US)

- 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. indicated in pregnancy.

*US is good for stones because they make a shadow.

Computed Tomography (CT)

1. Same basic principle of radiography.
2. More precise.
3. Costly.
4. +/- contrast.
5. Useful for trauma, stone, tumor and infection.



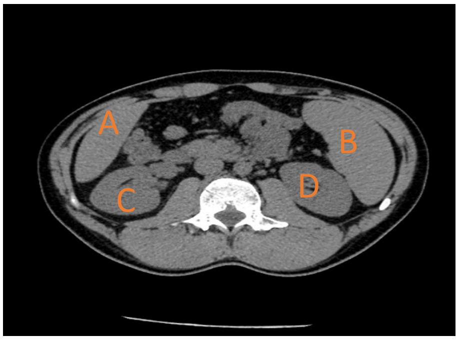
Notes:

1-Usually CT of kidneys is without contrast (e.g. we don't use contrast for assessing stones) but contrast is added if we wanted to assess the presence of a TUMOR or in case of trauma (to assess blood extravasation) or infection.

2- Old CT: takes cut sections, while New CT: use helical method so everything is captured. Also, we can reconstruct images to make 3D.

Image features of computed tomography (CT)

- Cross sectional images.
- Image contrast determined by tissue.
- density +/- contrast.
- Better evaluation of soft tissue.



A = Inferior cut of the liver.
B = Spleen.
C= Right Kidney.

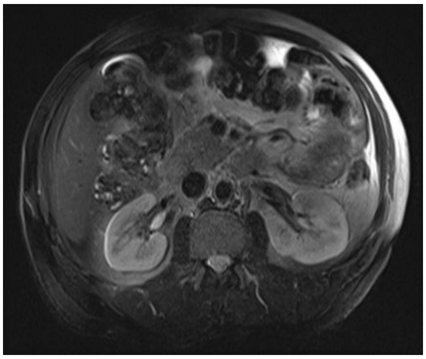
- Q) Where is the left kidney? **D** (Don't forget in all radiology your left is the pictures right (opposite)… ONLY except in nuclear medicine (also called scintigraphy) the right is also right (same side).
- We always say that nuclear medicine is used to assess function… here also CT with contrast is used to assess the function of renal system.

Magnetic resonance imaging (MRI)

If we need more specification,

- Cross sectional images.
- Image contrast determined by tissue properties.
- Excellent for soft tissue evaluation.

Image features of Magnetic resonance imaging (MRI)



1. Better evaluation of soft tissue.
2. Uses magnetic field (No Radiation).
3. Expensive.
4. Useful for soft tissue pathology: tumor, infection.

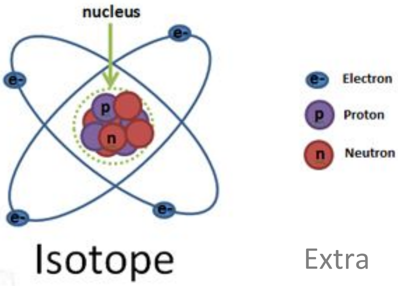
* We rarely use MRI for urinary system

Nuclear medicine (scintigraphy)

1. Utilizes a gamma camera and radioactive isotopes.
2. Functional test.
3. Less expensive.
4. Useful for: obstruction and split function

We usually assess renal function by creatinine clearance and GFR but these only indicate the general function of BOTH kidneys.

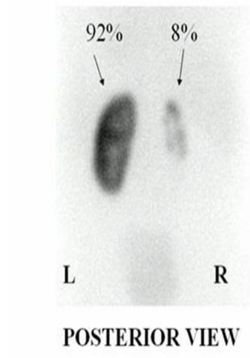
If we want to assess the function of each kidney (separately) we use nuclear medicine because it assess "split function" of each kidney separately (the normal kidney takes the radioactive material more than the failing kidney. The failing kidney -in renal failure- doesn't take the radioactive material).

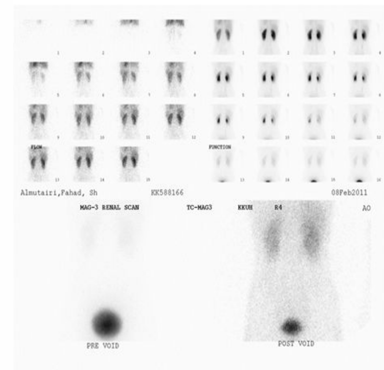


Extra

Image features of Nuclear medicine

- Projectional image.
- Image contrast by tissue uptake and metabolism.





Anatomy

To know the abnormal in radiology

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You should know the normal in radiology

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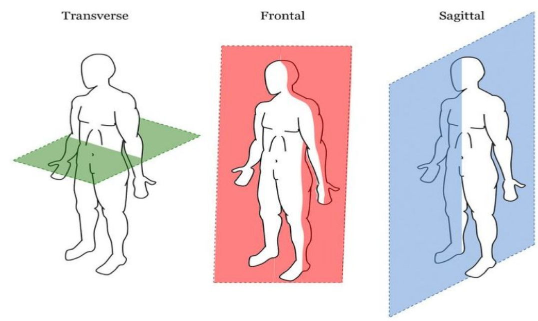
You should know anatomy

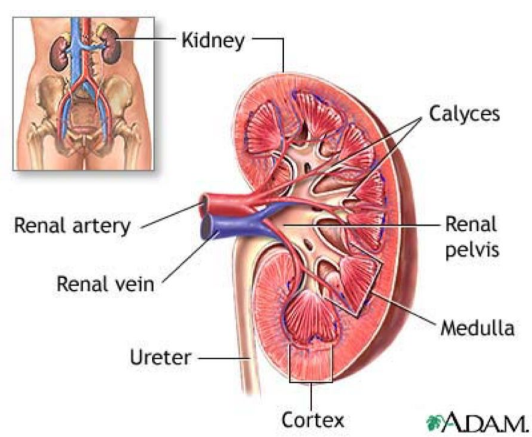


Kidneys

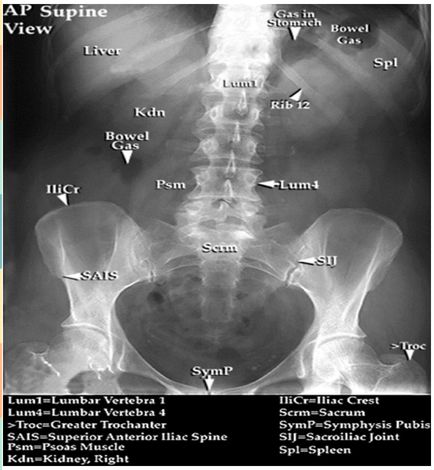
- Bean shaped structure.
- On either side of the lower thoracic and upper lumbar spine.
- Usual location – between (T11-L3). If you got confused where kidneys are in the image, look between T-11 and L3 (sometimes between T12 and L3 according to size of kidney) and you should find kidneys.
- Right kidney is 2 cm lower than the left kidney.
- 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?

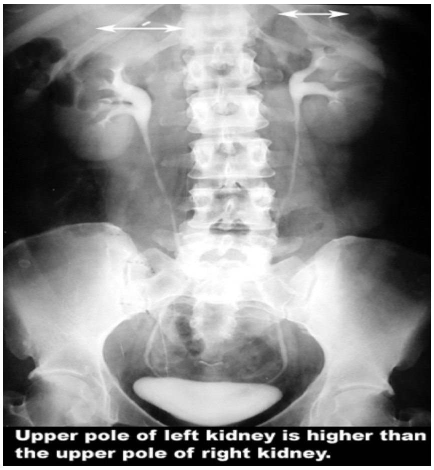
- Bilateral small kidneys - chronic diseases (GN Glomerulonephritis).
- Bilateral normal or large kidneys:
  1- Polycystic kidney disease.
  2- Amyloidosis.
  3- Diabetes mellitus.
- One small, other large- consider:
  1- Renal artery stenosis.



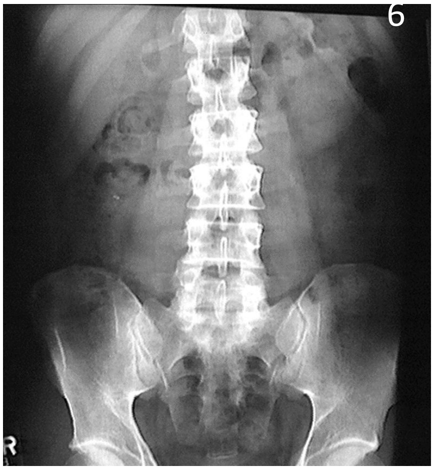
- Kidneys are visualized on the X-Ray due to presence of **perirenal fat.**
- They (The kidneys) are contained within the renal capsule and surrounded by perirenal fat and enclosed within the **Gerota's fascia**.
- Perirenal hemorrhage, pus and urine are contained within the fascia and detected on CT and US.
- Note that stomach is a superior relation for the left kidney.



Useful when we suspect renal stone

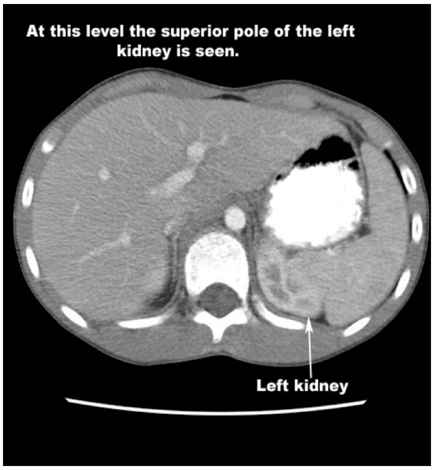


Kidneys are retroperitoneal organs and may be obscured by bowel loops (Sometimes we don't see kidneys because bowel loops are in front of them)

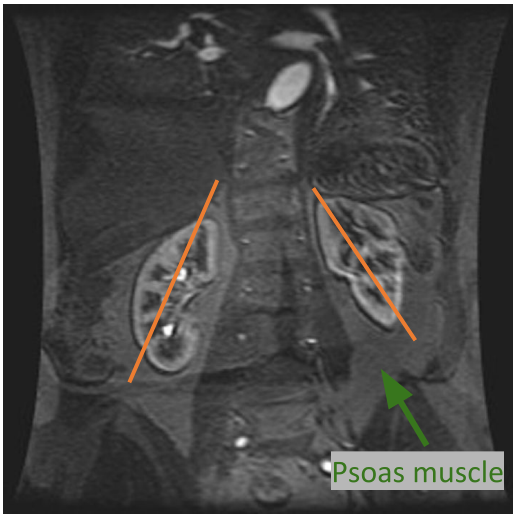


We don't usually see ureters in X-ray unless we are using contrast

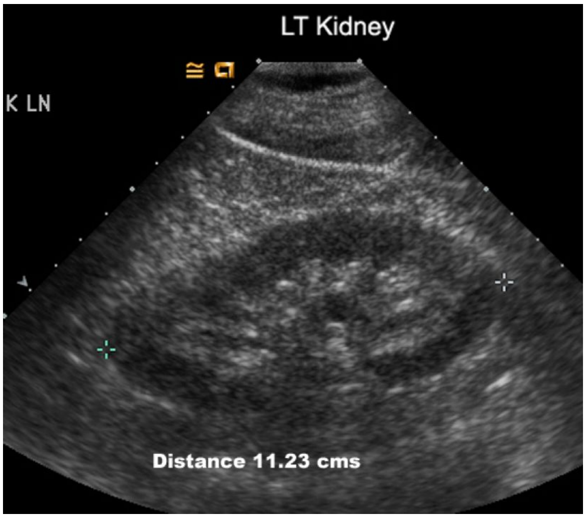
MRI showing Left Kidney is higher than Right Kidney



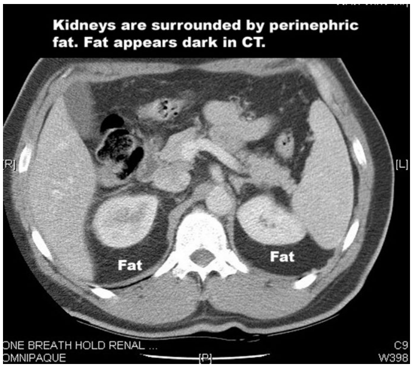
CT Scan showing left kidney higher than right Remember that right kidney is lower in level that left kidney (because of liver) … so in CT don't quickly think of an absent kidney! Maybe it's just the level of the image



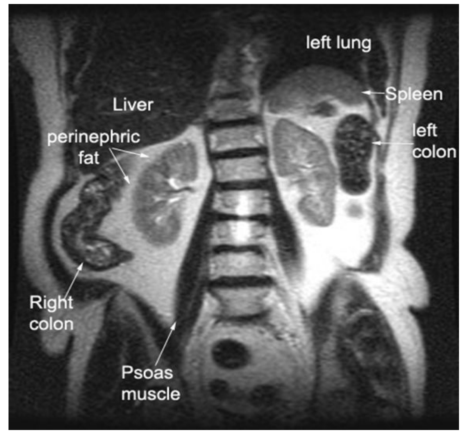
Long axis of the kidneys is directed downward and outward, parallel to the lateral border of the psoas muscles



Ultrasound is the best method to measure the size of the Kidney (with finding the long axis)

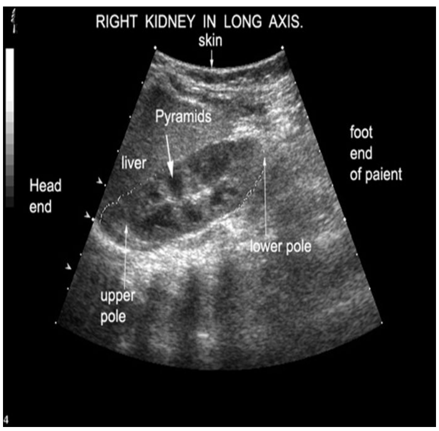


in X Ray we say radiopaque for white and radiolucent for dark, but in CT we say hypodense and hyperdense



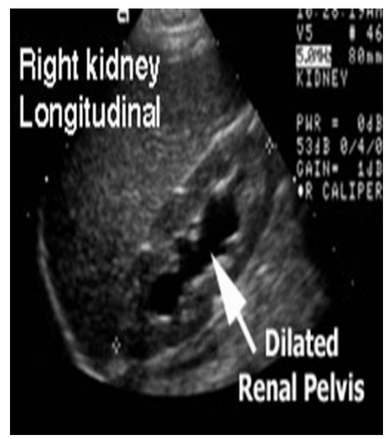
MRI: Fat is bright in T2

Ultrasound Of Kidneys



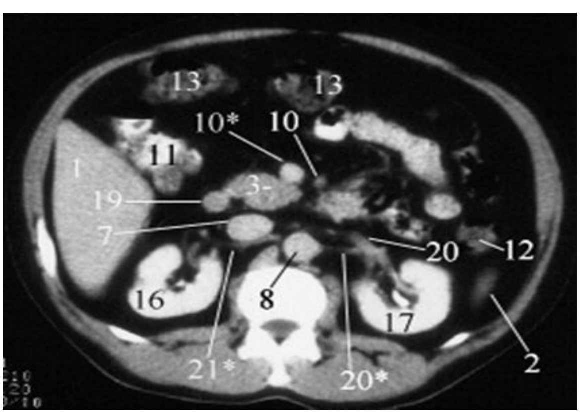
Ultrasound of Right Kidney

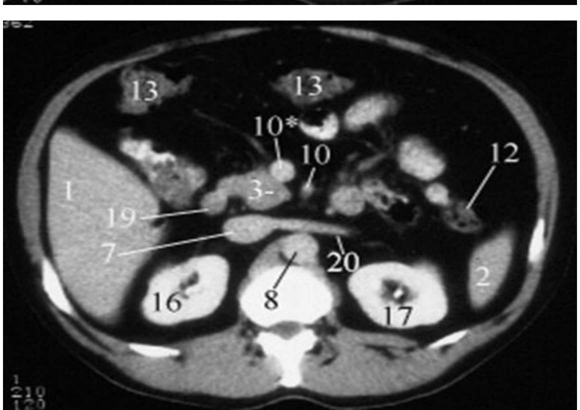
Normal Study



Dilated Renal Pelvis

CT Scan of the Kidneys





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

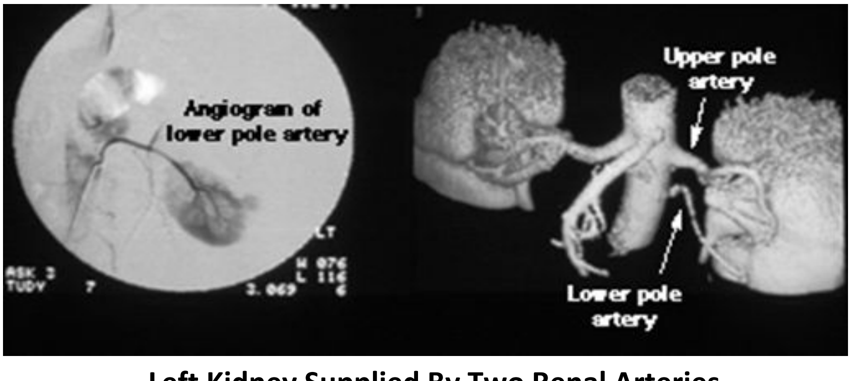
Renal Vasculature

- 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.
- 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.
- Remember the branches of abdominal aorta (from up to down): celiac artery then superior mesenteric artery then renal arteries then inferior mesenteric artery… So renal artery is located between the superior and inferior mesenteric.

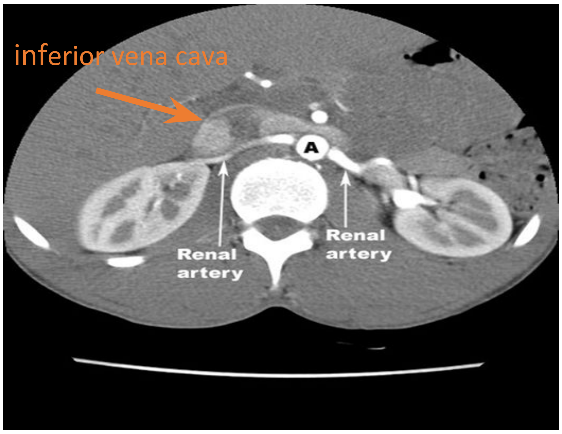
Renal Angiography

Normal Supply Of Both Kidneys each By **Single** Renal Artery

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 pool 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)



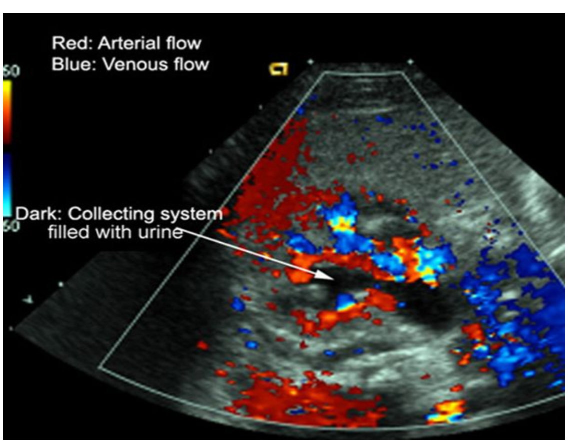
Left Kidney Supplied By Two Renal Arteries



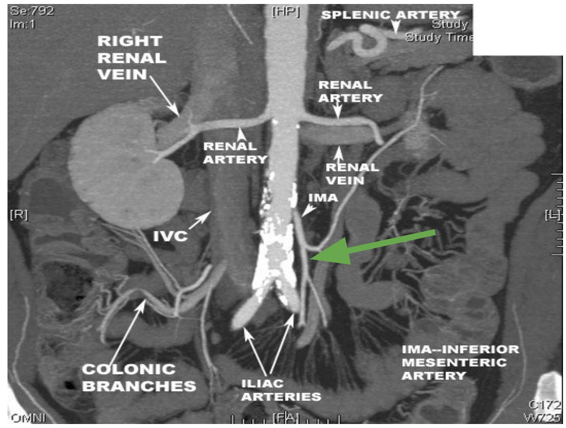
When you want to image arteries or veins with contrast remember it's all about the timing.

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) within few seconds the contrast will reach the heart via vena cava then become pumped into aorta and different major arteries in the body (after 20 seconds of injecting contrast it reaches arteries)…

so if you want to image veins with contrast, you have to take images very early after administering contrast to the patient, or you wait for the blood to be exchanged within capillaries which will go back to veins again.

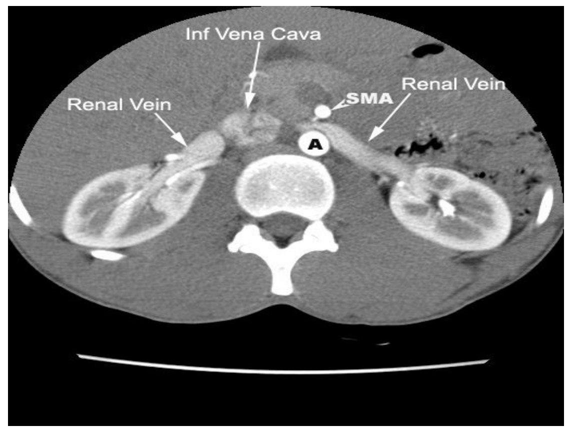


in doppler we see high flow of blood in arteries and veins but we don't see urine because urine is not high in flow (not quick) so with doppler the urine appears black while blood in arteries and veins appear colored.

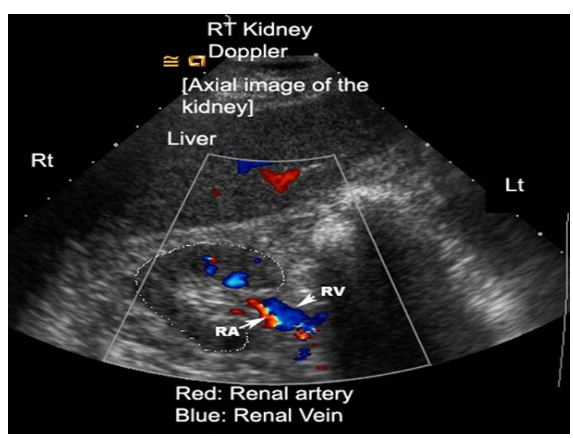


Coronal CT reformat

Coronal reconstruction of CT with IV contrast… here we see calcification of aorta



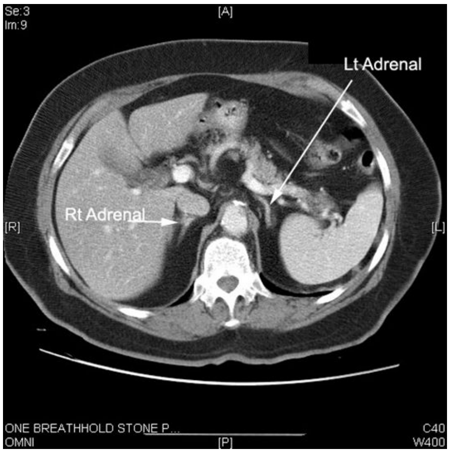
Left Renal Vein Passes Anterior to the Abdominal Aorta and posterior to superior mesenteric artery (SMA), sometimes left renal vein is compressed between superior mesenteric artery and abdominal aorta which causes left renal vein stenosis (the nutcracker syndrome)

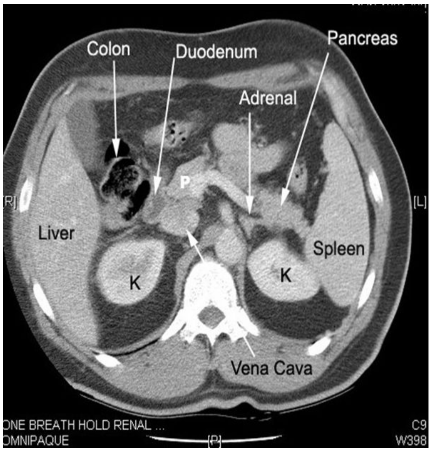


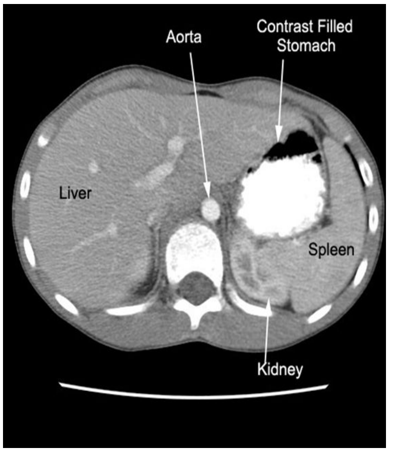
Renal Veins Lie Anterior to the Arteries

Always the arteries are deeper than veins

Relations Of the Kidneys







Adrenal Glands are superior to the Kidneys

kidneys are surrounded by fat. fat makes it easier for us to see kidneys. We call that "contrast" it's the "difference" in color between structures so we can identify structures

Renal structure

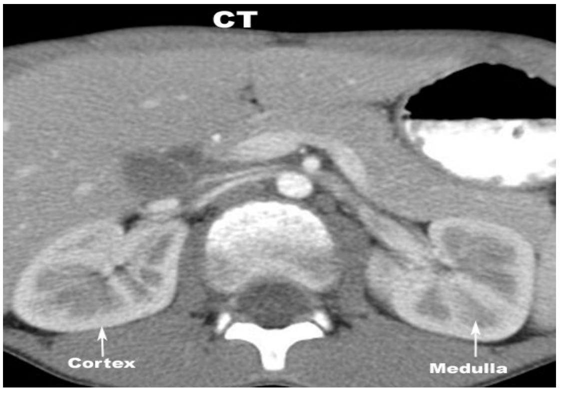
Cortex

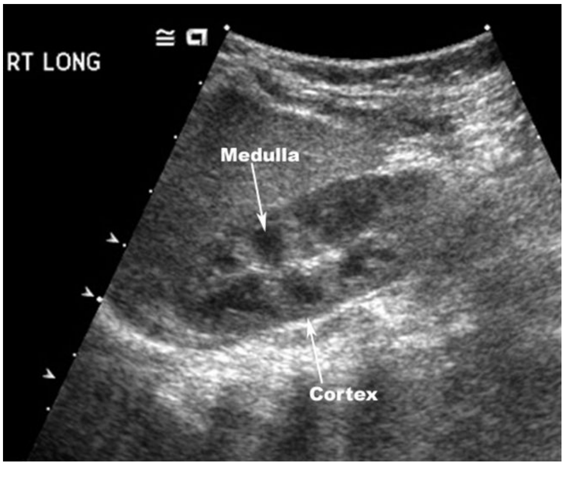
- Renal cortex consists of glomeruli and renal tubules.
- Normal thickness is 2.5 cm.

Medulla

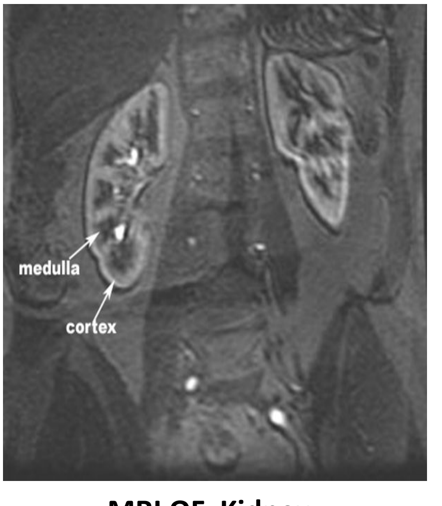
- Consists of multiple renal pyramids.

Nephrons are in the cortex, so the urine is first filtered in cortex then moves to medulla.



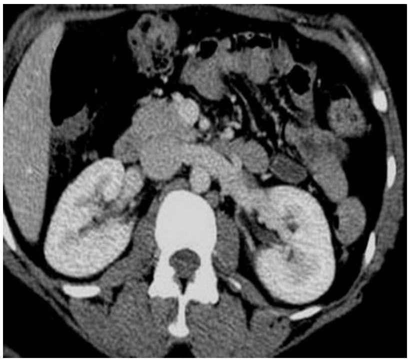


Ultrasound of Right Kidney



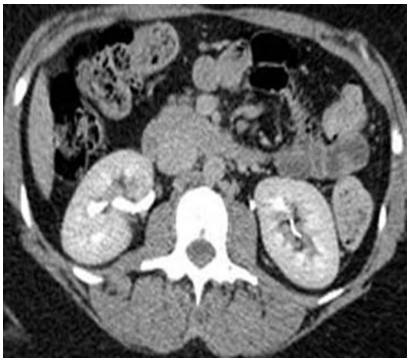
MRI OF Kidney

Nephrogram phase



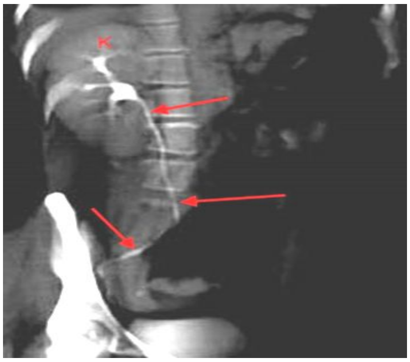
- Contrast enhanced CT scan through the kidneys in **nephrogram phase** (showing corticomedullary differentiation).
- This is approximately 100 seconds following contrast administration and would show renal lesions well.
- If the kidney isn't filtering well there will be thinning of the cortex for less than 2.5 cm (remember that nephrons -responsible of filtration- are present in renal cortex).
- Cortex appears more whitish than medulla.

Pyelogram phase



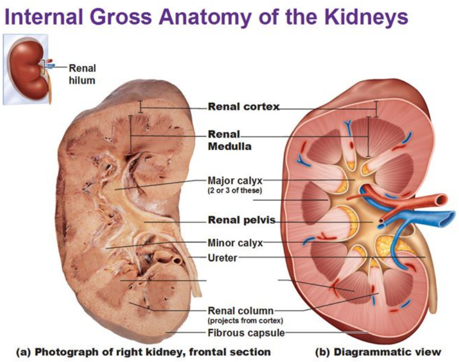
- Contrast enhanced CT scan through the kidneys in pyelogram phase (showing excretion of contrast into the collecting system).
- This is approximately 8 minutes following contrast administration and would show urothelial lesions well, such as **transitional cell carcinoma**, stones, blood clots.
- 3D reconstructed image from CT scan of the abdomen and pelvis known as CT urography.

IVU imaging



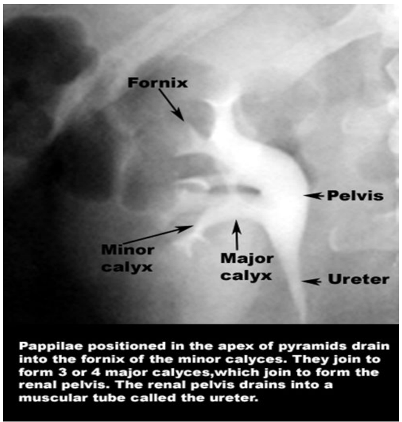
- Nowadays, this exam is quickly replacing the conventional IVU.
- Last pic: 3D reconstruction is performed through the right kidney (K) and follows the normal ureter (arrows) all the way to the ureter insertion into the bladder.

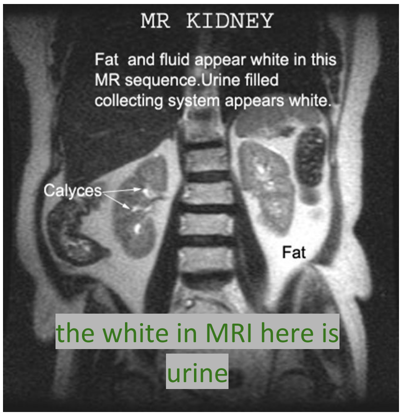
Renal Collecting System

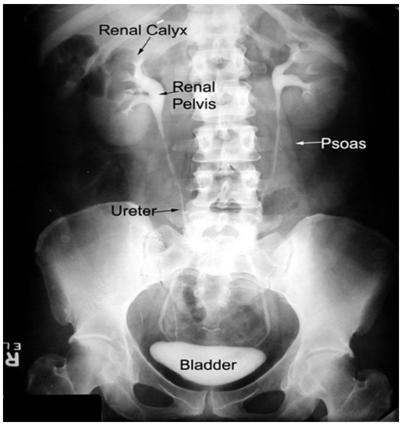


Calyces

- 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.





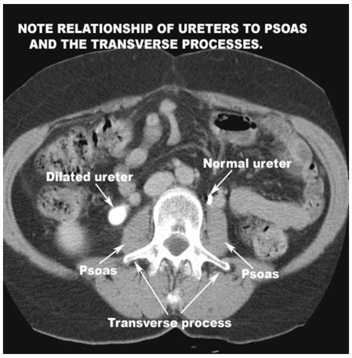


Ureters

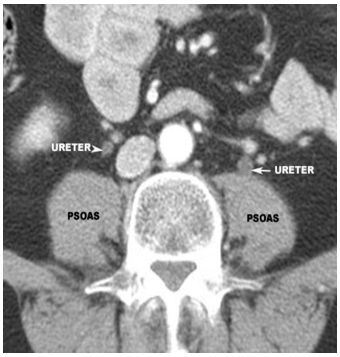
- 25-30 cm in length and 3 mm diameter If ureters' diameter is wider than 3mm then it might be dilated because of a stone or tumor obstructing.
- Three areas of normal narrowing:

1. Ureteropelvic Junction.
2. Bifurcation of the iliac vessels.
3. Ureterovesical Junction.

When there is stone usually it impacts stuck) in these areas.



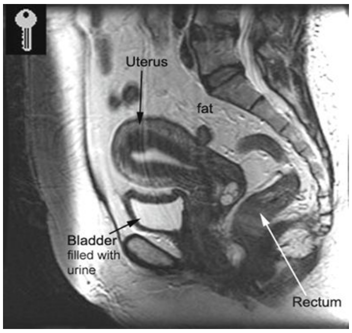
Since this image show contrast inside ureters then this is excretory phase

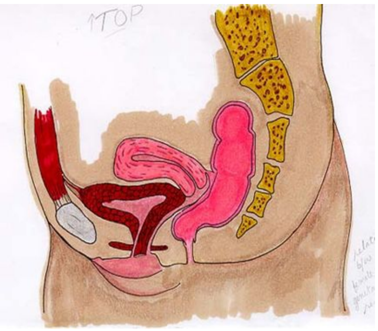


Here ureters without contrast in them

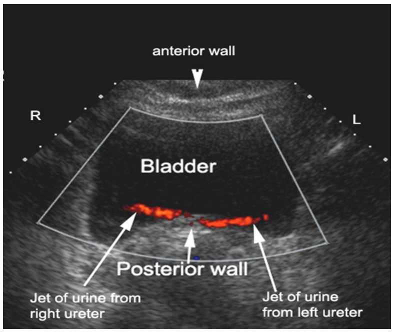
Urinary Bladder

- 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.

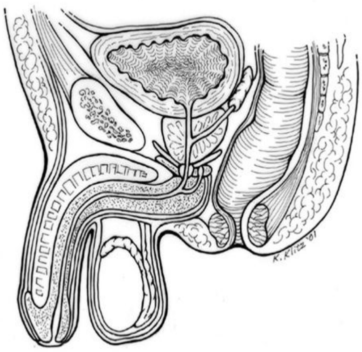




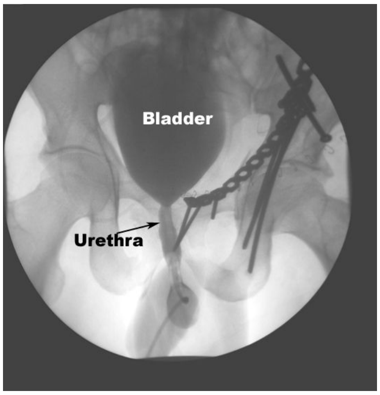
Anatomy of Female Pelvis showing the Urinary Bladder

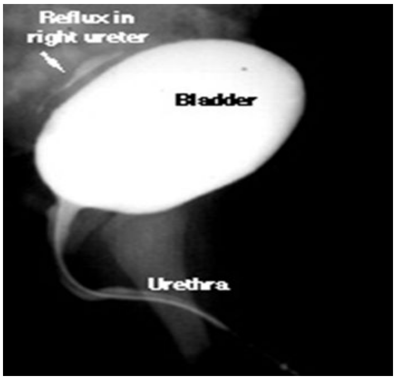


*see note about this image in next slide



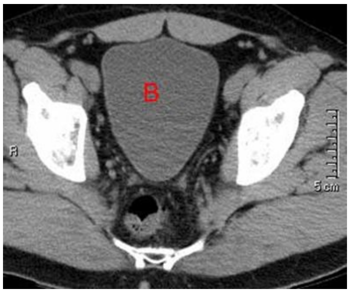
Anatomy of Male Pelvis showing the Urinary Bladder





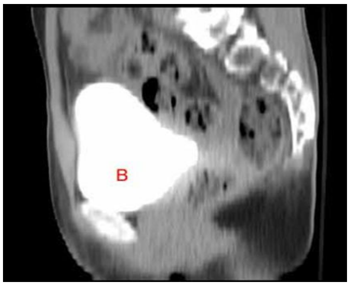
Voiding Cystourethrogram

usually done in pediatric patients. We inject contrast through urethra to see if there is contrast reflux from urethra to bladder -abnormal-)

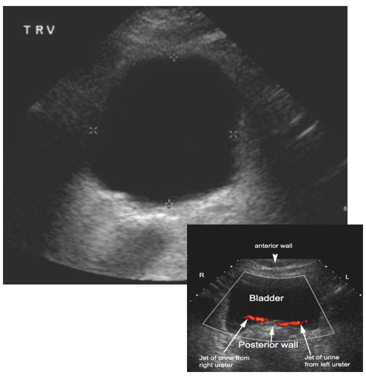


- Unenhanced CT scan through a normal bladder (B) shows a normal fluid density structure (less than 10 Hounsfield units on CT density scale).

Why the bladder is **hypo**dense here? because of urine.



- 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) When we add contrast and we see filling defect in bladder (black area inside the bladder) it might be a tumor.



- Transverse image through a normal urinary bladder 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).

Prostate Gland

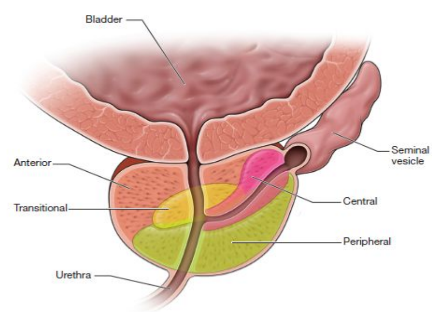
- Largest accessory gland of male reproductive system.
- Lies around the first part of the urethra at the base of the bladder (Tr=Transitional) 4 cm x 3 cm (height) x 2 cm (AP) in size.
- Surrounded by dense fibrous capsule.
- Anatomy of prostate gland:

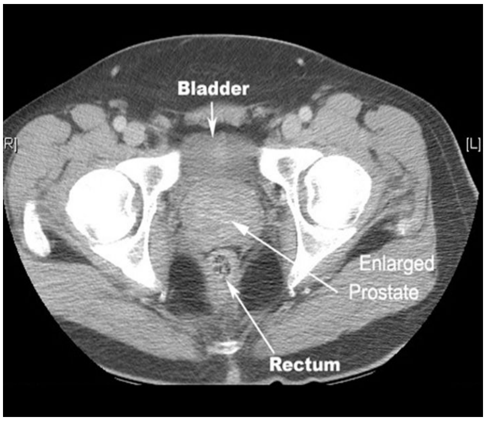
1. Base – closely related to neck of bladder.
2. Apex.
3. Posterior surface.
4. Anterior surface.
5. Anterolateral surfaces.

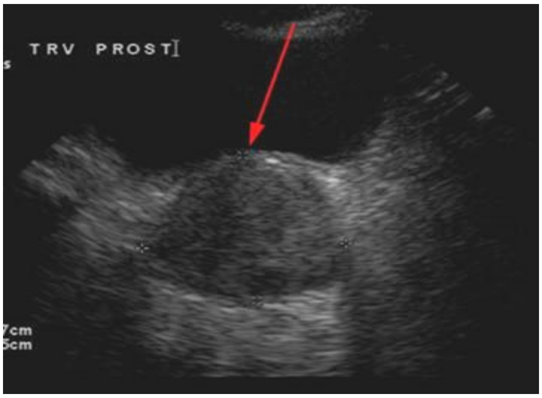
- Prostate gland can be divided into:

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

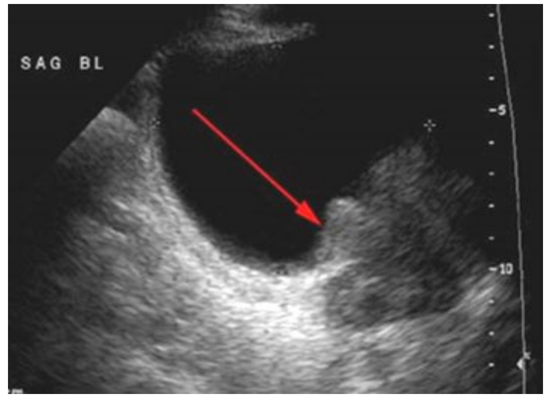
- Transition zone which lies in periurethral location is the site of benign prostate hypertrophy which can occlude the urethra.
- Peripheral zone is the primary tumor site in 70% patients.





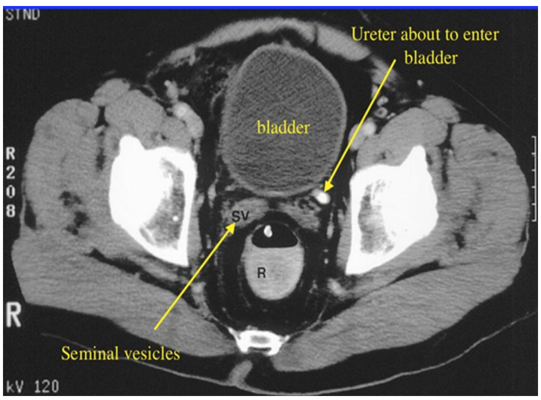


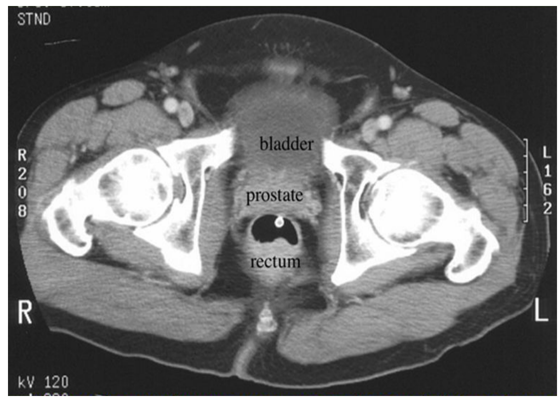
Axial section



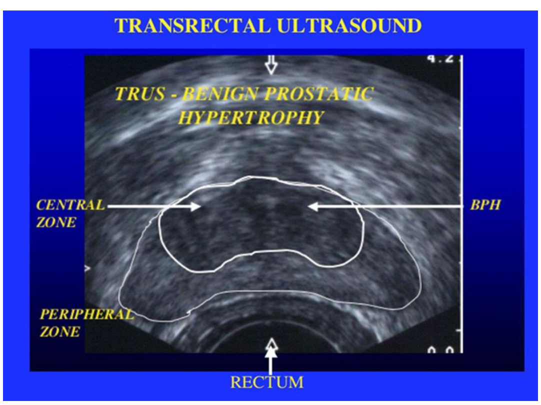
Longitudinal

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

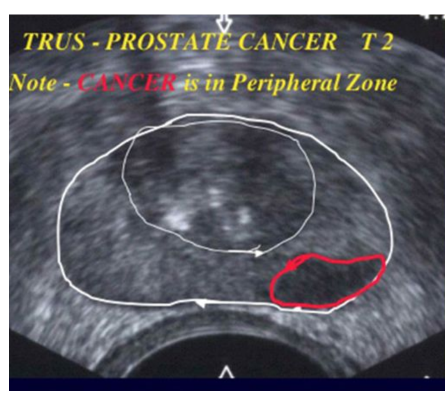




Prostate just anterior to the rectum
easy to palpate on digital rectal exam

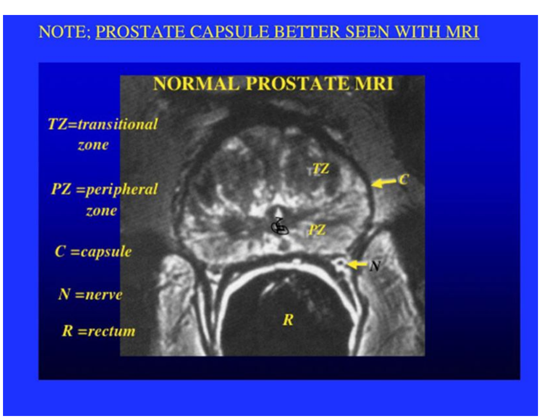


Hypoechoic central zone = BPH



this picture is important

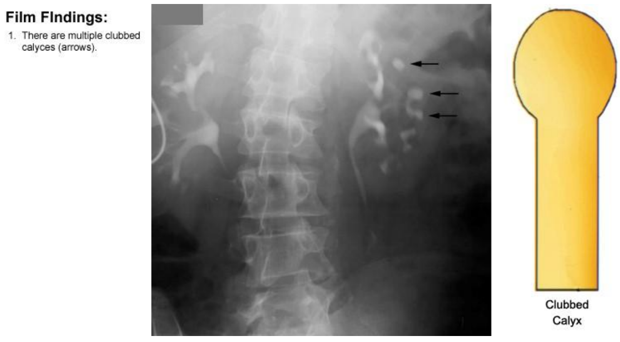
Hypoechoic seen in peripheral zones = tumor.
We can take a biopsy using the same probe.



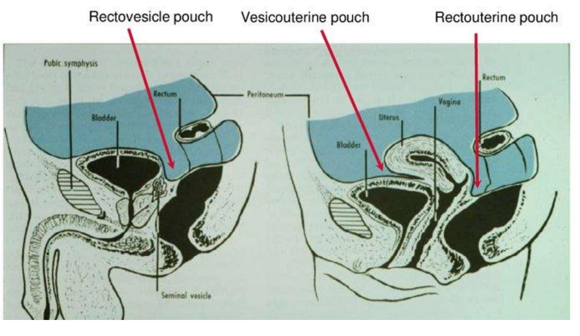
- **Best modalities for prostate gland imaging: transrectal ultrasound and then MRI.**
- CT is **not** a very good modality for prostate gland.
- In prostate ultrasound we use pelvic not abdominal ultrasound, usually hypoechoic areas in peripheral zone are cancer.
- BPH is usually in transitional zone while malignant tumors are usually in peripheral zone. So if we see a tumor in transitional zone its usually benign while if there is tumor in peripheral zone it is usually malignant.

For better understanding

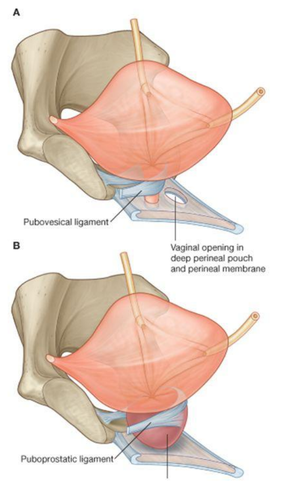
Doctor's notes and extra images:



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

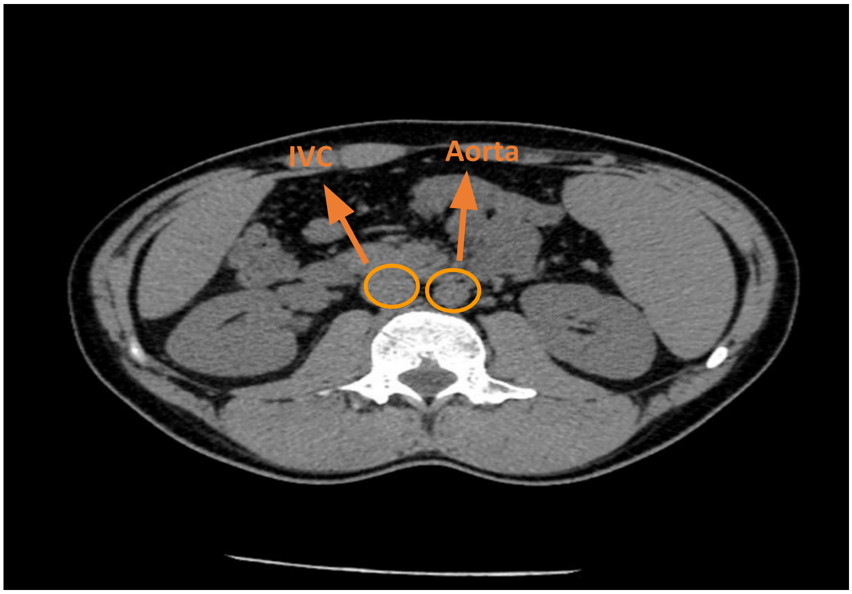


different pouches in females and males



different ligaments and pouches in males and females

From slide 5:



Summary

Plain X-Ray.	1. First imaging modality 2. Cheap. 3. Useful for radio-opaque stones.	• Projectional image. • Image contrast determined by tissue density. • Good evaluation of radio-opaque stones.
Intravenous Urogram (IVU).	1. Conventional x-ray + IV contrast 2. Cheap. 3. Recently replaced by CT and MRI. 4. Provides functional and anatomical information.	• Projectional image. • Image contrast determined by tissue density and IV contrast. • Good evaluation of collecting system and radio-opaque stones.
Ultrasound (US)	1. Uses High Frequency Sound Waves (No Radiation). 2. Contrast	• Operator dependant. • Good resolution. • Used for stones, hydronephrosis,and focal lesions.
Computed Tomography (CT)	1. Same basic principle of radiography. 2. More precise. 3. Costly. 4. +/- contrast. 5. Useful for trauma, stone, tumor and infection.	• Cross sectional images. • Image contrast determined by tissue. • density +/- contrast. • Better evaluation of soft tissue.
Magnetic resonance imaging (MRI)	1. Cross sectional images. 2. Image contrast determined by tissue properties. 3. Excellent for soft tissue evaluation.	• Better evaluation of soft tissue. • Uses magnetic field (No Radiation). • Expensive. • Useful for soft tissue pathology: tumor, infection.
Nuclear medicine	1. Utilizes a gamma camera and radioactive isotopes. 2. Functional test. 3. Less expensive. 4. Useful for: obstruction and split function.	• Projectional image. • Image contrast by tissue uptake and metabolism.

Questions

Q1: Which of the following would you use first to assess presence of kidney stones?

A- CT-with contrast
B- CT without contrast
C- X- ray
D- MRI

Q2: A patient presented to E.R. with trauma of kidney. which of the following would you use first:

A- Ultrasound of kidney
B- CT of kidney
C- MRI of kidney
D- Nuclear imaging of kidney

Q3: Which of the following most likely indicates a primary site of malignancy:

A- Ultrasound image showing hypoechoic area in the peripheral zone of prostate
B- Ultrasound image showing hypoechoic area in the transitional zone of prostate
C- Ultrasound image showing hyperechoic area in the peripheral zone of prostate
D- Ultrasound image showing hyperechoic area in the transitional zone of prostate

Q4: Which of the following is an area of normal narrowing?

A- Ureteropelvic Junction
B- Bifurcation of the mesenteric vessels
C- Ureterovesical Junction
D- A and C

Q5: Which of the following is the most used modality for assessing the size of kidneys?

A- Ultrasound of kidney
B- CT of kidney
C- MRI of kidney
D- Nuclear imaging of kidney

Answers :
1- C
2- B
3- A
4- D
5- A

WE NEED YOUR FEEDBACK