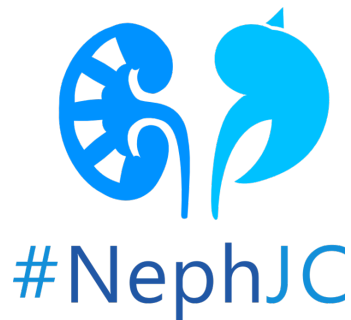




Nephrology Fellow Clinical Compendium



Edited by: Hector Madariaga, Beje Thomas, Sayna Norouzi, Sam Kant, Ami Patel, Paul Phelan, Diana Mahbod, Samira Farouk, Edgar V. Lerma, Matthew A. Sparks

Disclaimer- This guide is intended as an overview with salient details only. In order to provide high quality patient care it is important to maintain close and appropriate supervision.

Chapter 11: Kidney Imaging and POCUS

By Abhi Koratala [@KoraAbhi](#), Bhavnish Bucktowarsing [@Buck1486](#), Vandana Dua Niyyar [@vandyiniyyar](#) and Ankit Sakhuja [@ansakhuja](#)

Websites to check out:

[What is POCUS \(Ink to video\)?](#)

[RFN POCUS Gallery \(link to website\)](#)

[NephroPOCUS \(link to website\)](#)

Approach to urinary tract sonography:

Getting ready to scan:

- Transducer type: Low frequency (~2-5 MHz) curvilinear or convex array transducer. Low frequency allows deeper penetration of ultrasound waves.
- Can use cardiac probe or the phased array transducer if you do not have the curvilinear probe available.
- Choose abdomen preset when available. This would optimize the machine settings for the abdominal scan you are going to perform.
- Use ultrasound gel warmer when available to reduce patient discomfort from cold gel.
- Raise the patient's bed to appropriate height so that you are comfortable while scanning.
- Scan both kidneys from one side of the patient. That way, you are always close to the machine and do not need to struggle to reach the console while saving the images or performing measurements.

Patient position:

- Supine in general
- Lateral decubitus helps sometimes, especially when scanning the left kidney
- Prone while using ultrasound for kidney biopsy guidance

Scanning technique - right kidney:

- Right kidney is easier to image than the left because the liver provides a large acoustic window (we are looking at the kidney through the liver using it as a window)

- Key barriers to image acquisition: bowel gas and ribs (both are poor transmitters of ultrasound waves and produce shadowing, obscuring the view of deeper structures)
- To obtain longitudinal view, place the probe in the anterior axillary or mid axillary line in the 10th rib interspace with probe marker facing towards the patient's head. Alternatively, you can use the junction between subxiphoid line and the anterior axillary line as a starting point.
- Once you see the liver, it's usually easy to find the kidney posterior to it by gently sliding the probe anteriorly or posteriorly.
- Once you find the kidney, tilt the probe slightly counterclockwise so that the probe marker faces posterior axillary line to get a better view, as the kidneys are obliquely positioned in relation to long axis of the body.
- Now tilt the probe gently side to side to image the entire kidney. If we don't do this, small lesions such as stones may be missed.
- Measure the length of the kidney from pole to pole in the longest image you have in longitudinal plane.
- To obtain the transverse view, rotate the probe 90 degrees counterclockwise. Now the probe marker will be towards patient's right.
- Mid-portion of the transverse view is c-shaped because of the structures entering and leaving the kidney hilum (you can get a good view of the vessels in Doppler mode) and it becomes circular as you go towards the poles.
- Asking the patient to take a deep breath helps getting better pictures especially in the transverse view by opening the rib spaces.
- In addition to obtaining grey scale images, it's a good idea to obtain a few color Doppler images in both planes to get an idea of the blood flow and identify small stones

Scanning technique – left kidney:

- The spleen provides a smaller acoustic window for scanning the left kidney compared to the liver on the right. It is located more lateral and posterior and so interference from the bowel gas is higher in anterior planes.
- Therefore, more lateral scanning approach is required to image the left kidney and most of the time, you'll have to force your knuckles into the mattress in order to obtain optimal image window.
- Placing the patient in right lateral decubitus position is helpful when possible.
- Except for this key difference, the rest of the landmarks and scanning technique remain the same as that of right kidney.

Scanning technique – kidney transplant:

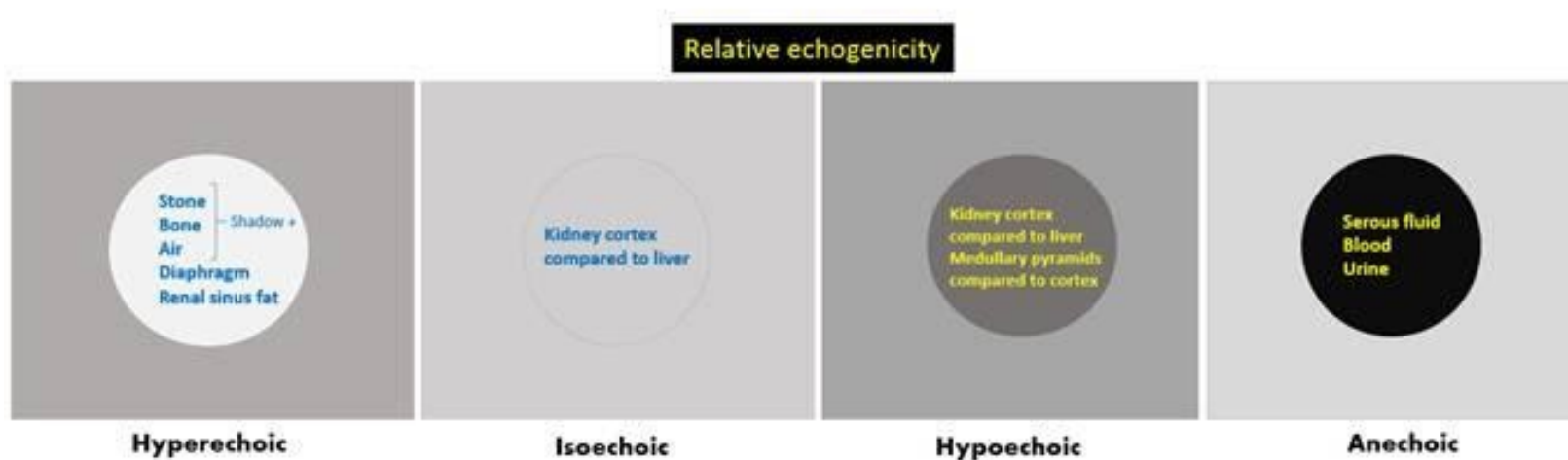
- The kidney is easily identifiable as it is usually palpable in the right or left pelvis.
- Decrease the depth of the image as the kidney is superficial.

- Obtain longitudinal and transverse images paying attention to perinephric space for evidence of any fluid collection.
- If a ureteral stent is in place, an attempt should be made to determine the proximal and distal extent of the stent.
- Obtain color Doppler images of the entire kidney for global assessment of transplant kidney perfusion and assess for vascular abnormalities.
- Measuring resistive indices is optional but relatively easy to perform in transplanted kidney than in native kidneys because the allograft does not move with respiration.

Scanning technique – urinary bladder:

- Longitudinal view: The probe is placed sagittally in the midline above the pubic symphysis with probe marker towards patient's head. Then it should be angled laterally and swept to left and right to examine the lateral borders.
- Now rotate the probe 90 degrees counterclockwise to obtain the transverse view and swept superior to inferior to image the bladder completely.
- Measure length in the longitudinal view, anteroposterior and side to side measurements in transverse view. Bladder volume = $0.52 \times$ these 3 measurements.
- Ask the patient to urinate and remeasure the volume to calculate post-void residual volume.

Image interpretation – Terminology:



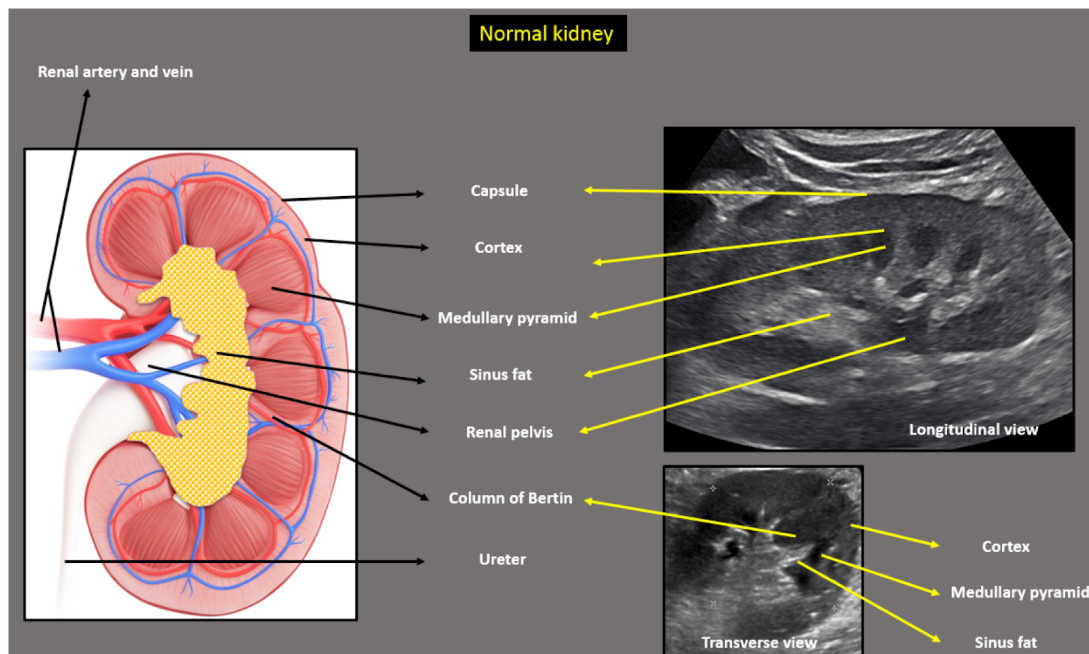
- Greyscale ultrasound findings are described in terms of echogenicity.
- Echogenicity refers to how bright or dark something appears in the gray scale ultrasound image; the brighter something appears, the more echogenic it is. In other words, the brighter structure makes strong echoes or returning sound waves.
- Echogenicity is 'relative' to the surrounding structures as the ultrasound image is typically composed of several different shades of grey and each shade can be both brighter

(hyperechoic) and darker (hypoechoic) relative to other shades, unless it is completely 'white' or 'black' (anechoic).

Image interpretation – orientation:

- The direction of probe marker corresponds to the orientation marker on the screen, which is typically in the upper left hand corner in abdomen preset.
- During standard abdominal exam, the probe marker should be pointed toward the patient's head when obtaining longitudinal images and to the right in the transverse plane.
- Therefore, if the lesion is on the pole closer to the screen indicator, it is towards the head of the patient, i.e., superior pole of the kidney in the longitudinal plane.
- Structure that is closer to the probe is displayed on the top of the image while the farther structures are at the bottom.

Normal features (link to RFN Post):



- Kidney capsule is echogenic and makes the bean shaped organ easily identifiable.
- Kidney length in adults is typically ~10–12 cm but varies with body size.
- Kidney cortex is either isoechoic or hypoechoic (more commonly) compared with the normal liver or normal spleen.
- The medullary pyramids are hypoechoic or anechoic compared to cortex. On most occasions, the pyramidal shape not well visualized.
- The kidney cortical tissue extends into the medulla separating pyramids in the form of columns called 'columns of Bertin'. These columns can sometimes hypertrophy and mimic a neoplasm. But unlike a true neoplasm, the hypertrophied column of Bertin is in continuity with, and of similar appearance to normal cortex, and the kidney outline is typically preserved.

- Renal sinus fat is echogenic and occupies the major part of the inner kidney.
- The collecting system is usually not visualized unless distended and is embedded in the surrounding echogenic sinus fat.
- Kidney pelvis area is hypoechoic but not 'black' unless there is hydronephrosis.
- Urinary bladder appears as an anechoic fluid-filled structure (urine is black on ultrasound) located in the mid pelvis.
- You need full bladder to comprehensively evaluate the characteristics of its walls, contents and pelvic organs.
- Decompressed bladder with a foley catheter is seen wrapping around the balloon of the Foley, which appears as a well-defined structure containing hypoechoic or anechoic fluid.

Common sonographic pathologies:

Size and echogenicity:

- Kidney length usually decreases in CKD with some exceptions (e.g. diabetic nephropathy)
- Length may increase in infiltrative diseases (e.g. amyloidosis, multiple myeloma), infection (e.g. pyelonephritis due to edema) and kidney vein thrombosis (due to congestion and edema).
- Cortical thickness - measured from the base of the medullary pyramid to the outer margin of the kidney. It is generally around 7-10 mm, being thicker at the poles.
- If you don't see pyramids clearly, can measure parenchymal thickness from outer margin of the kidney till the sinus fat is visible, which is usually ~1.5–2.0 cm.
- Cortical and parenchymal thickness are expected to decrease in CKD.
- Increased cortical echogenicity is commonly attributed to CKD. However, it can also be seen in AKI where inflammatory infiltrates and proteinaceous casts reflect sound waves (e.g. acute glomerulonephritis, acute tubular necrosis). If a patient has hyperechoic cortex but normal or increased kidney length, think of AKI.
- Decreased cortical echogenicity usually results from interstitial edema in cases of inflammation or infection.

Hydronephrosis:

- Hydronephrosis appears as branching, 'interconnected' areas of decreased echogenicity (anechoic in general, indicating the presence of fluid) in the renal collecting system area.
- Look for the source of obstruction (e.g. ureteral stone when hydronephrosis is unilateral; bladder stone/mass/enlarged prostate when hydronephrosis is bilateral)
- Mild hydronephrosis - there is dilatation of the renal pelvis and calyces but the pelvicalyceal pattern is retained.
- Moderate hydronephrosis - medullary pyramids start to flatten due to back pressure in addition to dilatation of pelvicalyceal system.

- Severe hydronephrosis - renal pelvis and calyces appear ballooned and cortico-medullary differentiation is lost making the cortex thin.
- Parapelvic cysts and extrarenal pelvis can mimic hydronephrosis. If you see big black bulge in the pelvis area but it is not extending into the kidney, consider these possibilities.
- Prominent vessels can mimic hydronephrosis – color Doppler will differentiate ‘flowing’ blood from urine.

Cysts:

- Simple cyst: a well-defined, round, anechoic structure, with increased through transmission manifested by ‘acoustic enhancement’. No internal echoes.
- Acoustic enhancement refers to the increased intensity of echoes (bright area) relative to surrounding tissues, distal to a structure that transmits the sound waves very well (e.g. cyst, urinary bladder, gall bladder etc.)
- Multiple cysts with large kidneys and cysts in other organs such as liver – suggests ADPKD.
- Complex cyst: May have irregular thickened walls, septations, internal echoes, and calcifications.
- Ultrasound should not be used for Bosniak classification of the cysts - detection of neovascularization in malignant lesions, indicated by contrast enhancement can be done only by CT.

Stones:

- Grey scale images: stones appear as hyperechoic or bright structures with a posterior ‘acoustic shadow’. Acoustic shadowing is the black or anechoic area seen beyond structures that do not transmit ultrasound waves.
- Color Doppler: stones exhibit ‘twinkling sign’ or artifact - rapidly alternating focus of color Doppler signals mimicking turbulent flow - more pronounced with rougher stones – more sensitive than shadowing for detection of small stones (<5 mm).

Kidney infections:

- Ultrasound is relatively insensitive for diagnosis of acute pyelonephritis – abnormalities are found in less than 1/3 of patients with pyelonephritis and are variable.
- May find unilateral increase in kidney size, loss of renal sinus fat due to edema, changes in echogenicity due to hemorrhage (hyperechoic) or edema (hypoechoic), abscess formation, and areas of hypoperfusion (visible on Doppler mode).
- Pyonephrosis – pus in the collecting system – typically appears as hydronephrosis with echogenic debris in the collecting system.

Kidney mass:

- Grows outwards and usually disrupts the outline of the kidney.

- Kidney cell carcinoma can have variable echogenicity with areas of cystic degeneration, hemorrhage, and necrosis.
- Don't confuse dromedary hump with a mass: it is a prominent focal bulge on the lateral border of the left kidney caused by splenic impression - benign anatomic variant; exhibits the same imaging characteristics as adjacent kidney cortex with normal blood flow pattern on Doppler sonography.

Bladder stones:

- Hyperechoic structures - exhibit acoustic shadowing and twinkling similar to kidney stones.

Debris in the bladder:

- Appears as echogenic material in the anechoic bladder.
- Typically changes position when you turn the patient. If it doesn't, it's probably a clot or even a mass

Enlarged prostate:

- Sometimes seen as an external (outside bladder wall) solid structure compressing the bladder.
- Dedicated evaluation of prostate requires transrectal approach.

Obstructed Foley catheter:

- Presence of Foley catheter does not exclude obstruction. Blocked Foley appears as a full anechoic bladder surrounding the foley balloon.
- Foley can be misplaced in the prostatic urethra or the vagina. Pay attention to the location of the balloon.

Inferior Vena Cava (IVC) US**Major Indication:**

- To assess volume responsiveness

Getting ready for the scan:

- Transducer type: Phased array (1-5MHz).
- The transducer orientation marker should be facing to the operators right
- The screen marker should be towards the right upper side of the screen

Patient position:

- Supine
- If possible, ask the patient to bend the knees to relax abdominal wall musculature

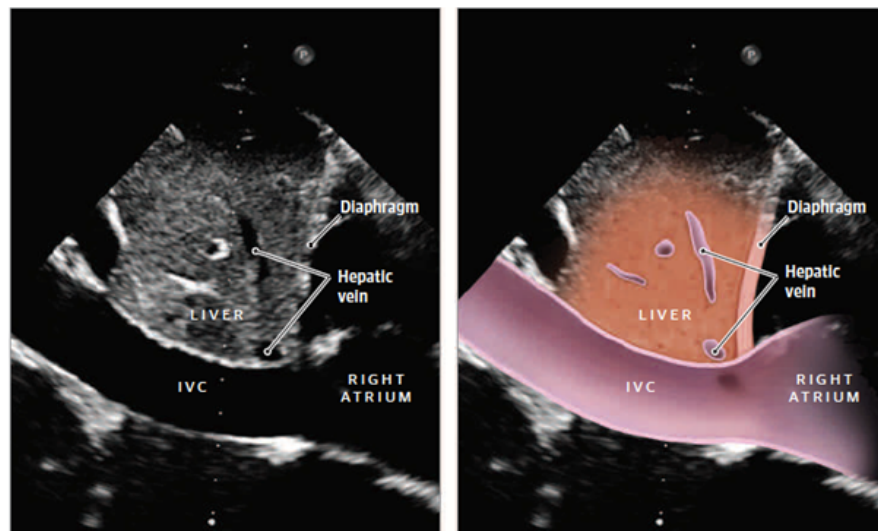
Technique:

- Start with a subcostal 4 chamber view of the heart with the transducer marker to the operators 3 o'clock position
- Then rotate the probe by 90 degrees in counterclockwise direction such that the probe marker is facing towards the patient's head
- Caution: Pulsatile, thicker walled aorta can be visualized when the transducer is tilted medially

Sonographic Findings:**IVC**

- The desired view should show IVC entering right atrium (RA) and a segment of hepatic vein joining the IVC

A Longitudinal subcostal ultrasound of IVC (left) with illustration of anatomical structures in view (right)



From: [JAMA](#)

IVC Diameter:

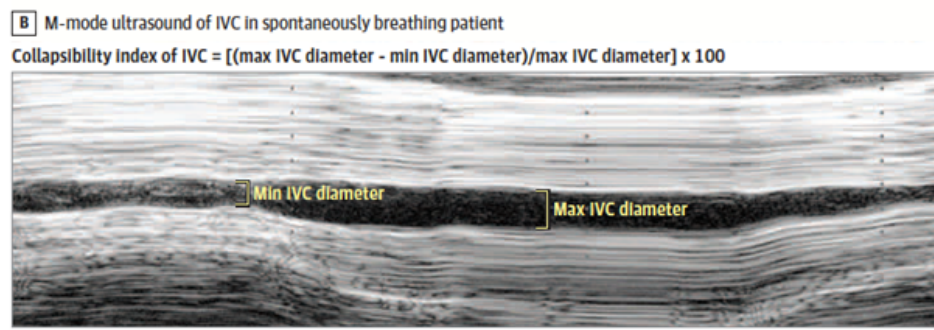
- IVC diameter is measured in M mode approximately 1 to 2 cm caudal to the hepatic vein–IVC junction (approximately 3–4 cm from the junction of the IVC and RA).
- Normal is <2.1cm with >50% collapsibility on inspiration



Measuring IVC Diameter

Fluid Responsiveness:

- Spontaneously breathing: If collapsibility index > 40%
- $[(\text{max IVC diameter} - \text{min IVC diameter}) / \text{max IVC diameter}] \times 100$
- On mechanical ventilation: If distensibility index > 15%
- $[(\text{max IVC diameter} - \text{min IVC diameter}) / \text{max IVC diameter}] \times 100$



From: [JAMA](#).

Illustrative images: