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Basics of Renal Ultrasound

Robert D. Harris

RAD-AID

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Basics of Renal Ultrasound- 2021

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Why kidneys and US?

- U/S primary screening modality
- Renal insufficiency-can't get contrast for CT or MRI
- Most often call case-frequent exam on call- to r/o **hydronephrosis**
- Thin pts, pediatrics, OB pts-first line imaging in developed world, go-to imaging in developing world
- Radiation risk of CT-i.e., multiple exams to evaluate renal stone burden

Renal physiology

- Kidneys prime function to excrete metabolic waste
- Filter about 1700 liters of blood day
- Generate 1-2 liters of concentrated urine
- Maintain homeostasis by regulating salt/water and acid/base balance
- Secrete many hormones including erythropoetin, renin, and prostaglandins

Renal embryology

- 3 sets of kidneys in embryo
 - Pronephros-4th gestational week, rudimentary
 - Mesonephros-interim, between 5-9th week
 - **Metanephros**-permanent kidneys
- **Metanephros** develops from 2 sources
 - **Ureteric bud** (ureter, pelvis, calices, collecting ducts)
 - **Metanephric blastema** – renal cortex/med/coll ducts
- Kidneys form in pelvis, ascend and rotate by 9th week

Pediatric kidneys – Unique Considerations

- Infantile kidneys large relative to body size
- More echogenic cortex (> liver) for 2-3 years
- Due to more cellular cortex and large concentration of glomeruli
- Pediatric renal pyramids relatively large c/w renal cortex
- Fetal lobations common, usually regress with age

Adult Kidneys

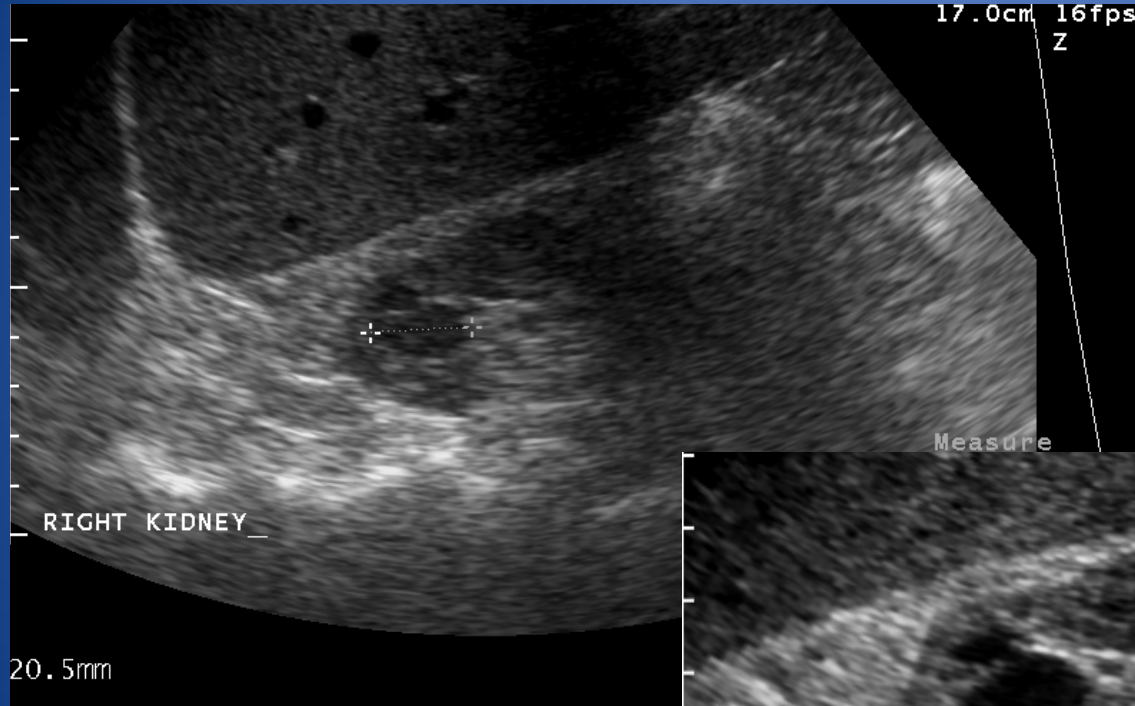
- Normal range 9-13 cm.
- Unilateral agenesis-get hypertrophy (12-15 cm)
- Parenchyma
 - Cortex
 - Medulla
- Echogenic or hyperechoic renal cortex:
 - Definition: brighter than the liver, prominent renal pyramids
 - High specificity (96%), PPV (67%) for abnormal renal function, low sensitivity (20%)

Harmonics in kidney imaging



Harmonics

Fundamental imaging

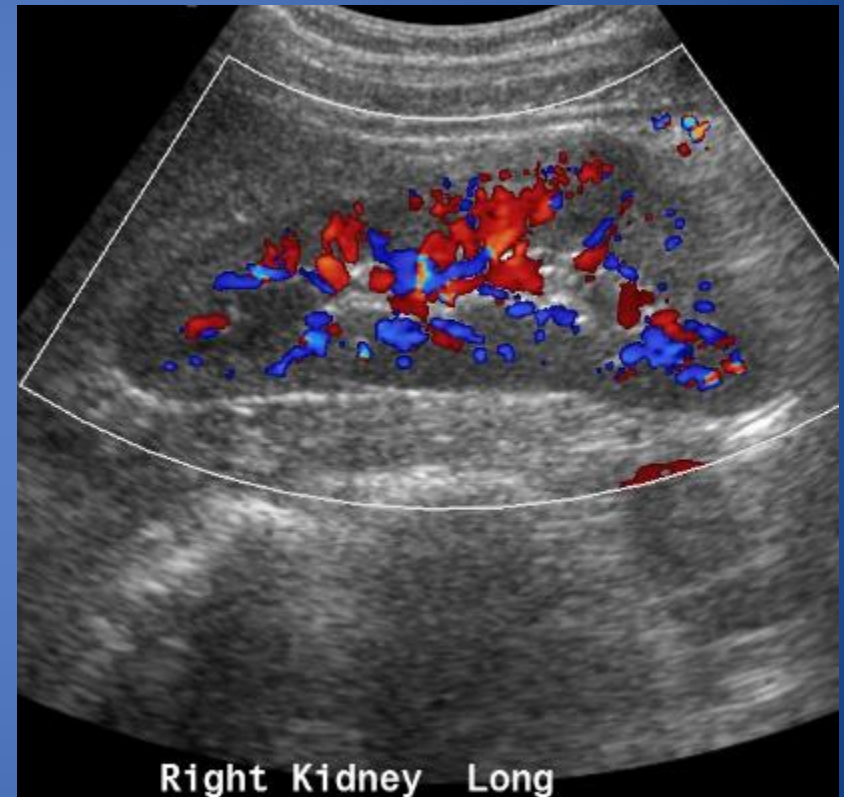


Harmonic imaging



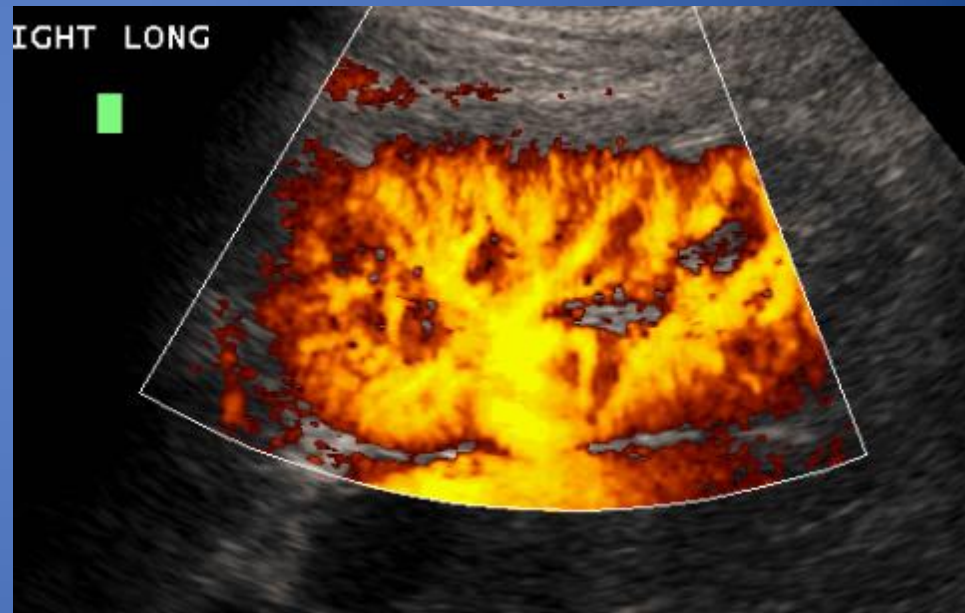
Color Doppler in Renal Imaging

- Excellent depiction of vascularity
- Useful for differentiating mild hydronephrosis from renal vessels

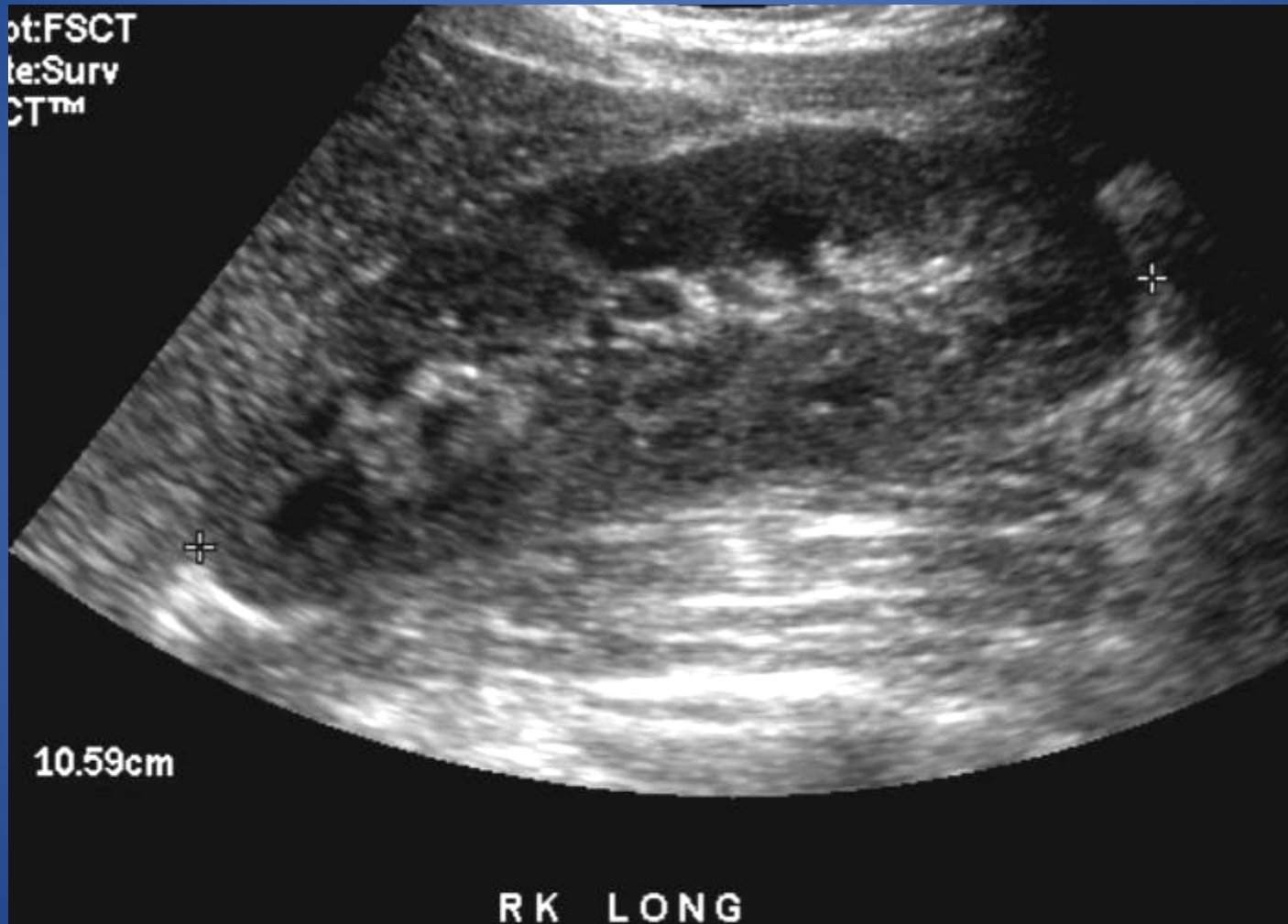


Power Doppler in Kidney

- Advantages over color
 - Not angle dependent
 - Less sensitive to noise artifacts
 - Amplitude sensitive, not directional (higher sensitivity for slow flow)
- Disadvantages
 - Susceptible to flash artifact
 - No info re direction or velocity of flow

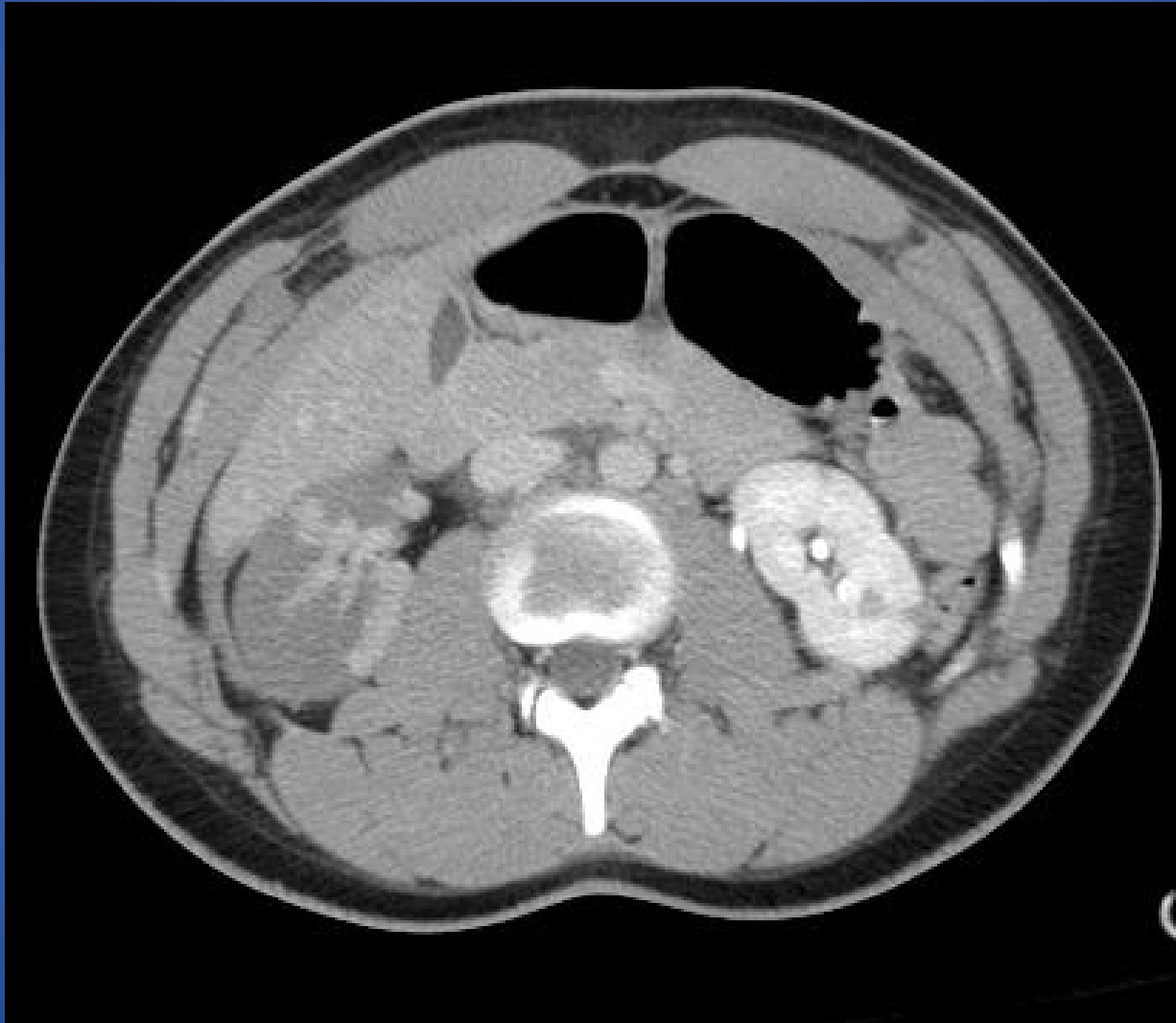


Medullary pyramids



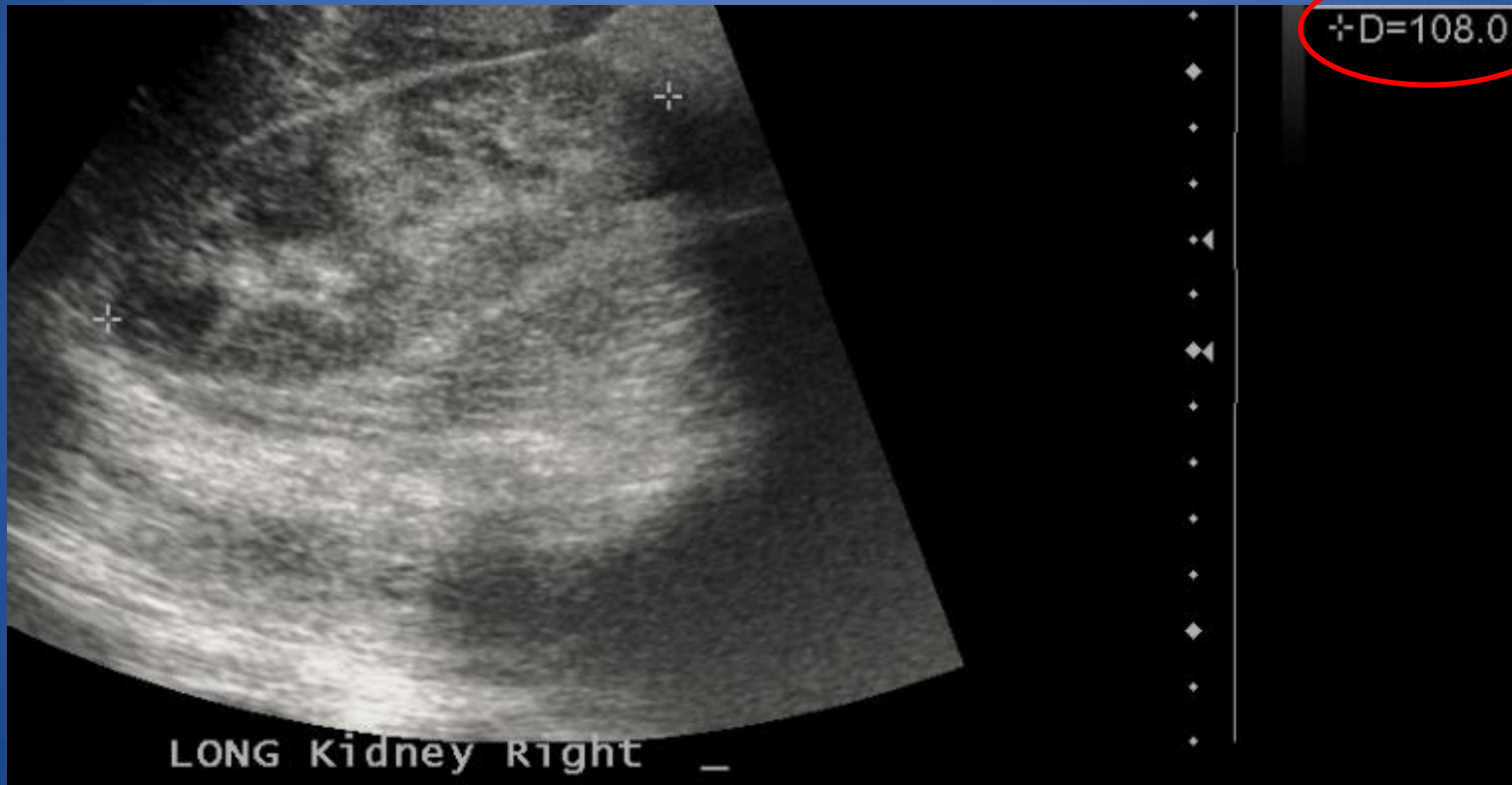
May see prominent medullary pyramids in infants, thin adults, renal transplant patients

Renal trauma due to car accident



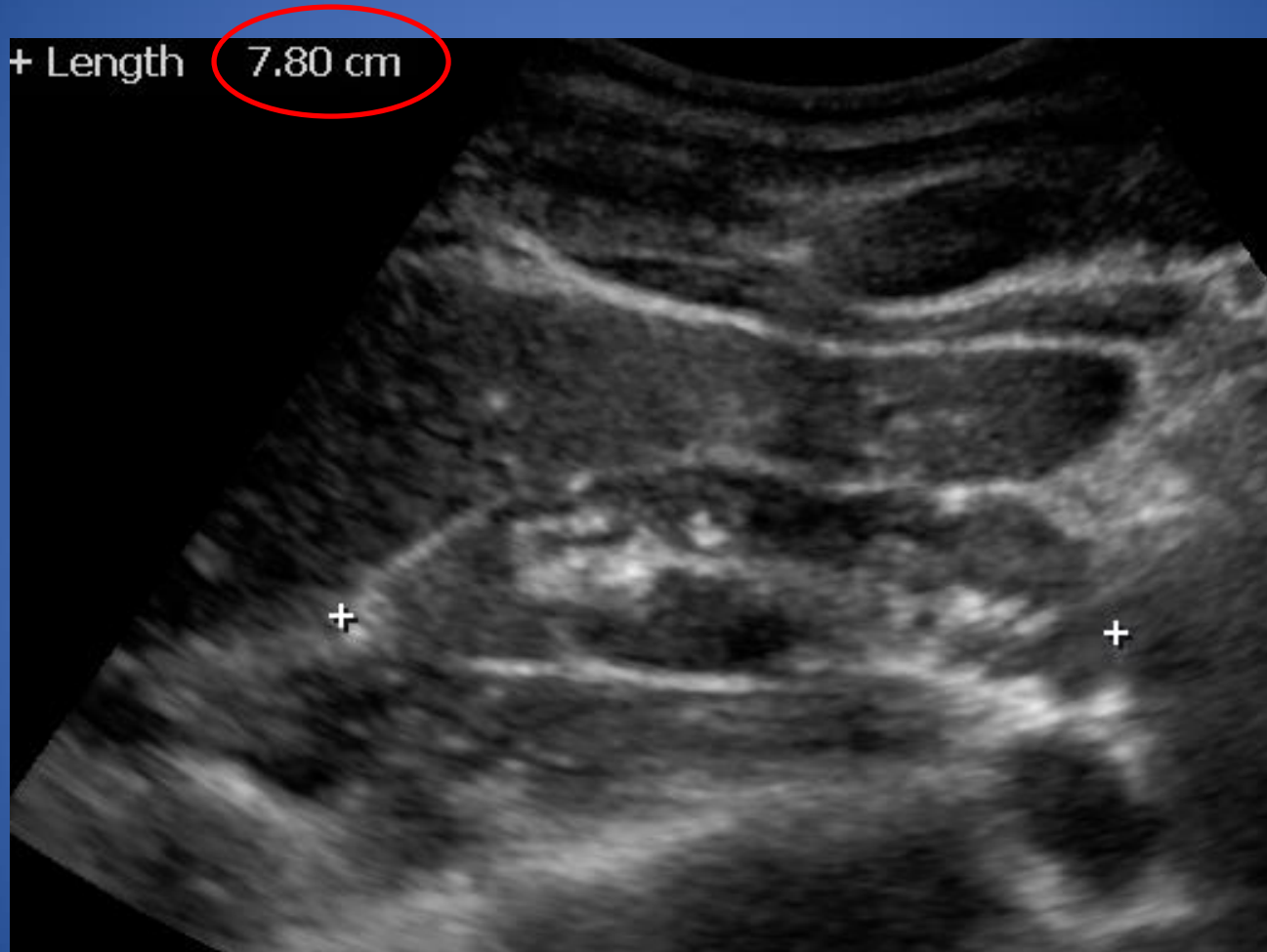
March 2009

Renal atrophy secondary to ischemia/trauma



March 2009

Renal atrophy



October 2009

Fetal lobation/lobulation (FL)

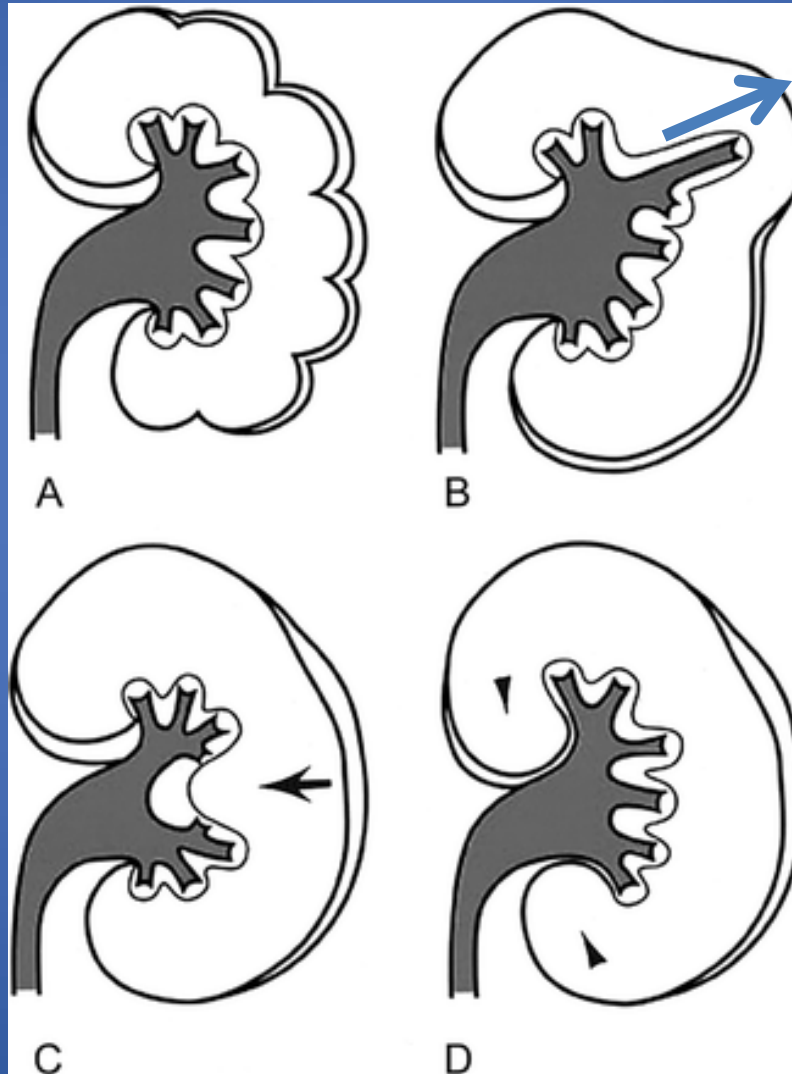
- Normal embryologic process
- May persist into adulthood
- Differentiation from scarring sometimes difficult
 - Fetal Lobations are thin, linear, sharply defined
 - Small, triangular notch at cortical end
 - Parenchymal thinning not present
- Scar-larger, irregular, often calyceal dilatation underlying

Fetal lobations



Renal “pseudomasses”

Fetal lobation

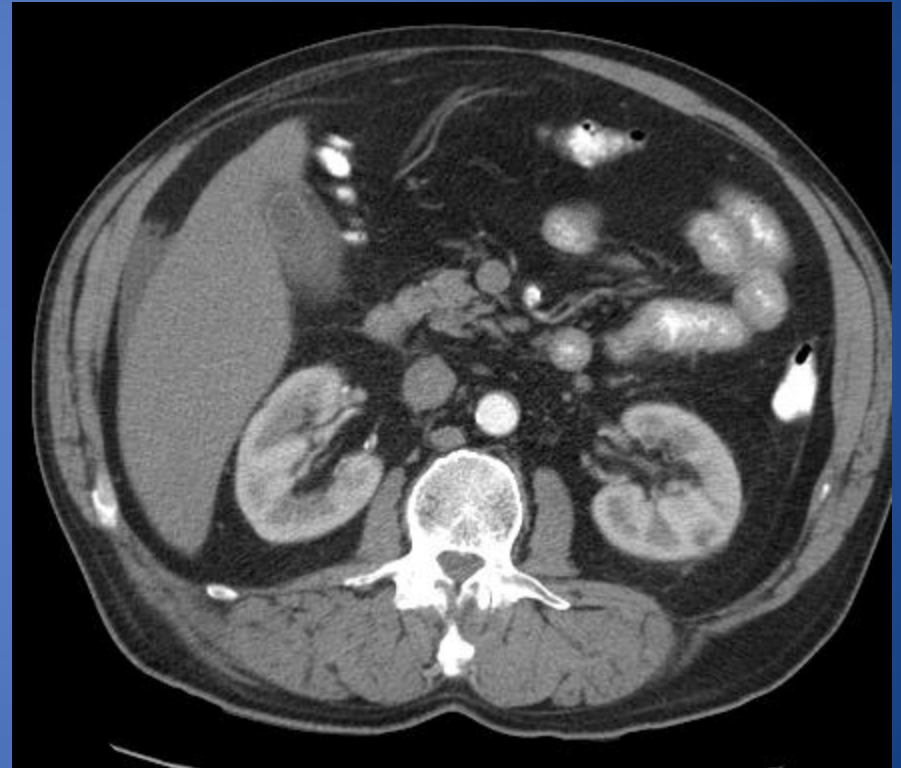
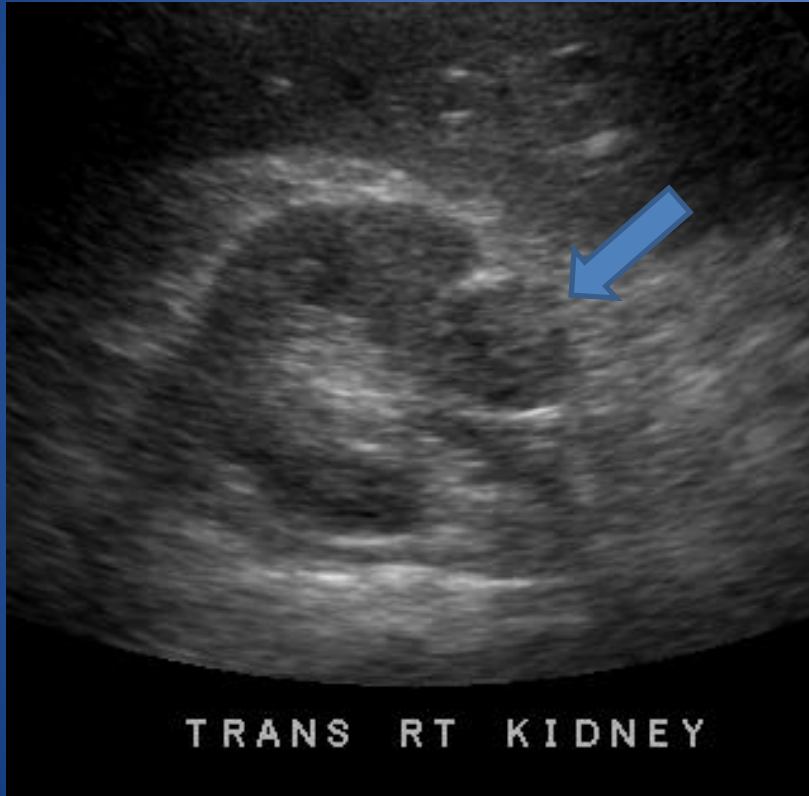


Dromedary hump

Column or
Septum of Bertin

Hilar “lips”

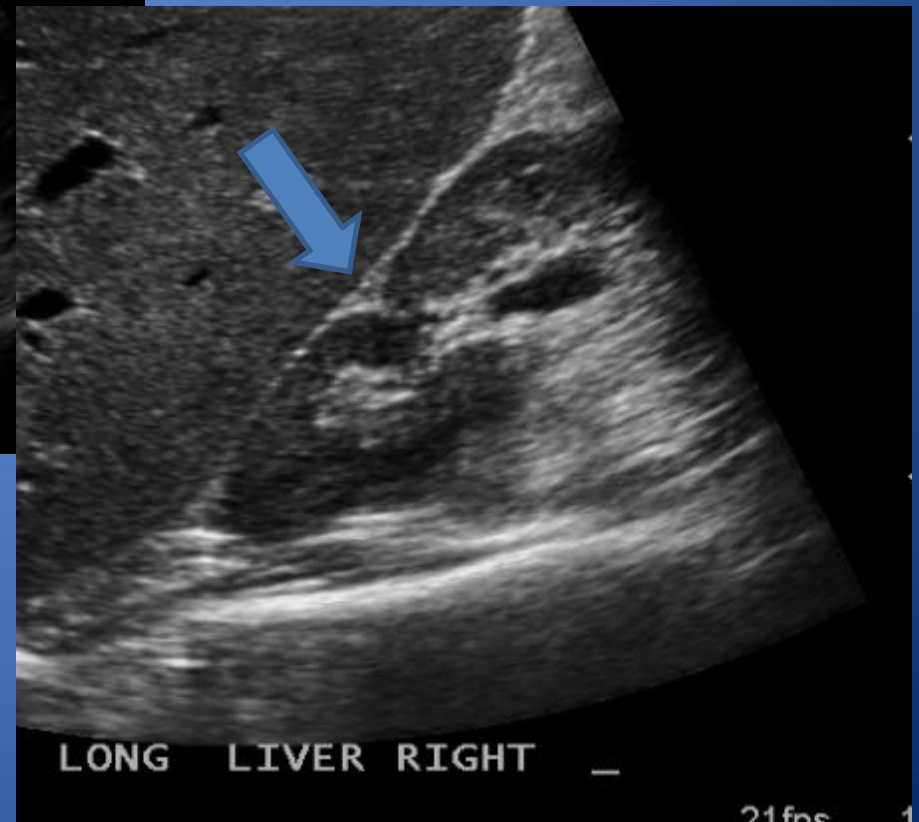
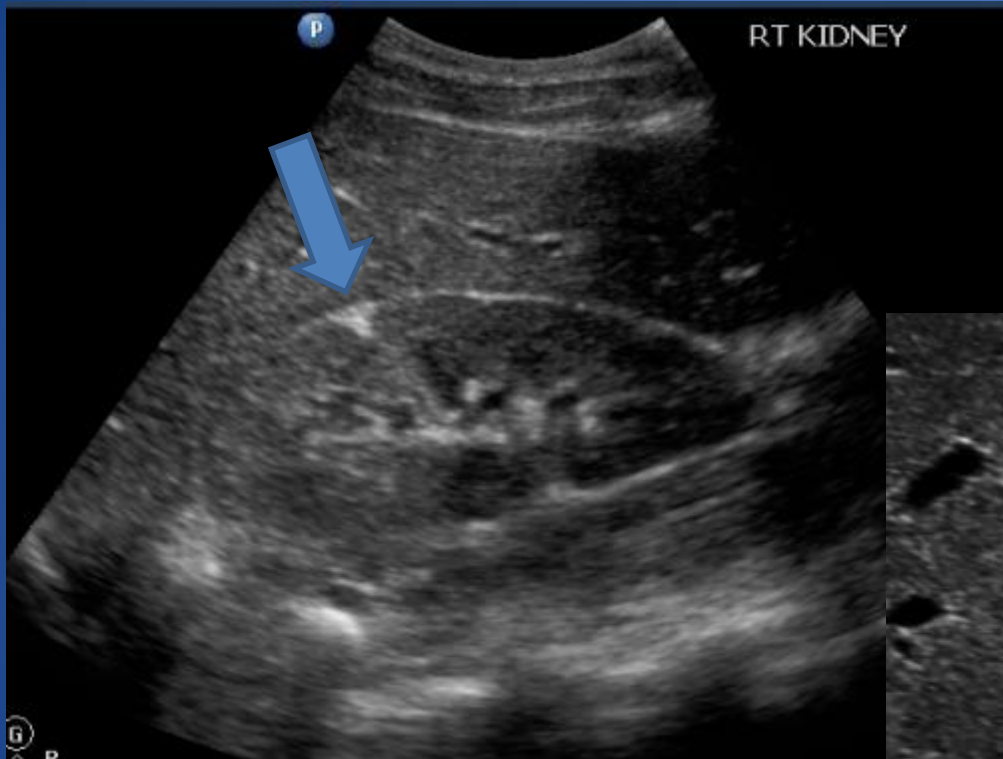
Renal pseudomass



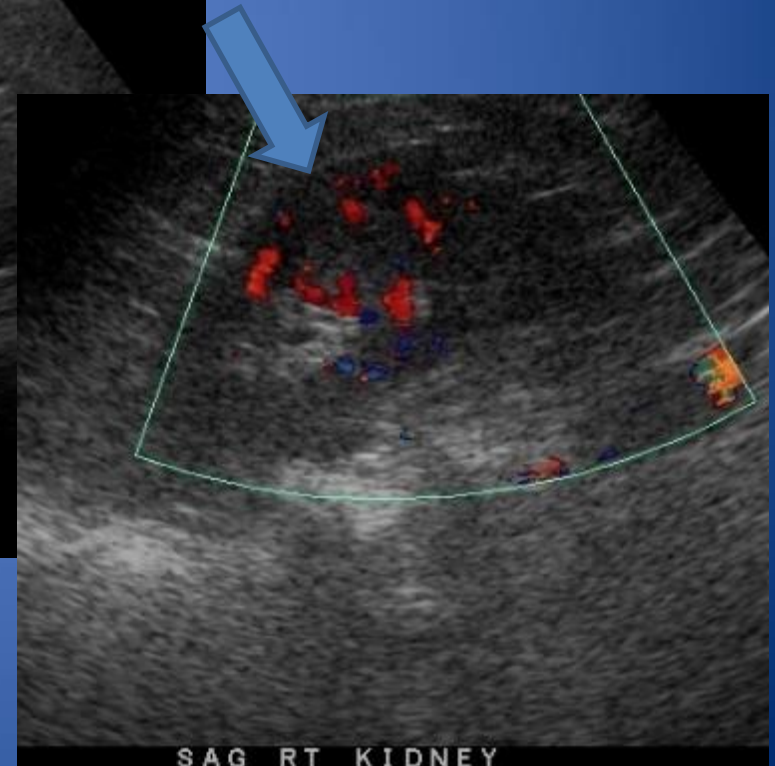
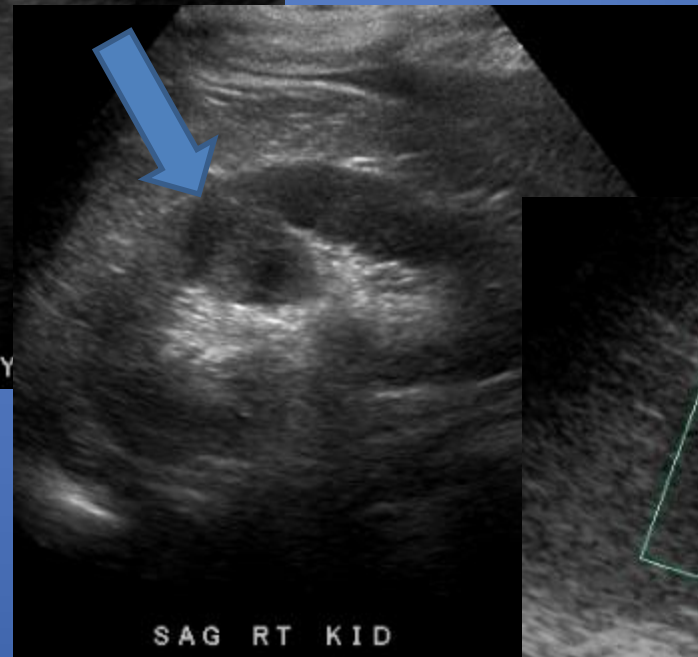
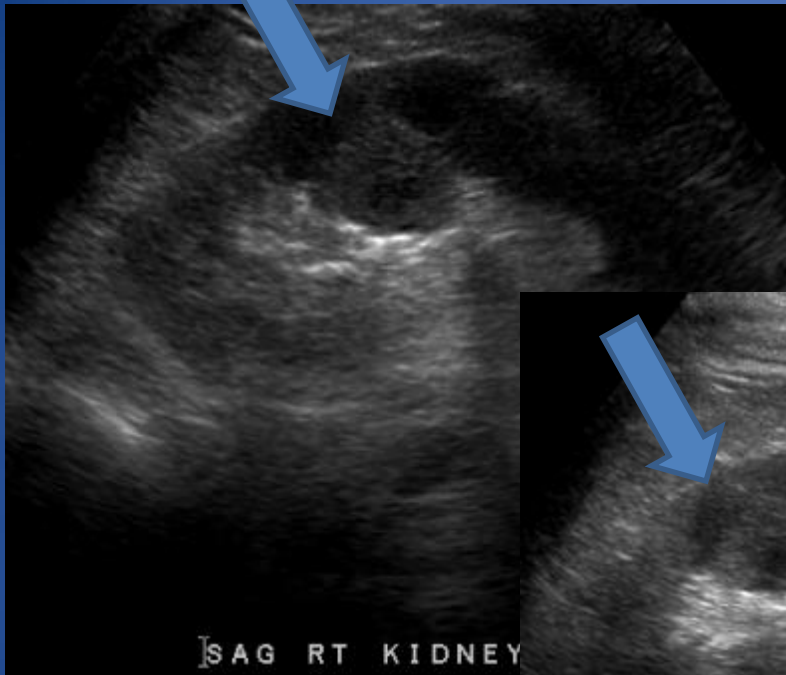
Other normal variants

- Junctional parenchymal defect
 - Mostly anterior, upper 1/3 of kidney
 - Seen only on longitudinal image
 - Oblique echogenic line, may course to sinus
- Column of Bertin (or septum)
 - Unusually thick cortex intervening between medullary pyramids
 - Triangular or oval in shape vs. spherical shape of tumor
 - Isoechoic, isovascular on color Doppler

Junctional parenchymal defect



Column of Bertin



52 yo woman s/p left partial
nephrectomy for oncocytoma

Renal Scar



Acute Renal Failure

- Pre-Renal
 - Renal US minor role (if any)
- Renal-Medical Renal Disease
 - U/S helpful but not essential, biopsy often performed (size important on U/S)
- Post-Renal-5% of Pts. With Acute Renal Failure
 - U/S plays significant part in work-up
 - Select pts **appropriately**
 - Low-risk for obstruction: PPV of 1%
 - High-risk: PPV of 30%

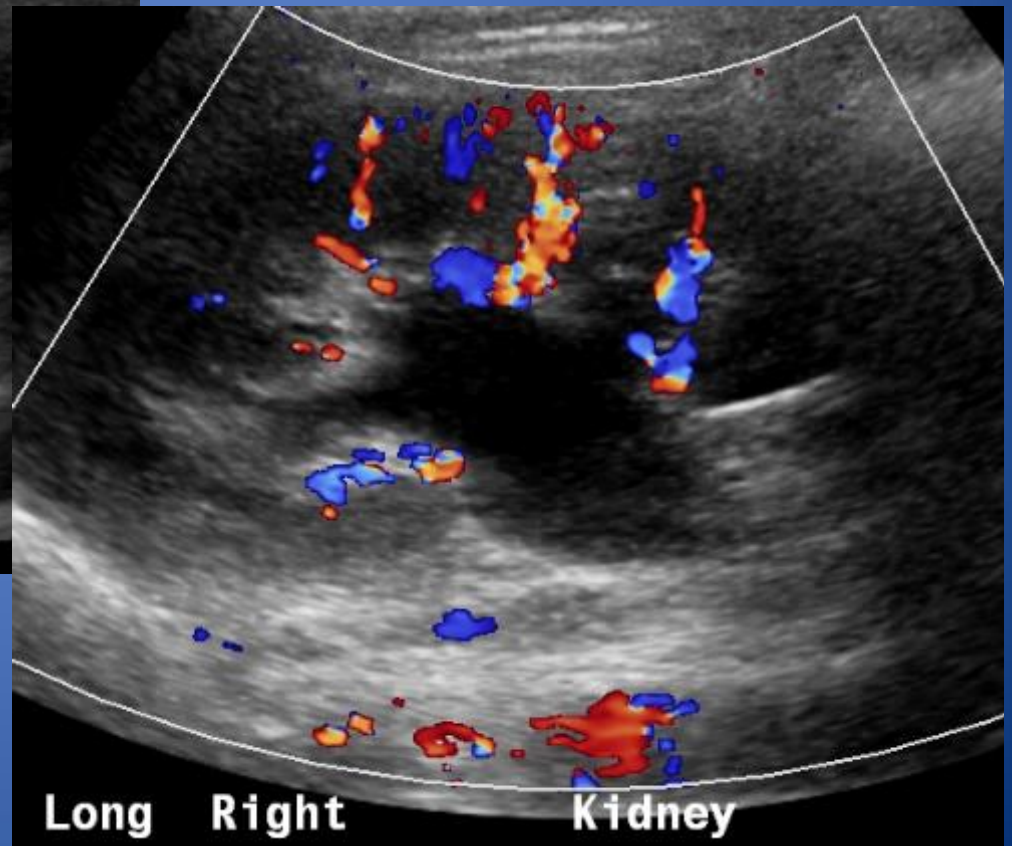
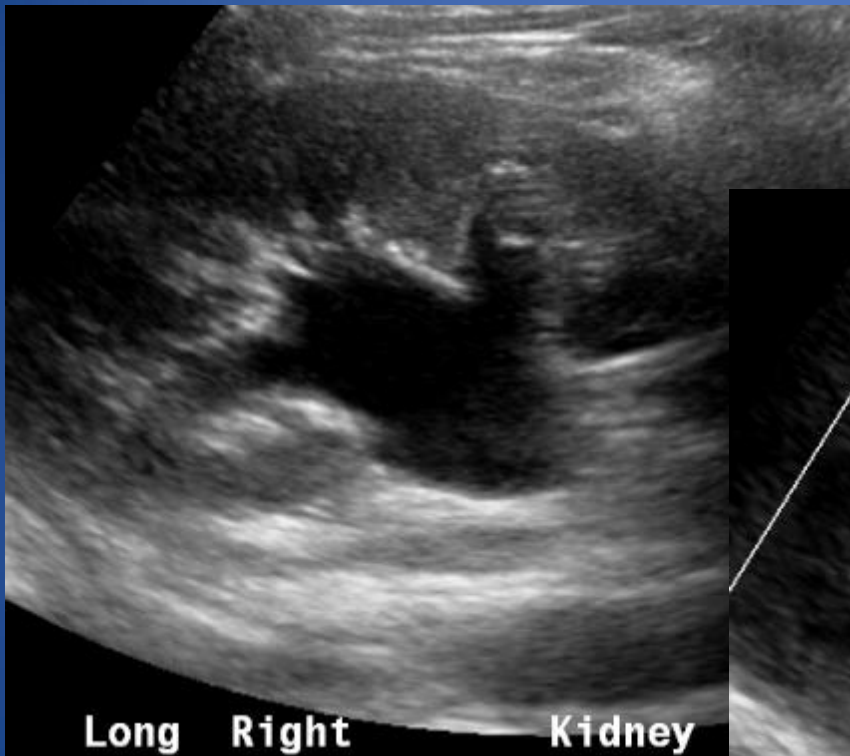
Hydronephrosis

- Definition: Distention of the kidney with urine. Due to obstruction of urine outflow (for example, by a stone blocking the ureter).
- If obstruction not known, prefer term “**pelvicaliectasis**”-anatomic
- Grades
 - Mild
 - Moderate
 - Severe

Causes of False +/- of Hydronephrosis

- False positive
 - Renal hilar vessels
 - Peripelvic cysts
 - Chronic vesico-ureteral reflux
 - Severe papillary necrosis
- False negative
 - Acute or partial obstruction
 - Dehydration
 - Observer error in mild hydronephrosis

Mild Pelviectasis (Hydro)



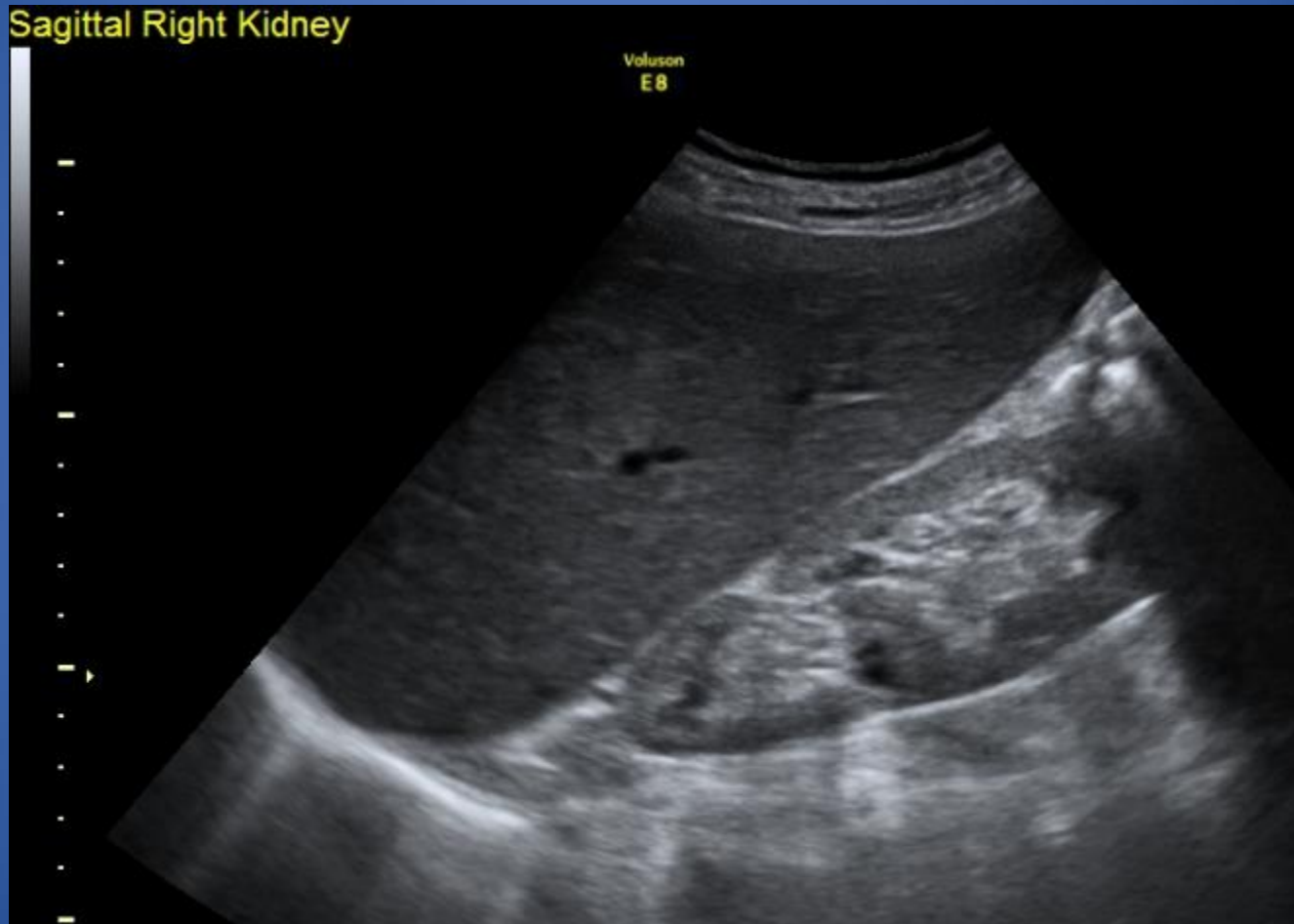
Moderate pelviectasis



Severe pelviectasis



Echogenic Kidneys due to ARF



Prominent Medullary Pyramids-Cr 1.6 (eGFR \sim 40 cc/min)



Renal Cysts

- Most common renal lesion or “mass”
- Incidence increases with age
 - ½ of pts > 50 y.o. have 1 or more cyst
- Etiology--Epithelial overgrowth of tubules or collecting ducts
- 4 simple cyst characteristics
 - Anechoic
 - Well-defined and smooth wall
 - Acoustic enhancement
 - Imperceptible wall

Benign renal cysts



January 2008 RadioGraphics, 28, 65-79.

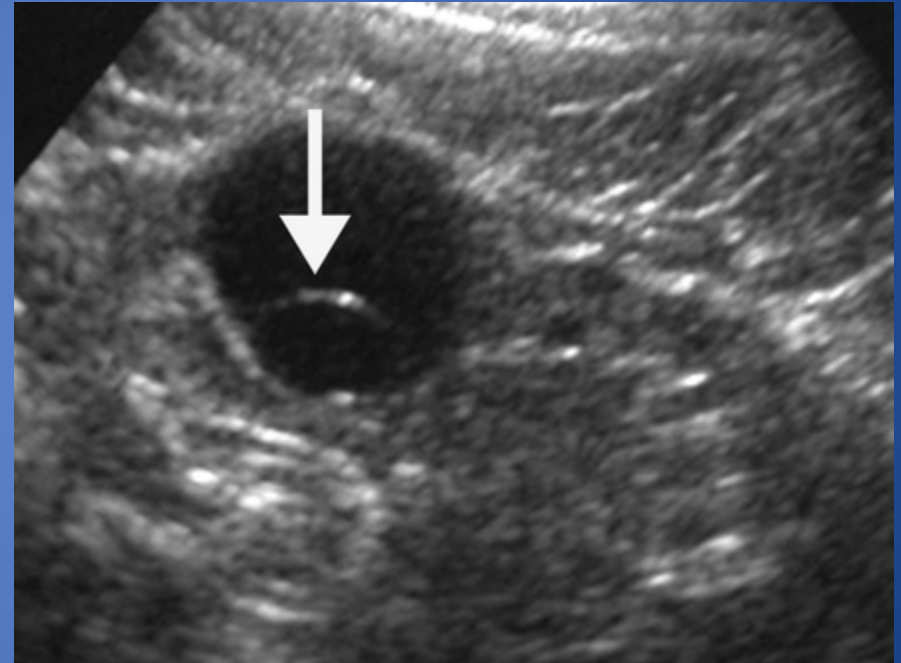
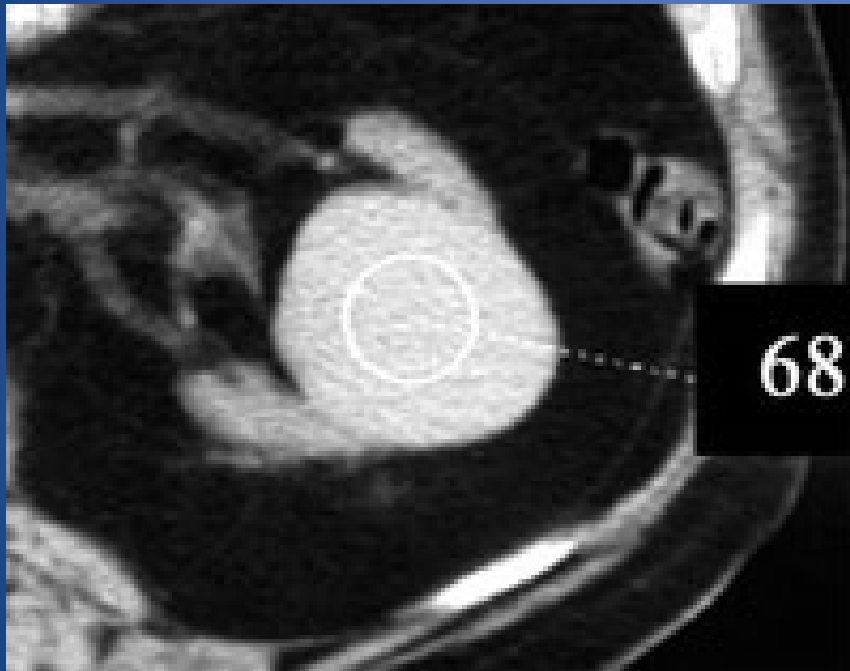
Benign renal cysts

- Doesn't have to fit 4 criteria on all views
- May have internal artifactual echoes
 - Role for harmonics technique in Ultrasound
- May have limited # thin septations
 - 5% of benign cysts have thin septations
 - Thin calcifications in wall
- Hemorrhagic cysts
 - 5% of all cysts
 - Low-level internal echoes
 - Fluid-debris level, fibrin membranes, internal clots

Renal cystic disease

- Complex cysts
 - Hemorrhagic cyst
 - Infected cyst
 - Proteinaceous cyst
 - Multi-septated cyst
 - Abscess
 - Hematoma
 - Cystic RCC
 - Multilocular cystic nephroma

Hyperdense Renal cyst

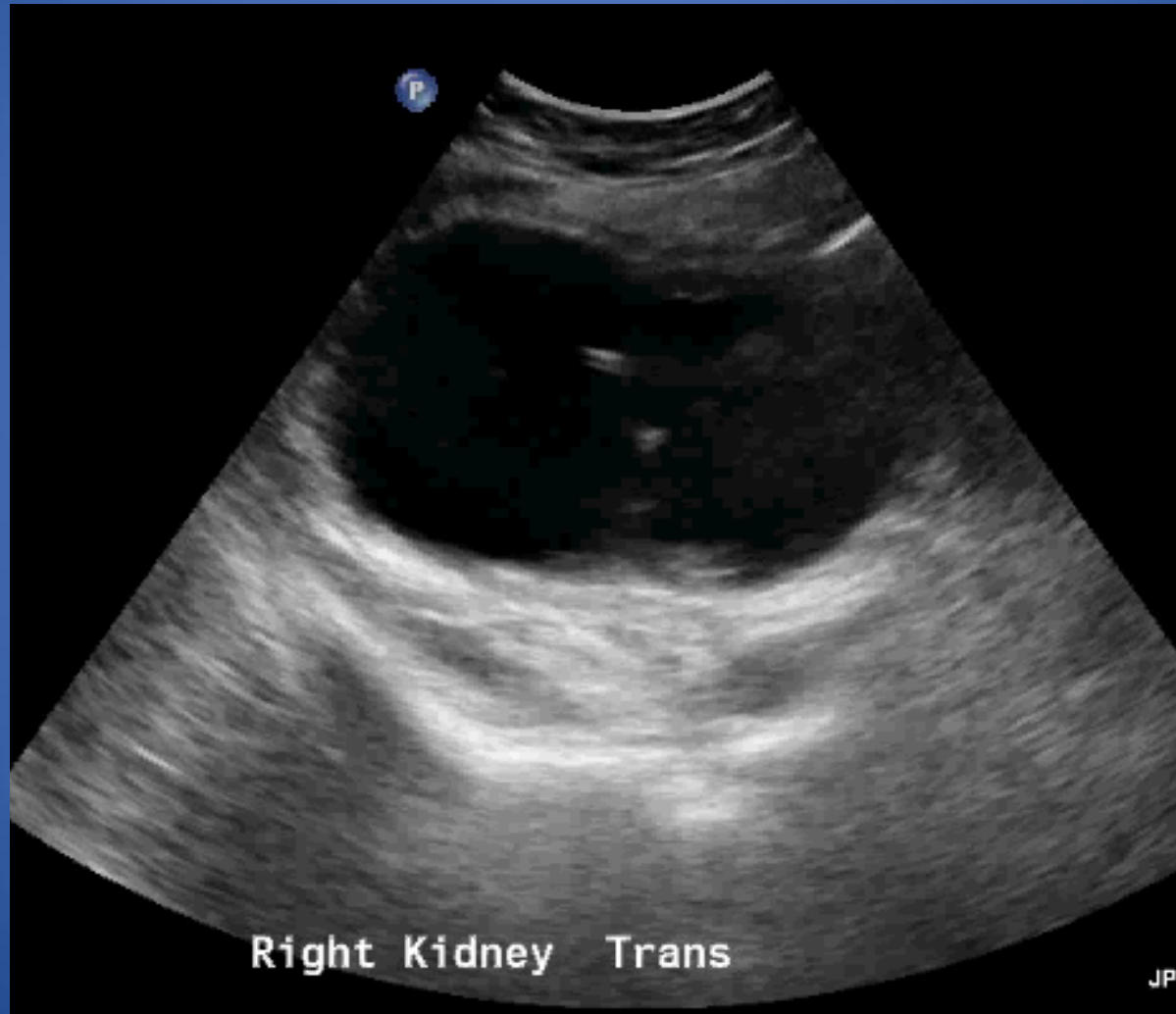


October 2004 RadioGraphics, 24, S101-S115.

Complex cysts

- Hyperdense cyst on CT
 - Due to protein or hemorrhage
 - Most appear simple on U/S
- Calcifications
 - 1-3% of cysts
 - Prior hemorrhage, infection, or ischemia
 - Thin, curvilinear generally benign
 - Thick, irregular more worrisome for malignancy

Polycystic Kidney Disease



Benign renal cysts in Von Hippel Lindau



Simple

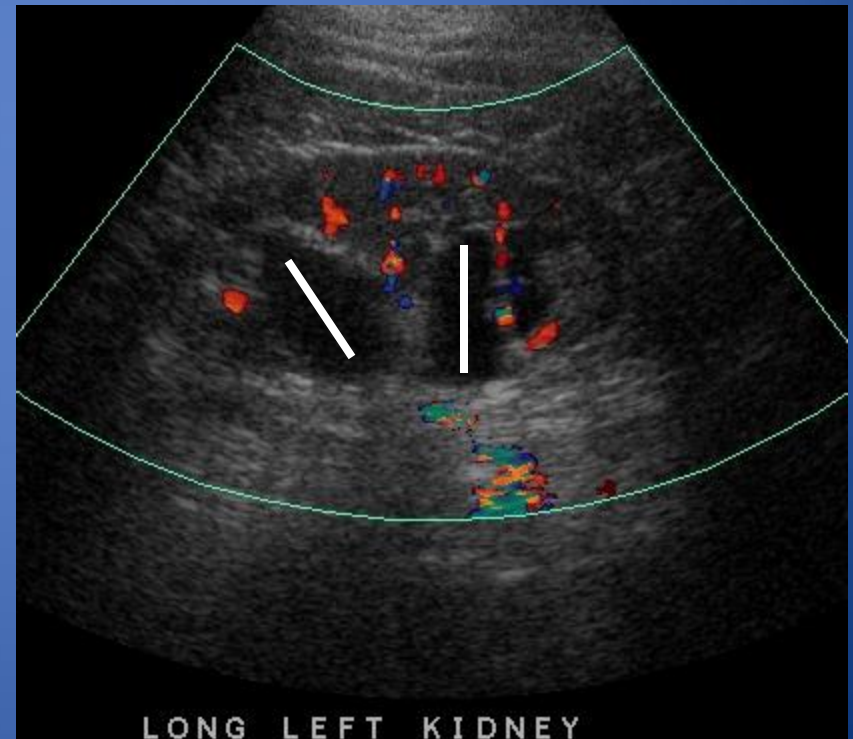
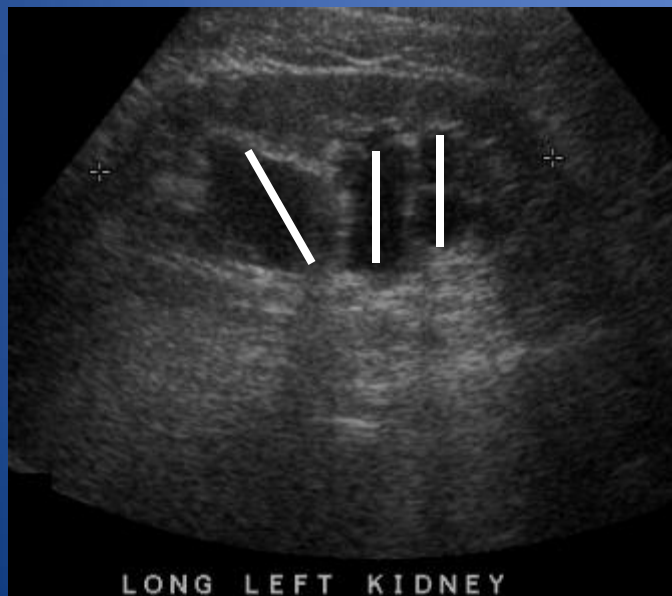


Complex

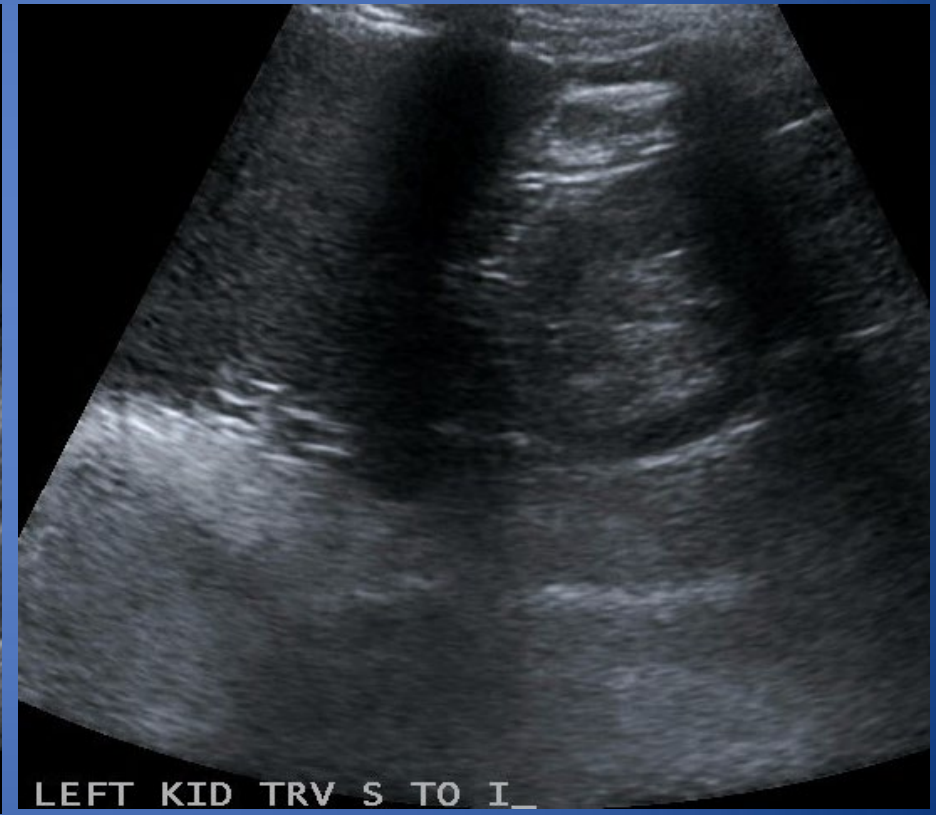
*January 2008 RadioGraphics, 28,
65-79.*

Peripelvic cysts-need to use real-time

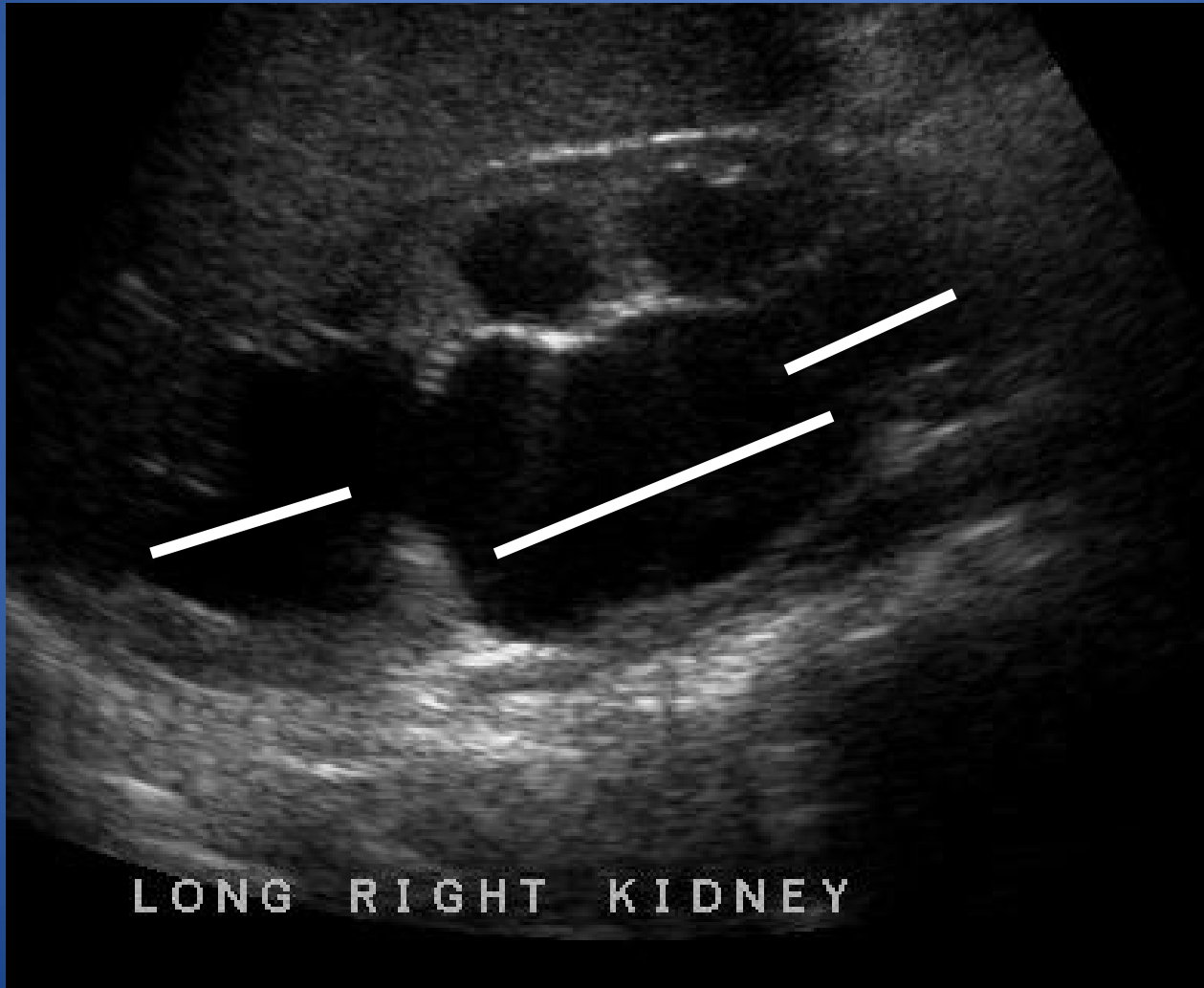
- Due to dilated pelvic lymphatics-vertical align
- May be mistaken for hydronephrosis-horizontal orientation



Parapelvic cysts-real-time U/S



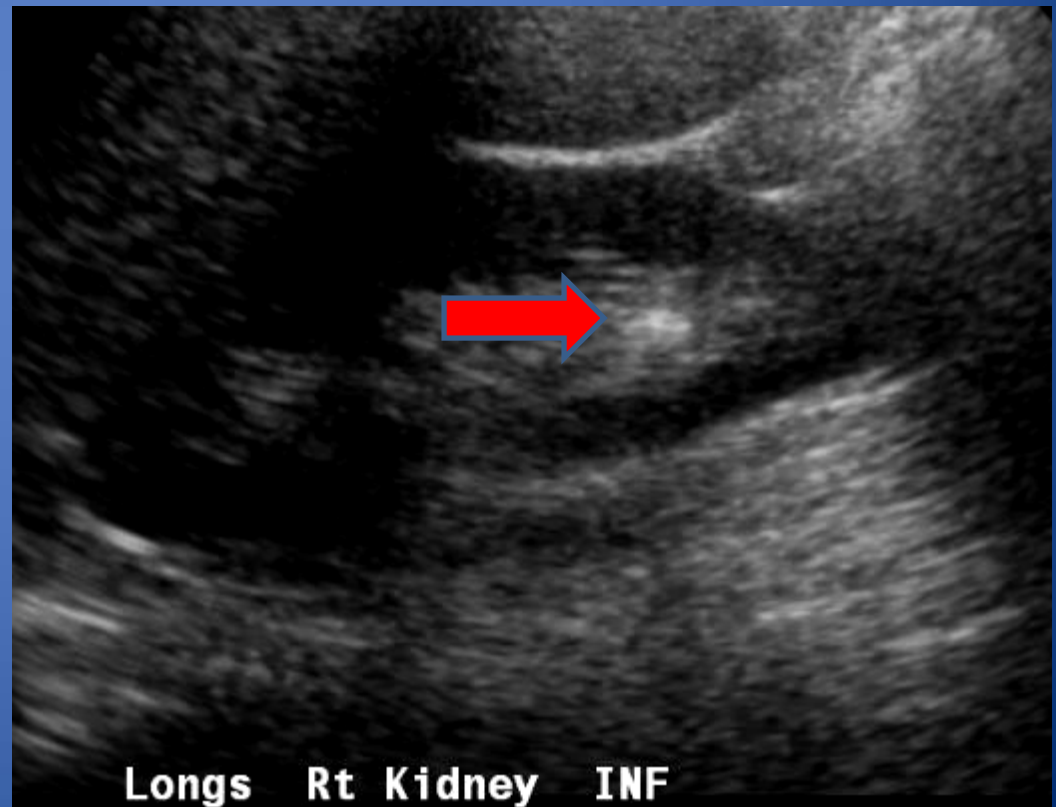
Hydronephrosis



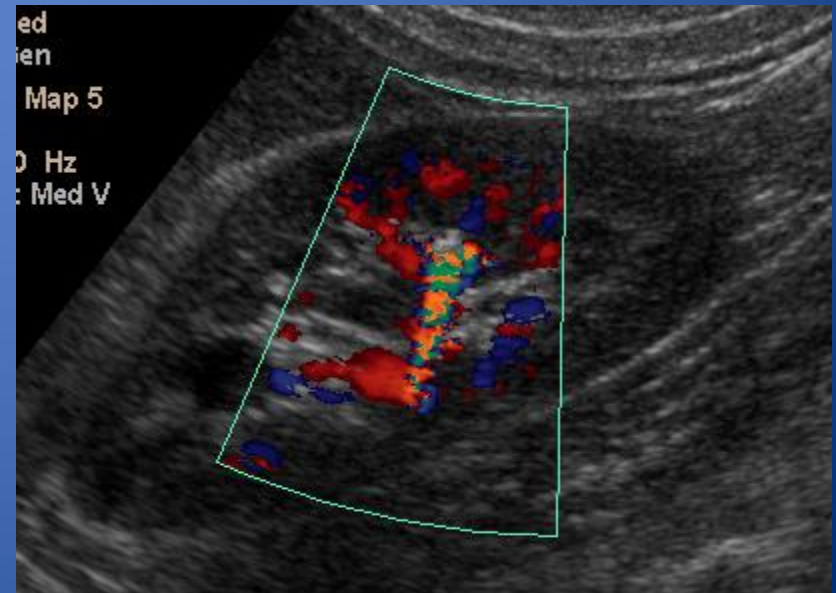
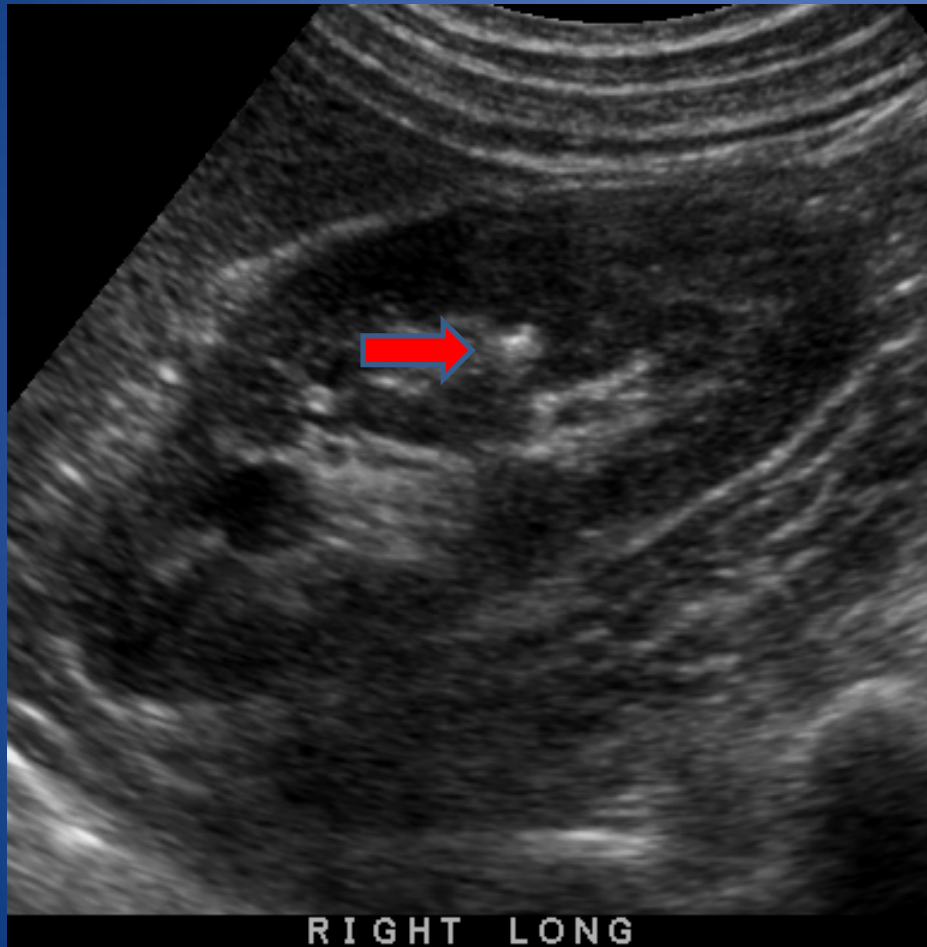
Renal stones

- **Urolithiasis**-stones in collecting system
 - 12% of population by age 70
 - United States epidemic?
 - White, male, Southern climates
 - Affluence??
 - Risk factors
 - Low fluid intake
 - High animal protein diet
 - Conditions that promote urinary stasis -> stones
- **Nephrolithiasis**-stones in renal parenchyma

Renal stone-echogenic focus



Color twinkle artifact



Renal Stones

- Predisposing factors
 - UPJ obstruction
 - ADPK disease
 - Caliceal diverticula
 - Tubular ectasia (medullary sponge kidney)
 - Horseshoe kidney
- Calcium containing most common-85%
- Uric acid 5-10%
- Cystine < 5%

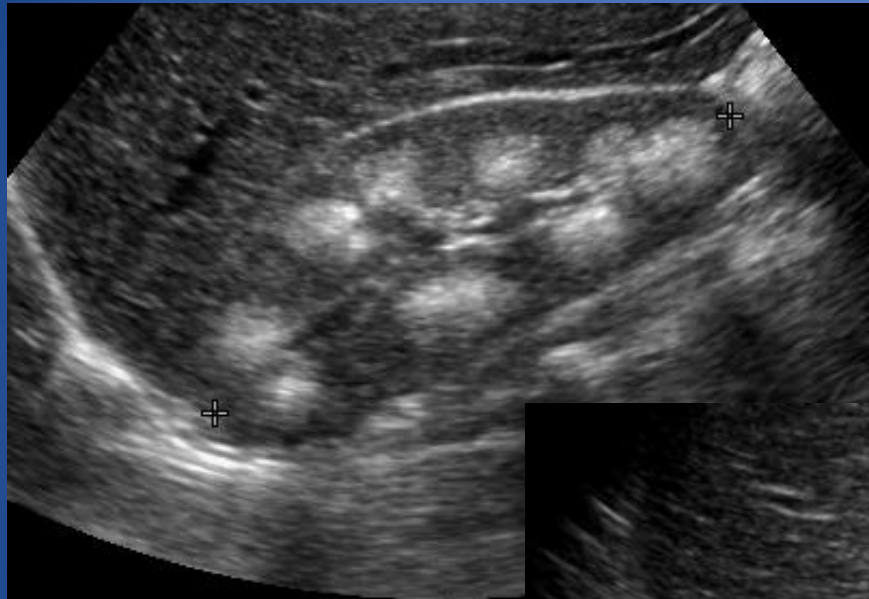
Renal stones

- U/S visualization depends on size, not composition
- Not very accurate in stone size
- Larger than 5 mm detectable with U/S (newer equipment, thin pts.--down to 2-3 mm)
- Smaller stones may not shadow, difficult to differentiate from vascular calcifications
- Tips
 - Use highest frequency probe (7-4 vs. 4-1 Mhz)
 - Color twinkle artifact

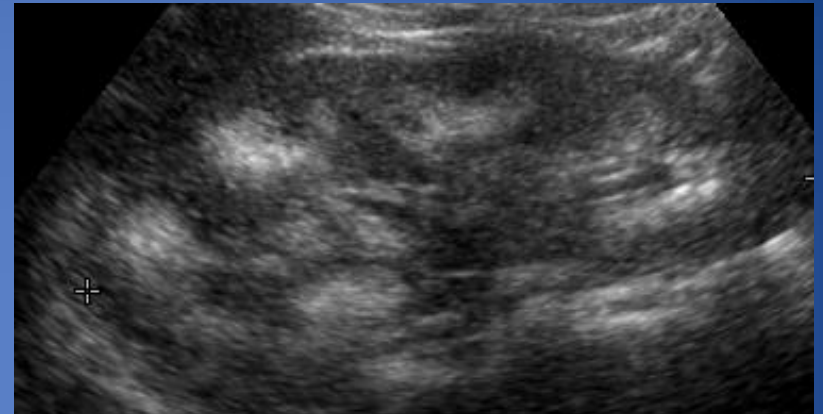
Nephrocalcinosis

- Medullary nephrocalcinosis
 - Tubular ectasia (Med Sponge Kidney)
 - Renal tubular acidosis (type IV)
 - Hyperparathyroidism
 - Sickle Cell disease
- Cortical nephrocalcinosis
 - Cortical necrosis, infarction
 - Oxaluria (Hyper)
 - Chronic GN
 - Alport's Syndrome

Medullary nephrocalcinosis



LONG RIGHT



LONG LEFT KIDNEY



TRANS RIGHT KIDNEY

Medullary Nephrocalcinosis

5/0 3
t Off
ot:FSCT
le:Surv
CT®



Medullary Nephrocalcinosis

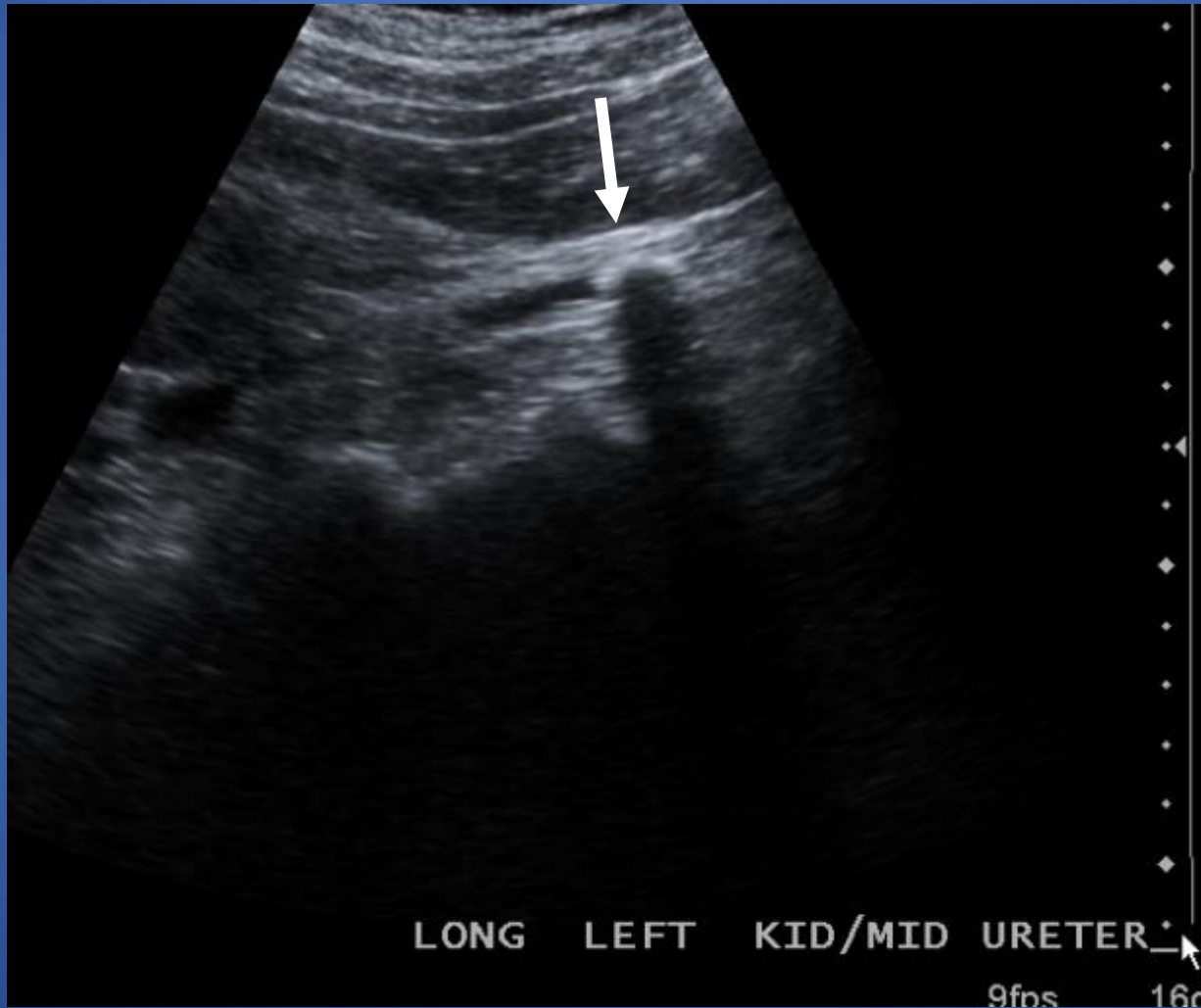


Cortical Necrosis



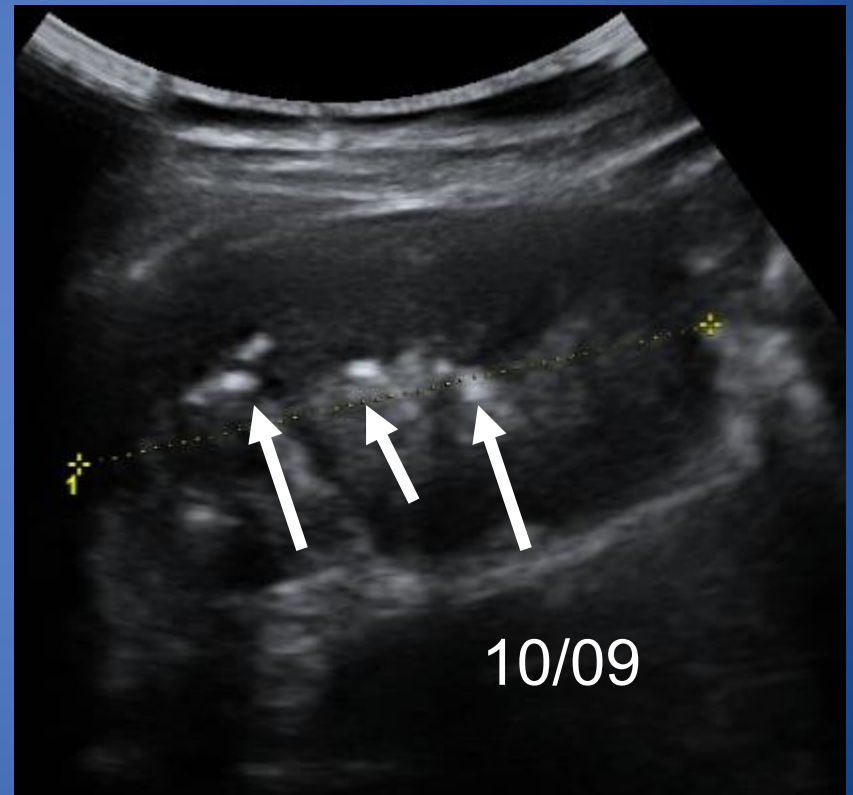
3 day old male, mother had placental insufficiency

Ureteral Calculus



Ureteral Calculi video clip

Unusual cause of echogenic foci

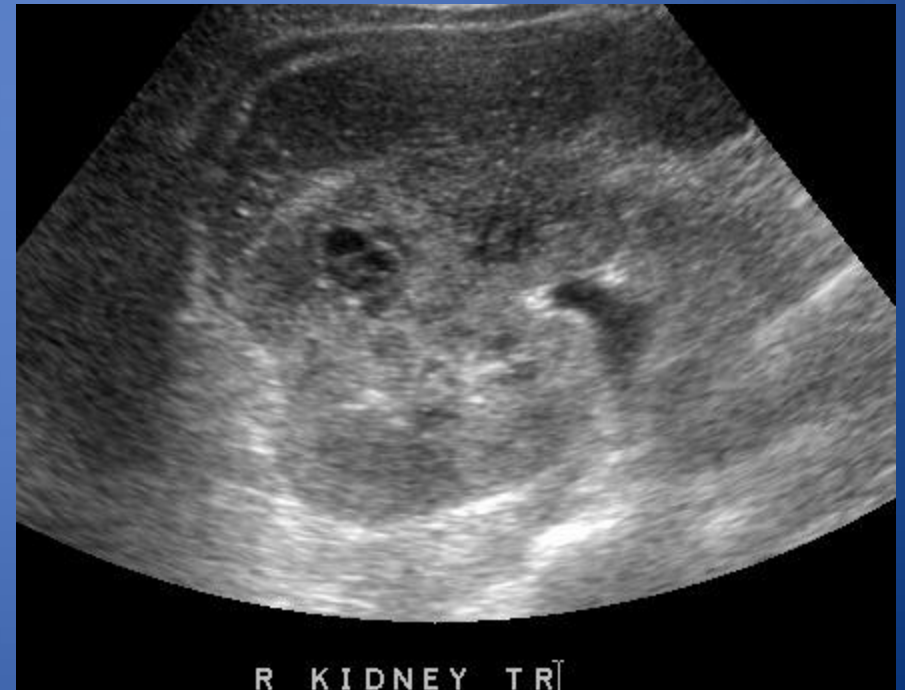


Pt s/p bladder instrumentation, reflux,
presumed air in collecting system

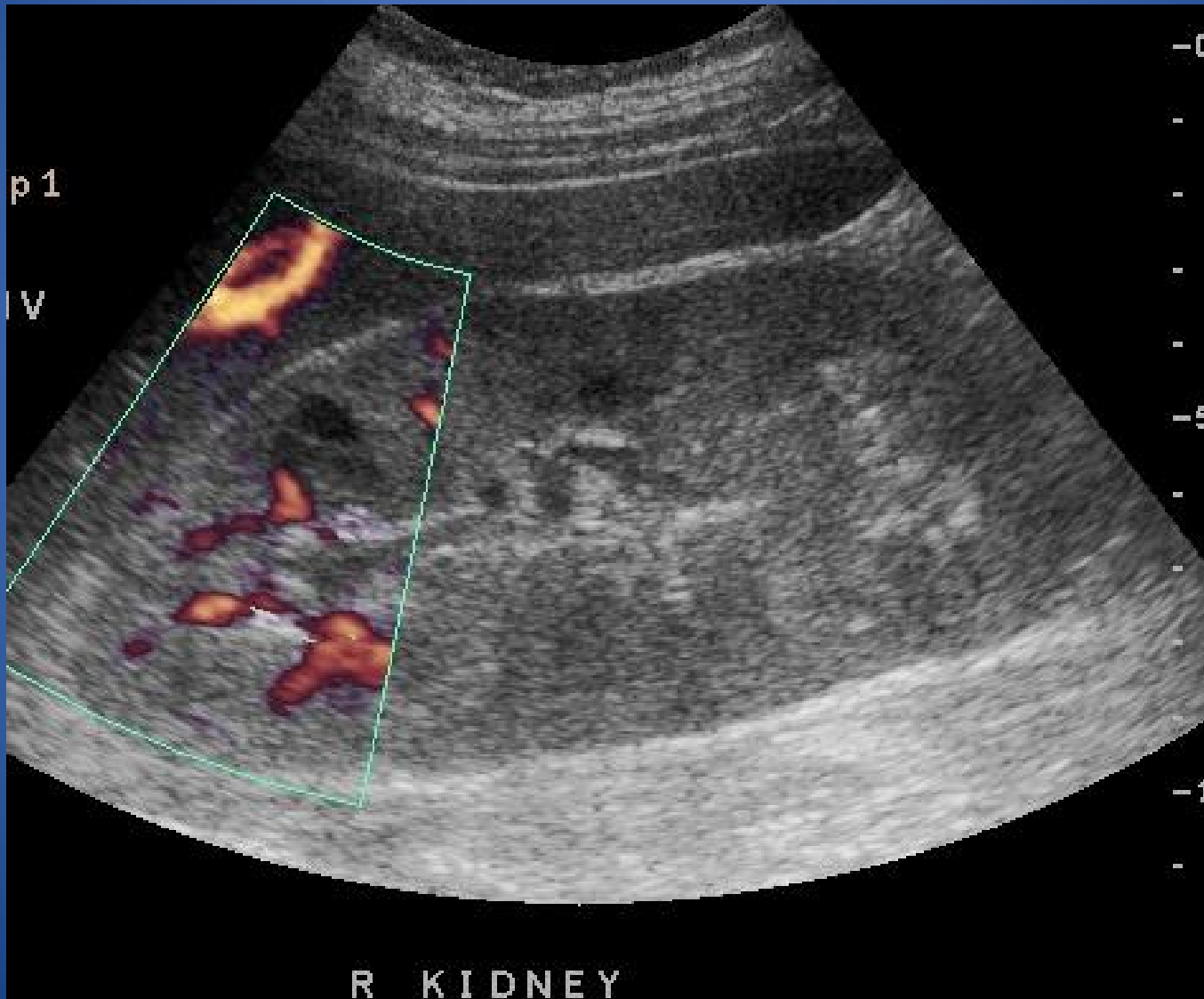
Urinary Tract Infection

- U/S has no role in uncomplicated UTI's responding to ABX
- Real role in persistent, chronic, or recurrent infections
- Urosepsis
- 2 functions
 - ID calculi, hydro, congenital anomalies
 - Detect complicated infections (i.e., abscess) or XGP

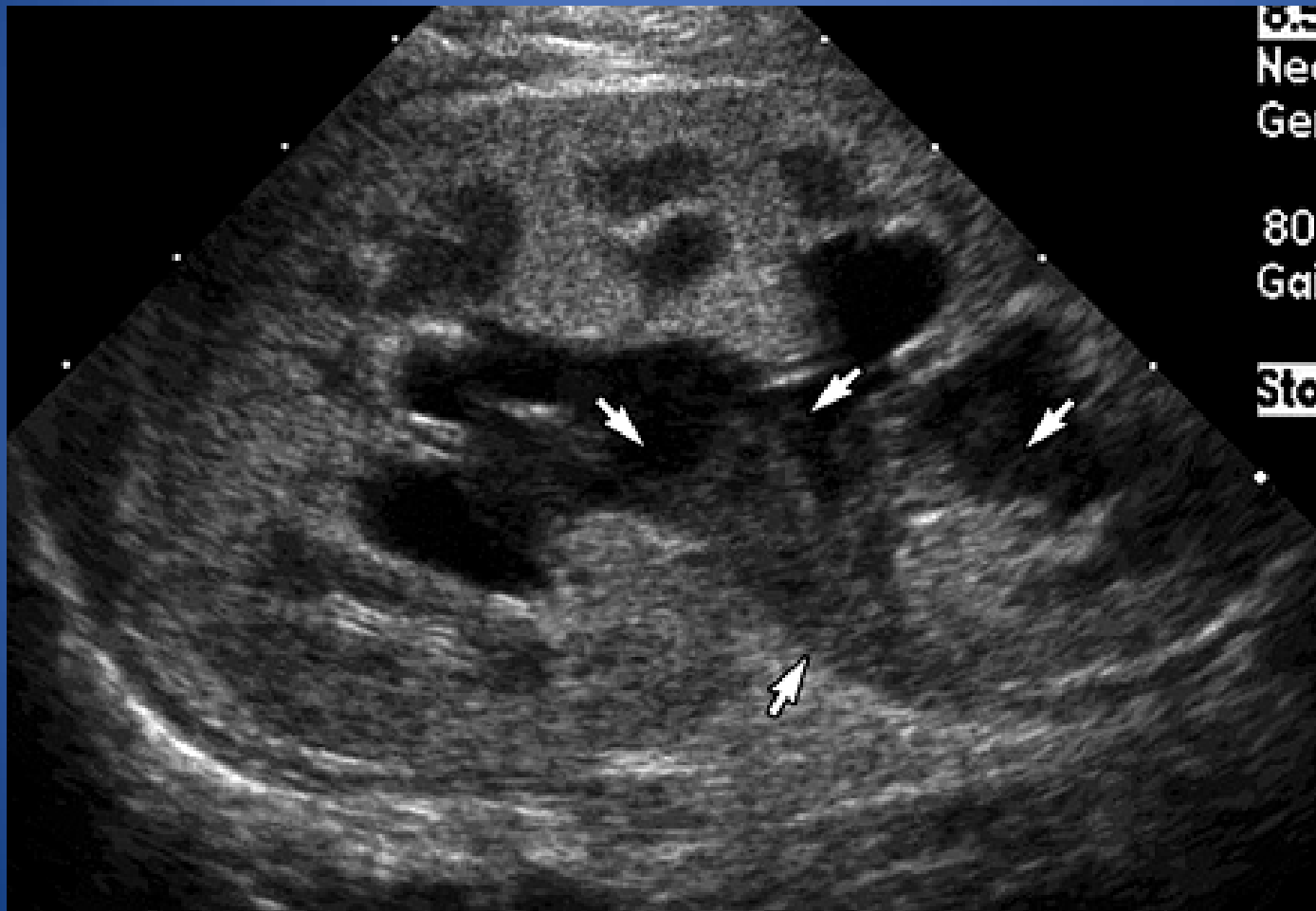
Focal pyelonephritis



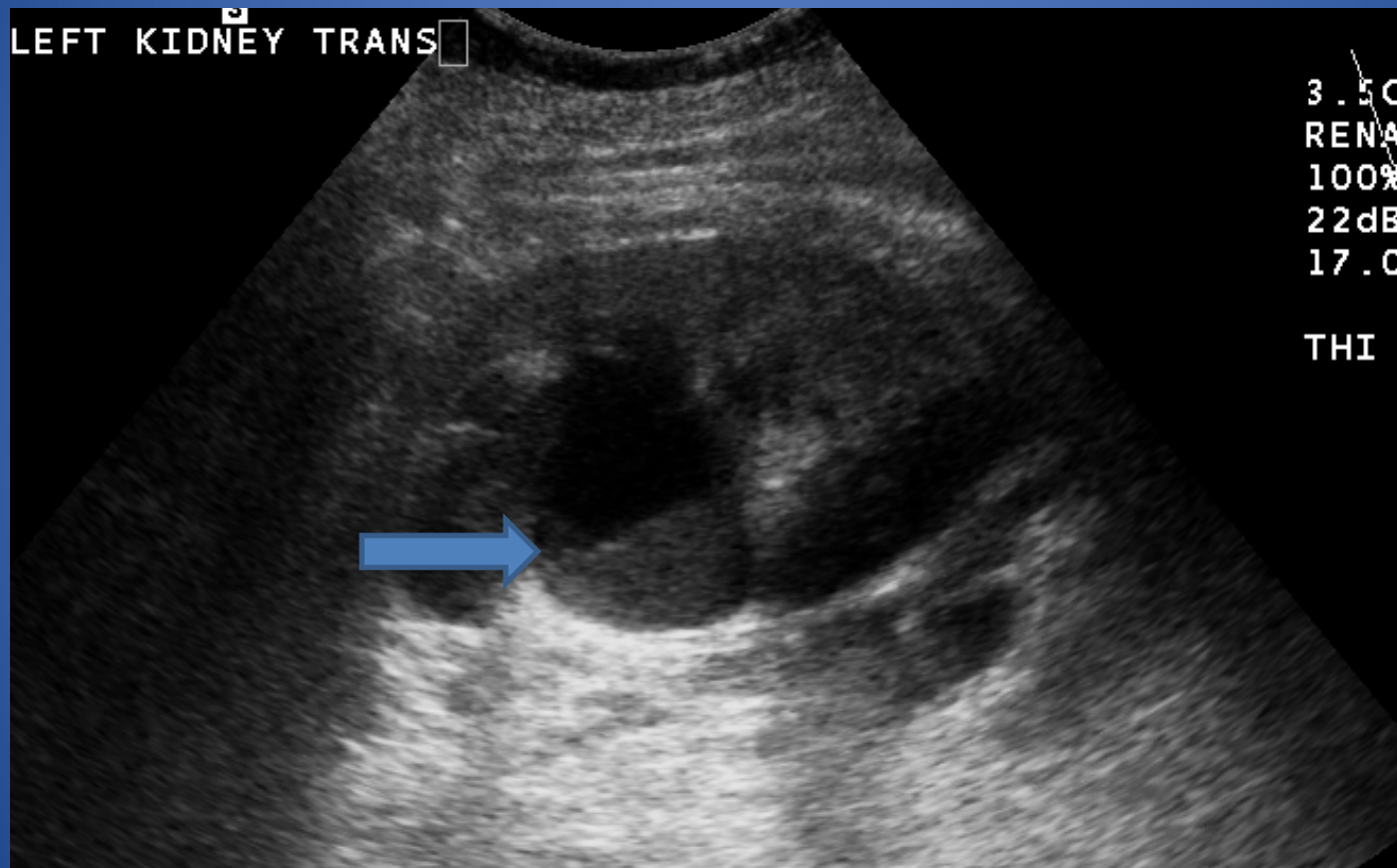
Focal pyelonephritis



Fungal balls



Pyonephrosis—fluid/debris level



DDX echoes in collecting system

blood, pus, fungal balls, tumor, crystals

Renal masses

- RCC-80-85% of renal neoplasms
- Uroepithelial tumors-5-10%
- Wilm's tumor-3-5%
- Miscellaneous-5%
 - Mets
 - Lymphoma
 - Leukemia
 - AML
 - Oncocytoma

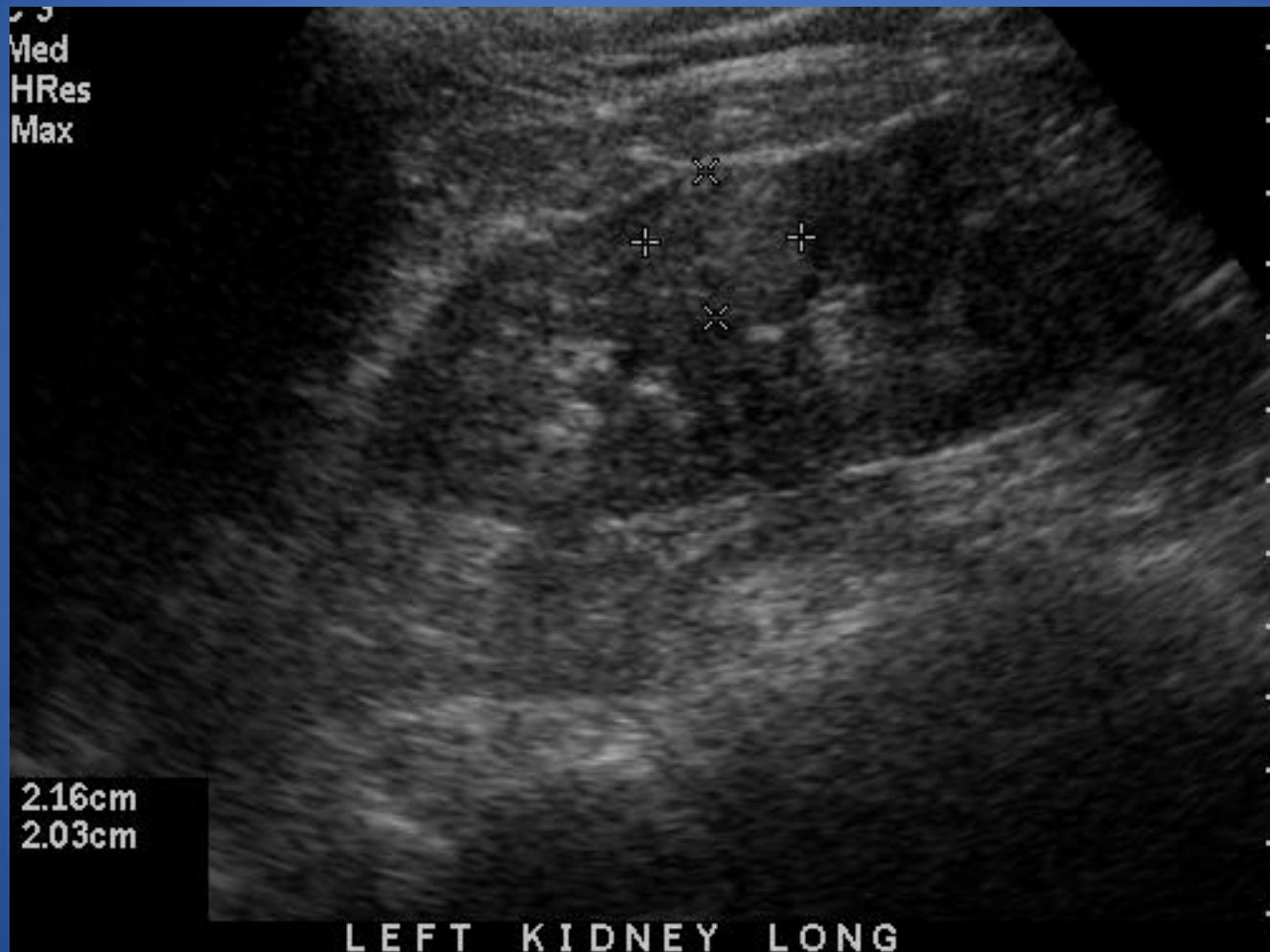
RCC-clinical

- Peak incidence 6th decade
- Hematuria, back/flank pain, palpable mass
cardinal signs or sx
- Weight loss, malaise, hypertension also
common
- Incidental discovery more common (Cross-
Sectional imaging for other reasons)
- Smaller tumors (< 3 cm) have good survival
rates

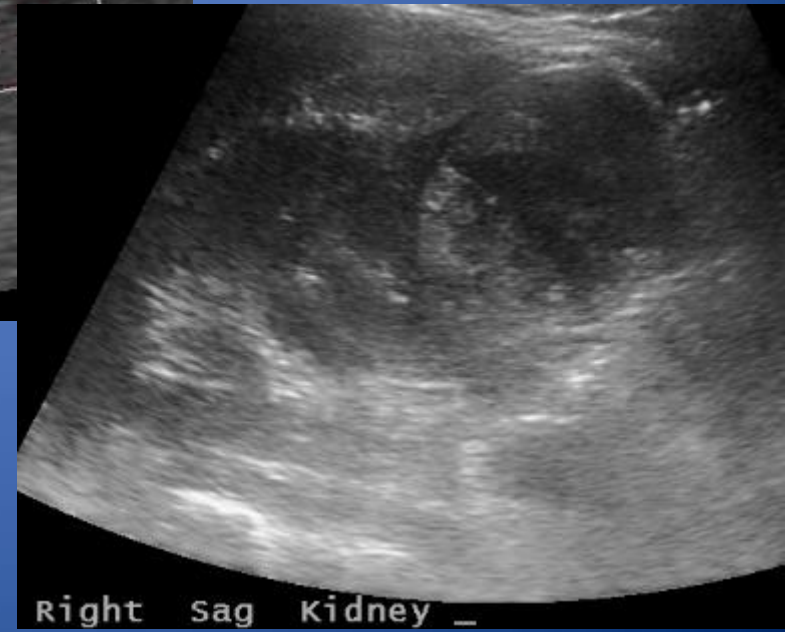
RCC on ultrasound

- Most hypoechoic to isoechoic
- 10% are hyperechoic
- Larger tumors are heterogeneous
 - Necrosis
 - Hemorrhage
 - Calcification
- Poorly defined borders (except for small RCC)

RCC-U/S



RCC



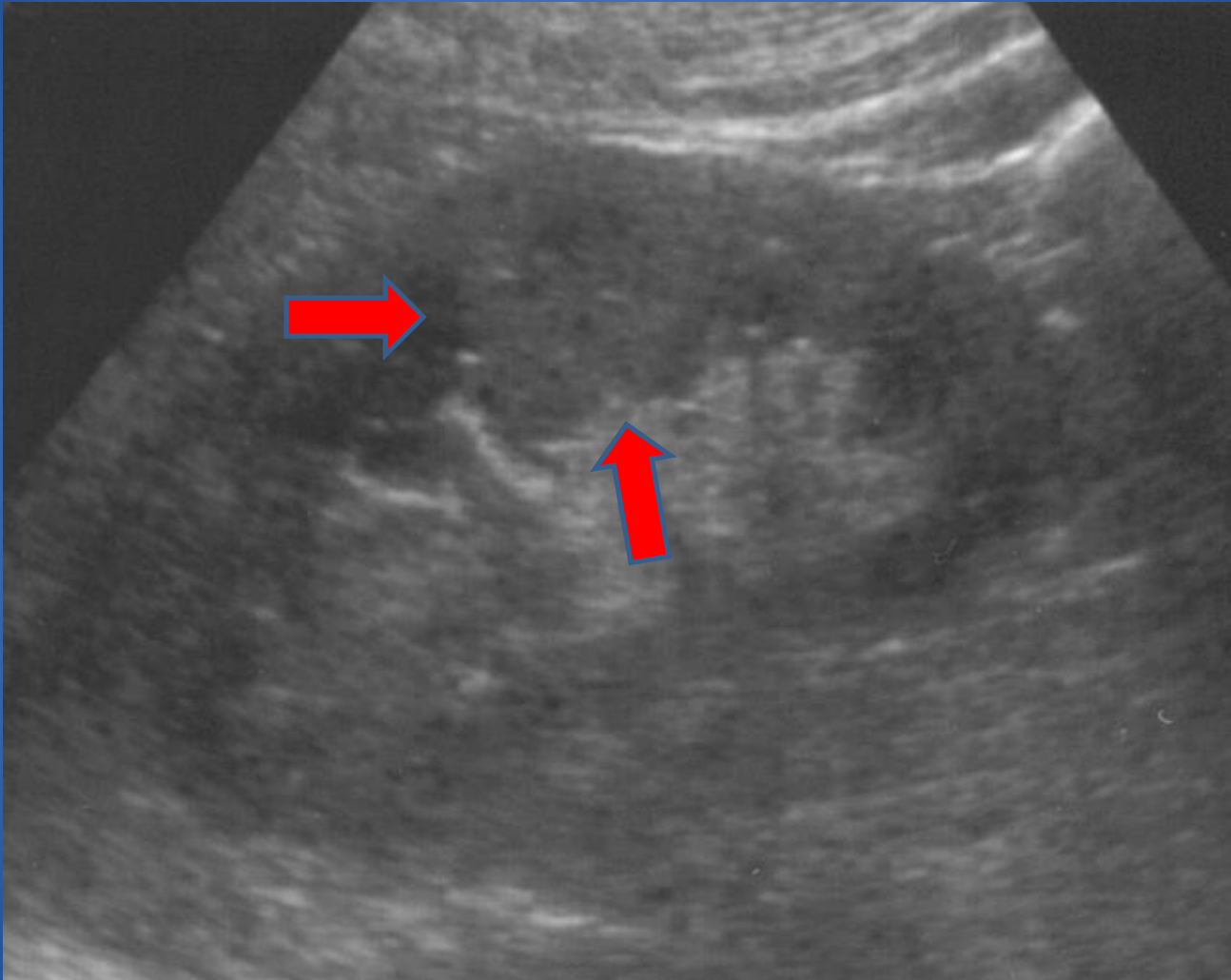
Hypoechoic Renal Sinus and TCC

- Difficult to distinguish renal pelvic tumors vs. hypoechoic fat
- Benign findings
 - Irregular and poorly defined margins
 - Central and symmetric location in renal sinus
 - Posterior acoustic attenuation with non-viz. of posterior border
 - Unaffected peripheral hyperechoic sinus
 - Traversing hilar vessels on color Doppler

Hypoechoic renal sinus

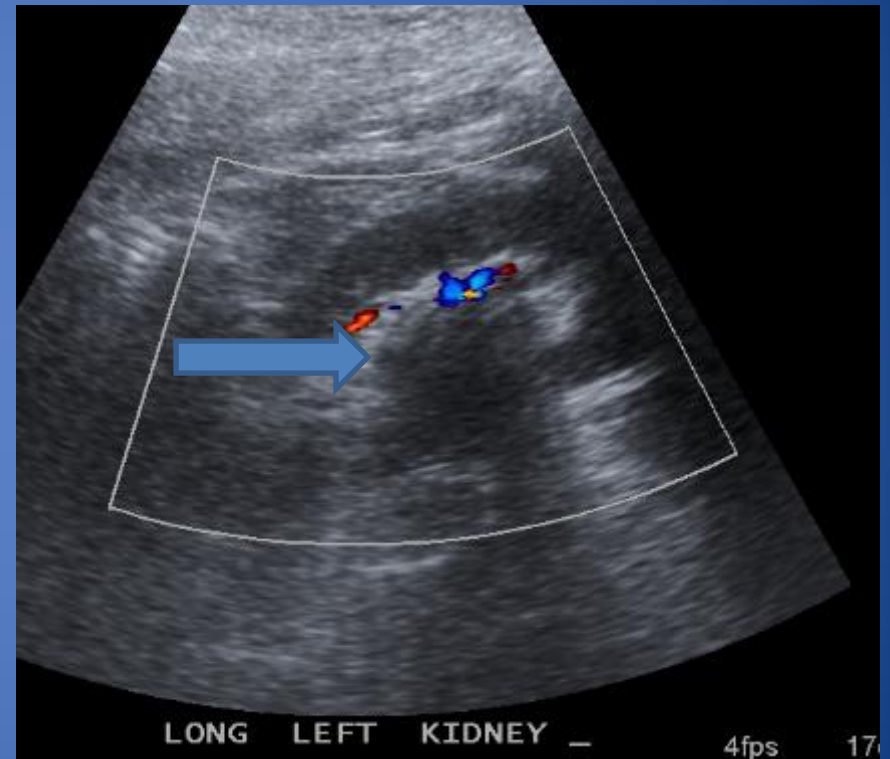
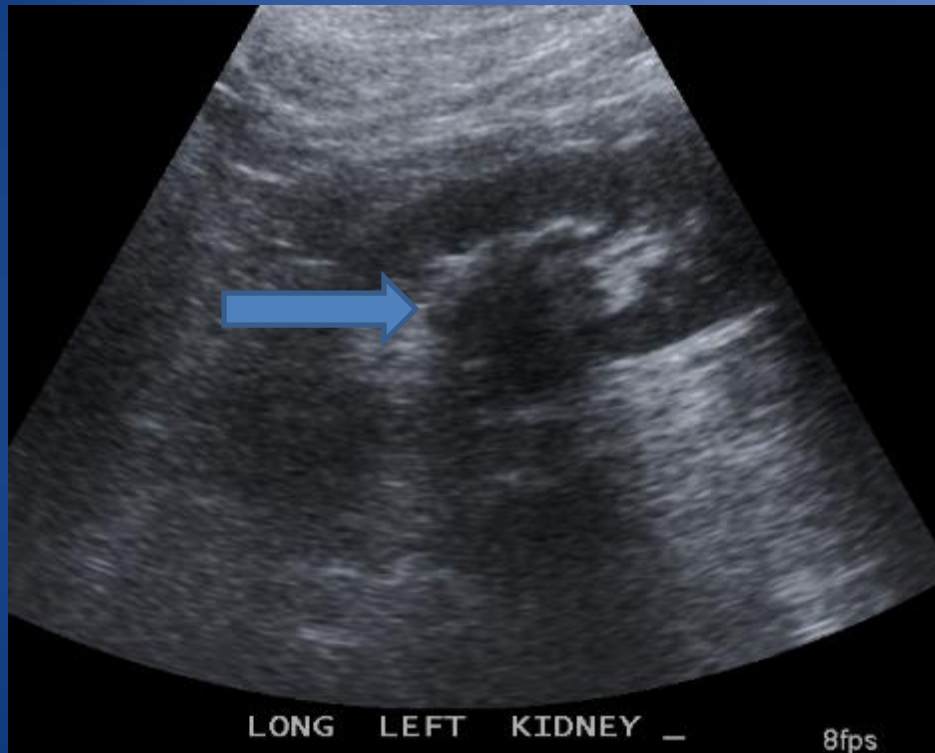
- Renal sinus tumors
 - Well defined margin
 - Eccentric location in sinus
 - Partial/complete obliteration of hyperechoic sinus
 - Visible posterior margin
 - No posterior shadowing
 - Vessel displacement by mass
 - Rarely, associated caliectasis

71-year-old man with transitional cell carcinoma (35 mm in diameter) of left kidney



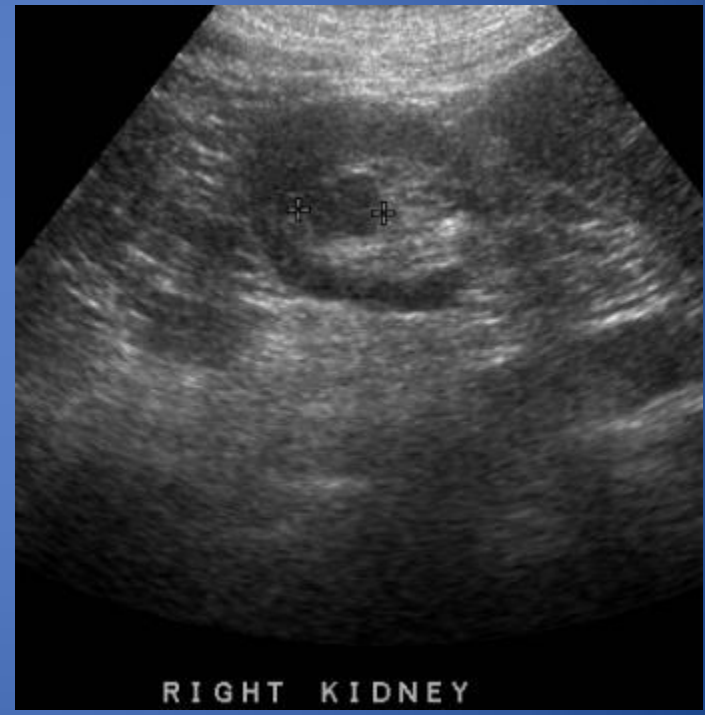
Schmidt, T. et al. Am. J. Roentgenol. 2003;180:1639-1647

Not TCC-probably sinus fat



No change in lesion size in 12 months.....CT
guided bx negative.

Hypoechoic renal sinus lesions



Column of Bertin



Solid, hypoechoic mass

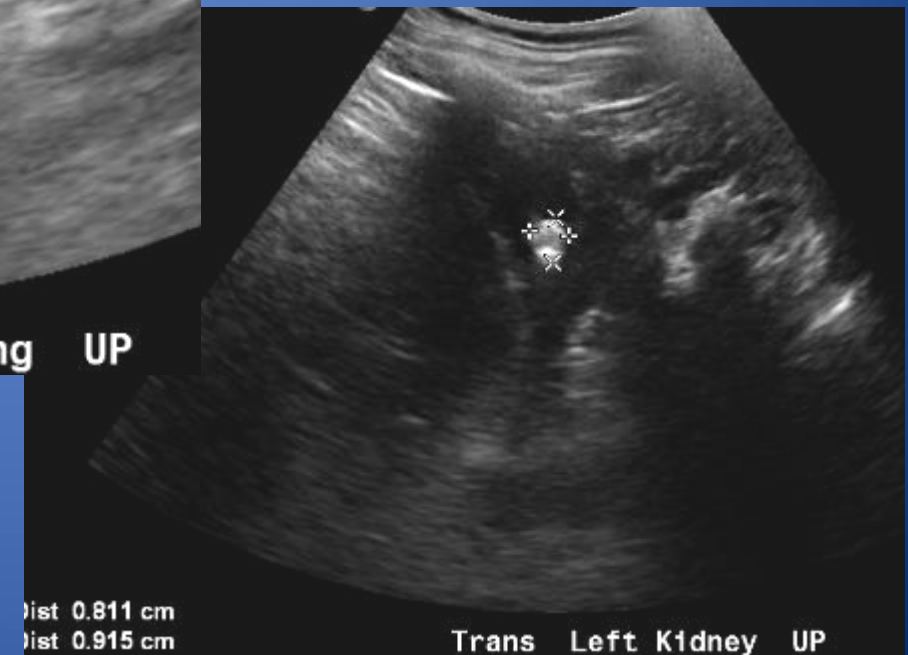
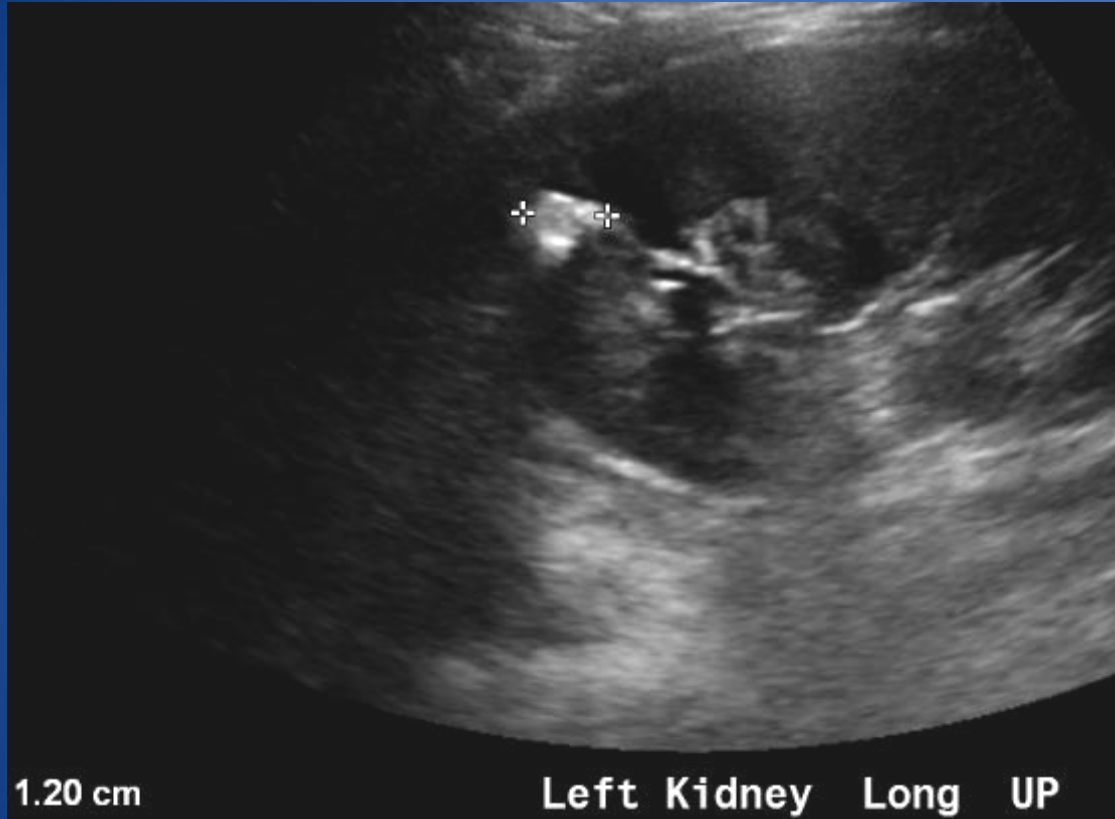


Renal lymphoma

13 yo boy with renal mass in 2004



Renal Mass in 2009



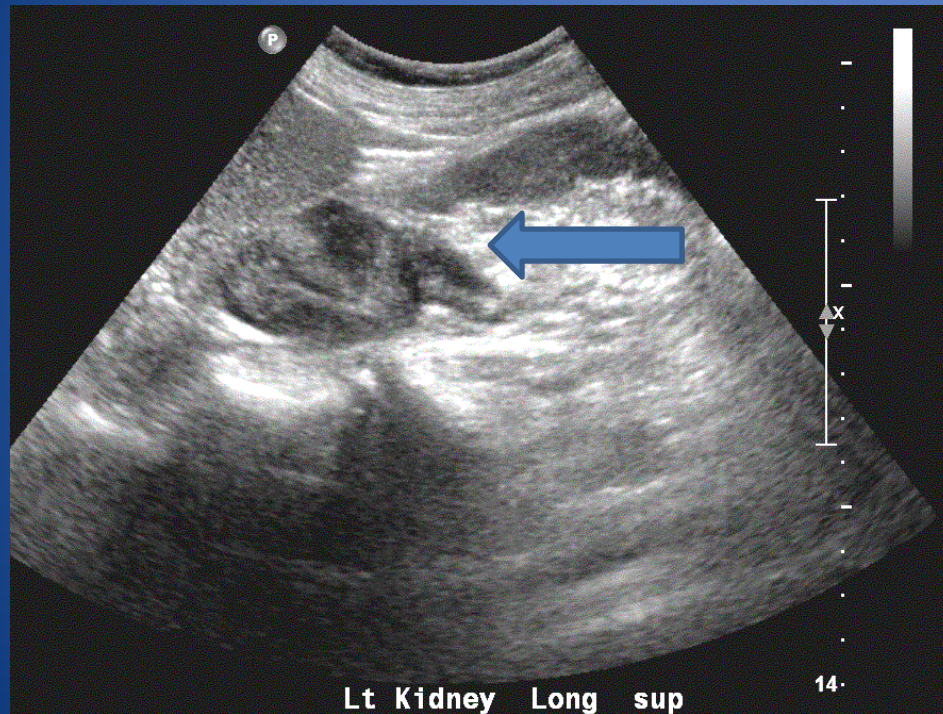
Probable old hemorrhage into cyst or focus of infection, now calcified, AML less likely

Renal mass?



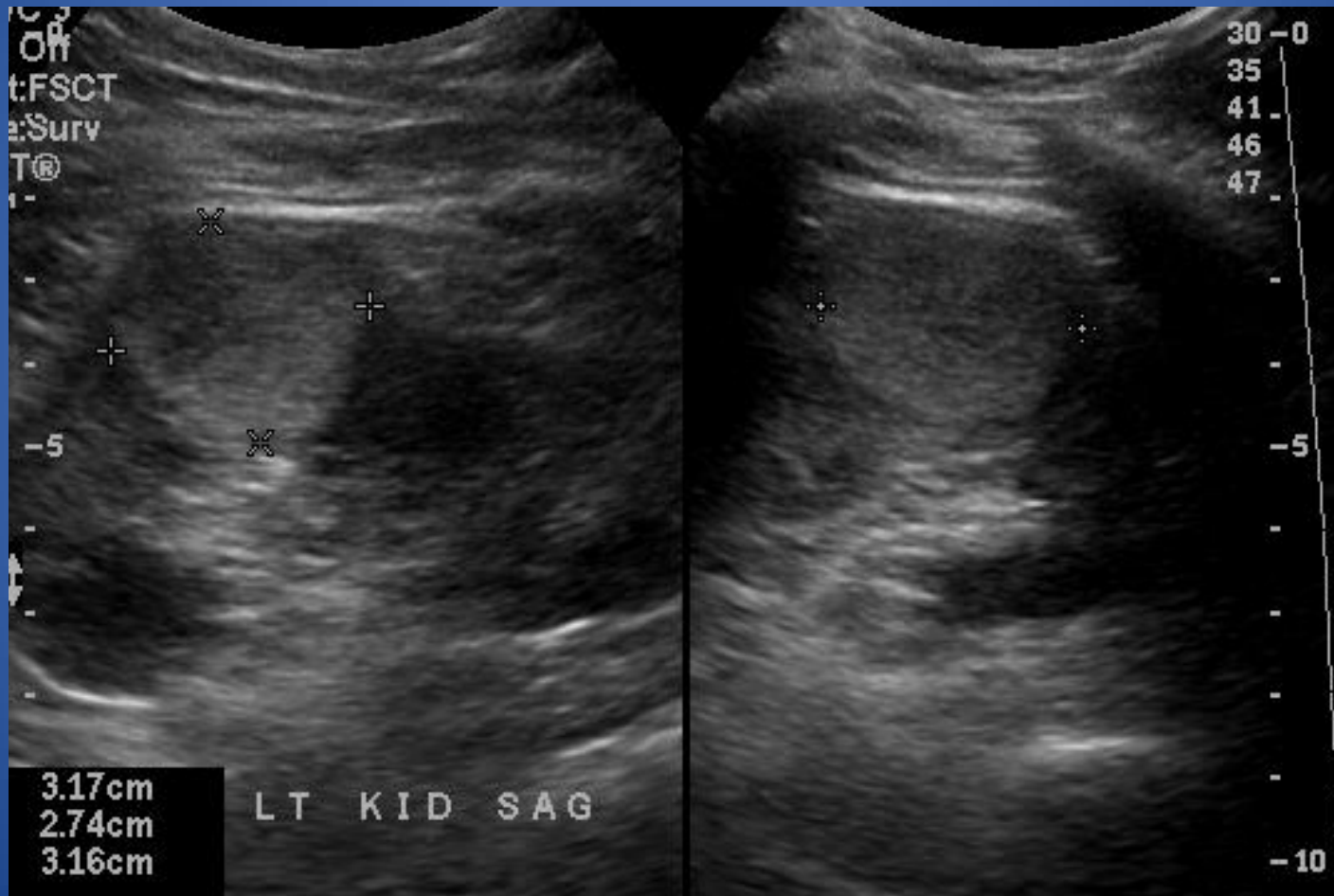
Both cases are cystic renal cell carcinoma

Typical RCC-atypical behavior

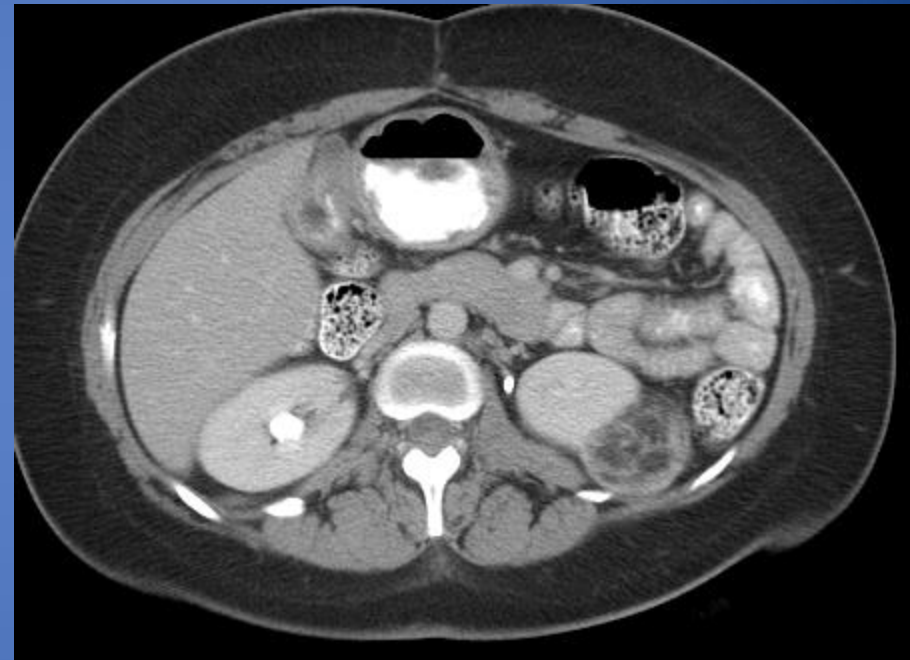


- 87 yo female with multiple med. problems
- Bx proven Furman Gr III chromophobe RCC
- No change in 2+ years
- Negative metastatic w/u
- Conservative RX

Oncocytoma



Angiomyolipoma



Renal AML



Enlarged kidneys DDX

- Hydronephrosis/cystic disorders
- Diabetes mellitus
- Acute GN
- Acute vasculitis (lupus)
- AIDS-related nephropathy
- Lymphoma/leukemia
- Amyloidosis
- Acute renal vein thrombosis

Enlarged, Echogenic kidneys



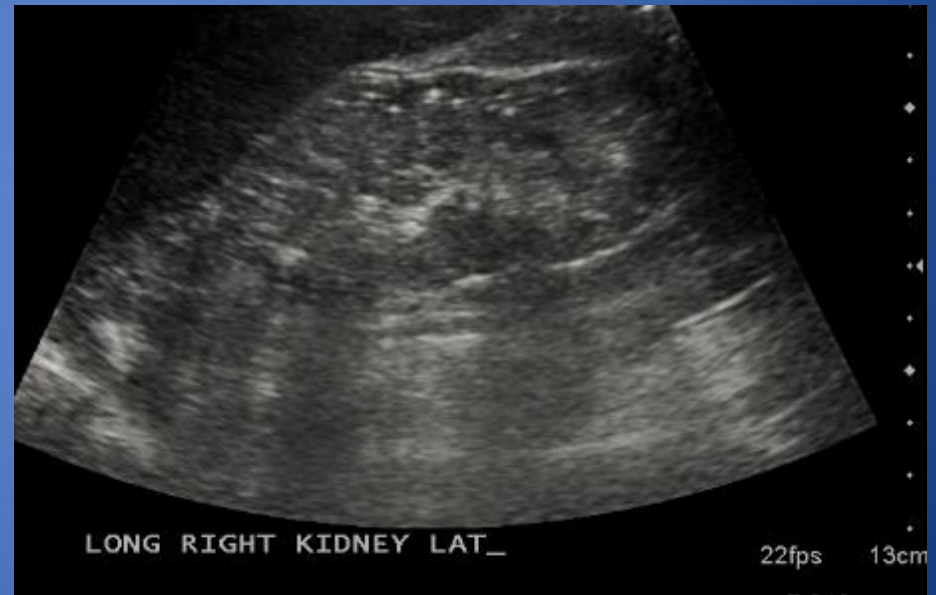
42 yo male s/p suicide attempt, ingested ethylene glycol

DDX: medical renal disease: acute GN, acute nephrotic syndrome, acute toxic nephritis, acute tubular necrosis, diabetic nephropathy

Lithium Toxicity



2/08



1/11

Lithium Toxicity video clip

Lithium Toxicity

- 10,000 case per year
- Narrow therapeutic window
- 3 meds that aggravate situation
 - NSAID's
 - ACE inhibitors
 - Sodium wasting diuretics
- US--Echogenic kidneys with punctate calcs.
- Chronic-renal atrophy

Conclusions

- Renal ultrasound generally excellent screening test
- Good for cysts, masses, r/o hydro, stones
 - Small stones still difficult, like to obviate CT's
 - > 5 mm. stones seen generally
- Color Doppler essential
- Parapelvic cysts may mimic hydronephrosis
- Most solid renal masses malignant