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 erythropoietin, 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
May see prominent medullary pyramids in infants, thin adults, renal transplant patients
Renal trauma due to car accident
Renal atrophy secondary to ischemia/trauma

March 2009
Renal atrophy

October 2009

Length 7.80 cm
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
52 yo woman s/p left partial nephrectomy for oncocytoma
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

Tsai, J.-D. et al. Pediatrics 2006;117:139-146
Echogenic Kidneys due to ARF
Prominent Medullary Pyramids-Cr 1.6 (eGFR ~ 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

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

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

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
Medullary Nephrocalcinosis
Medullary Nephrocalcinosis

Right Kidney
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

4/09 10/09
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 6\textsuperscript{th} 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
Hypoechogenic Renal Sinus and TCC

• Difficult to distinguish renal pelvic tumors vs. hypoechogenic 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

JUM 2002, 21:993-999, Seong et al
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

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
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