AAP experience PHILADELPHIA 2021
National Conference & Exhibition

"They told me there's water in the kidney!"
Follow-up of the abnormal prenatal ultrasound

Patty Seo-Mayer, MD, FAAP

Pediatric Specialists of Virginia / Inova Children's Hospital / Georgetown MedStar
UVA – Inova Campus / Georgetown School of Medicine

@PattySeoMayerMD

OCTOBER 8–12, 2021
AAPEXPERIENCE.ORG | #AAP2021

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN®

Faculty Disclosure Information (Option A)

I have no relevant financial relationships with the manufacturer(s) of any commercial product(s) and/or provider(s) of commercial services discussed in this CME activity.

I do not intend to discuss an unapproved/investigative use of a commercial product/device in my presentation.

I was very mindful of copyright restrictions so had to make do with homemade figures despite having no artistic skills

Learning Objectives

- Recognize common anomalies of the kidneys and urinary tract (CAKUT) and the factors that influence renal development
- Understand the imaging utilized to evaluate CAKUT
- Understand the implications of CAKUT and the role of the pediatrician in the long term management of these patients

Learning Objectives

- Discuss renal findings on prenatal ultrasound and how renal imaging can be used to make a diagnosis
- Review practices for follow-up and treatment as well as outcomes

Roadmap


Epidemiology
Pathophysiology
Diagnosis
Management
Outcomes
Complications and challenges

Epidemiology

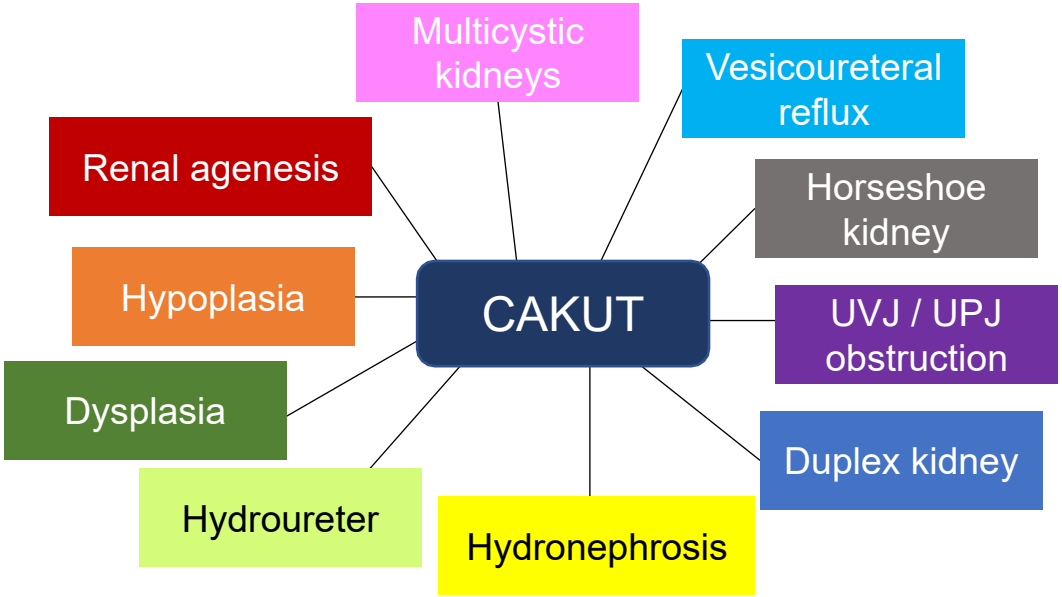
CAKUT

- Detected in ~1:500 (2%) of all fetal ultrasounds
  - Higher % reported in tertiary care systems
- Male > female
- Represent 20-30% of all prenatally diagnosed anomalies
- Account for 30-50% of all cases of pediatric ESRD
  - 60-70% of CKD in children <1 year
- Family history found in 10-15% of affected children

-Harambat J et al, 2012
-Quiesser-Luft A et al, 2002
-Rosenblum et al, 2017
-Walker KA et al, 2011
-USRDS, 2020

Pathophysiology

What is “CAKUT”?

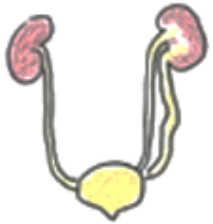


-Choi YH et al, 2016
-Rodriguez M, 2012

Pathophysiology

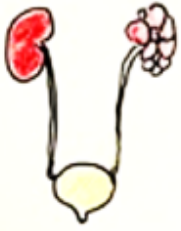
Hypoplastic kidney

Duplex kidney

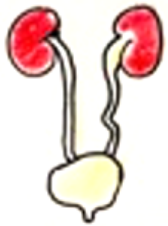


UPJ obstruction

Multicystic dysplastic kidney



Vesicoureteral reflux



Posterior urethral valves

Pathophysiology

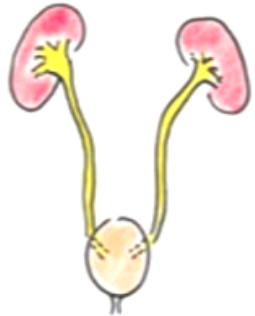
Kidney development

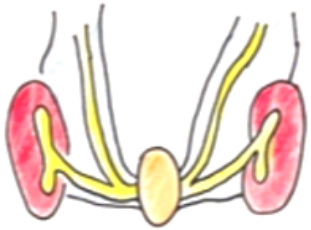
First trimester	Second trimester	Third trimester
• Pronephros forms (simple tubules) at 3 weeks • Mesonephros (filtering units) forms at 4 weeks, generating mesonephric (Wolffian) duct • Ureteric bud outpouches and undergoes branching to develop collecting system • Metanephric mesenchyme converts to renal epithelia • Ureteric tree becomes collecting ducts, pelvis, ureters • Glomeruli form at 9-10 weeks	• Number of glomeruli increase • At 16-20 weeks, fetal urine is major contributor of amniotic fluid	• At 32-36 weeks nephron development complete

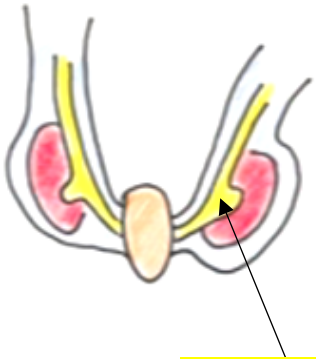
-Rosenblum et al, 2017

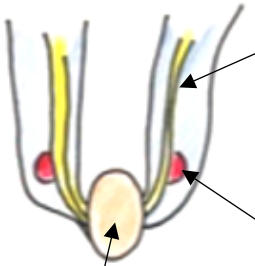
Pathophysiology

Kidney development









Mesonephric duct

Metanephric mesenchyme

Urogenital sinus

Ureteric bud

- Pronephros forms (simple tubules) at 3 weeks
- Mesonephros (filtering units) forms at 4 weeks, generating mesonephric (Wolffian) duct
- Ureteric bud outpouches and undergoes branching to develop collecting system
- Metanephric mesenchyme converts to renal epithelia
- Ureteric tree becomes collecting ducts, pelvis, ureters
- Glomeruli form at 9-10 weeks

Kidney agenesis

Kidney hypoplasia

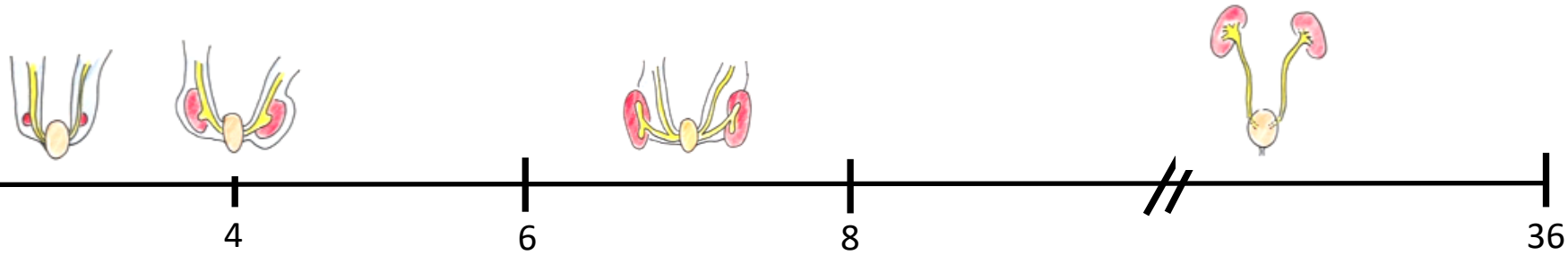
Ectopic kidney / Horseshoe kidney

Vesicoureteral reflux

Diminished nephron number

Kidney dysplasia

PUV



Ureteric bud formation

Ureter extension
Kidney formation

Bladder formation
UVJ formation
Kidney branching
Nephrogenesis

-Murgoogopathy et al, 2020
-Potter, 1972
-Vize, 2003

Multiple signaling pathways and genes are involved in kidney development

ALDH1A2	*LHX1*
BMP4/BMP7	*LIF*
CD2AP	*MET*
CITED1	*NOTCH2*
EMX2	*NPHP1-NPHP9*
EYA1	*NPHS1*
FAT1/FAT2	*NPHS2*
FGF2/FGF7	*PSR1*
FOXD1	*PAX2/PAXB*
FRAS1	*PKD1-PKD2*
FREM2	*PKHD1*
FRS2alpha	*POU3F3*
GDNF	*RET*
GFRA1	*SALL1*
GLI3	*SIX2*
GREM1	*TFFB2*
IRX3	*TP53*
KDR	*VEGFA*
KIRREL	*WNT4/WNT9B/WNT11*
	WT1

-Walker K et al, 2011

Environmental risk factors for CAKUT	
Factors	**Phenotype**
Maternal diet Folic acid use Vit A deficiency	 Duplex collecting system, VUR, PUV VUR, renal hypoplasia, renal dysplasia
Maternal conditions Obesity Diabetes Malnutrition	 Duplex collecting system, VUR Wide range of CAKUT phenotypes Low nephron number, low birth weight
Maternal substance use Cocaine Alcohol ACE-I or ARB	 Horseshoe, renal hypoplasia, dysplasia Renal hypoplasia AKI, renal hypoplasia
In vitro fertilization	UPJ, duplex collecting system, PUV, VUR

-Murugapoopathy V et al, 2020

Genetic syndromes associated with CAKUT

Syndrome	Kidney finding	Extrarenal features
Turner	Agenesis, hypoplasia, horseshoe	Short stature, amenorrhea, webbed neck, cubitus valgus, hypogonadism
Down	Multiple	Intellectual disability, hypotonia, congenital heart disease, clinodactyly
Patau	Agenesis	Holoprosencephaly, midline anomalies, cleft lip/palate
CHARGE	Multiple	Cardiac defects, cleft palate, hearing loss, coloboma, choanal atresia, genital anomalies
DiGeorge	Agenesis, dysplasia, VUR	Optic disc/nerve anomalies, hearing loss, CNS and genital anomalies, skin and ligamentous laxity
Orofaciodigital	Cysts	Lobed tongue, cleft palate, hypodontia, micrognathia, clinodactyly
Branchio-oto-renal	Agenesis, dysplasia	Lat cervical fistulas or cysts, ear pits, hearing loss
Frasier	Agenesis, dysplasia	Cryptophthalmos, syndactyly, tracheal stenosis/atresia, ambiguous genitalia, craniofacial anomalies
Alagille	MCDK, dysplasia, mesangiolipidosis	Chronic cholestasis, cirrhosis, cardiac, butterfly vertebrae, dysmorphic facies
Bardet-Biedl	Dysplasia, calyceal malformations, cysts	Obesity, intellectual disability, retinal dystrophy, polydactyly
Beckwith-Wiedemann	Nephromegaly, nephrocalcinosis, medullary sponge, renal tumors	Macrosomia, hemihyperplasia, macroglossia, omphalocele
Simpson-Golabi-Behmel	Multiple	Craniofacial anomalies, organomegaly, intellectual deficits
Smith-Lemli-Opitz	Hypoplasia	Syndactyly, microcephaly, intellectual disability, heart, lung and GI abnormalities
Rubinstein-Taybi	Multiple	High arched eyebrows, high arched palate, micrognathia, internally deviated toes and thumbs, hirsuitism, heart and eye abnormalities

-Halima et al, 2019

It’s complicated...

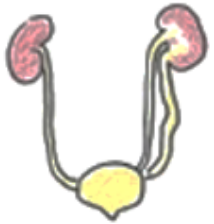
“Development of the urinary system is a highly complex process that depends on precise spatiotemporally regulated events and requires the integration of a variety of progenitor cell populations of different embryonic origins. These events culminate in precise anatomical connections between the proximal and distal nephrons in the kidney (upper tract) and the upper and lower urinary tract.”

-Jain et al Clin Kid Jnl 2019

Common kidney anomalies

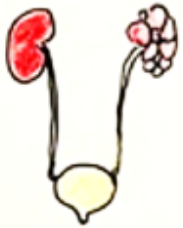
Hypoplastic kidney

Duplex kidney

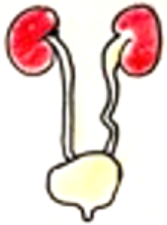


UPJ obstruction

Multicystic dysplastic kidney



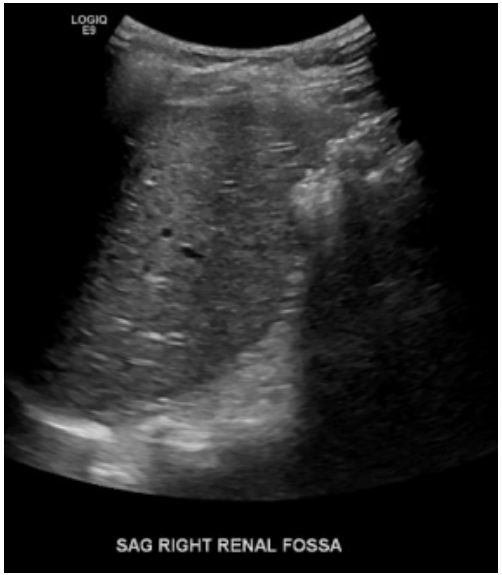
Vesicoureteral reflux



Posterior urethral valves

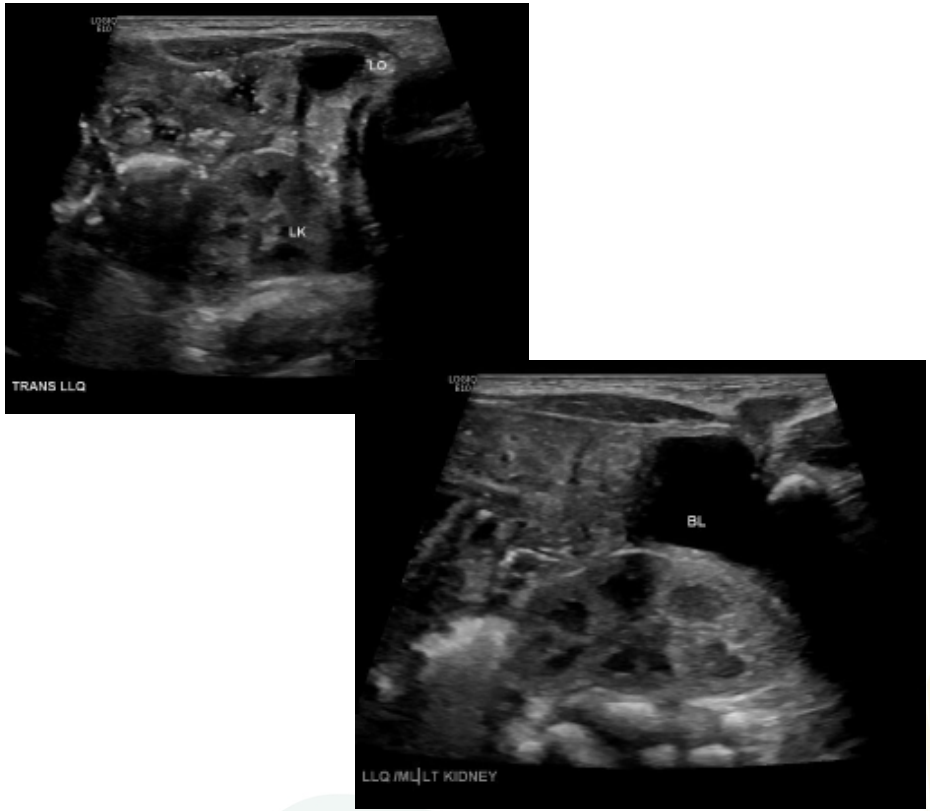
Renal agenesis

- 1:3000 unilateral
- 1:7,000-10,000 bilateral
- Male > female
- L > R
- Ureteric bud does not form
- Abnormal signaling proteins allowing differentiation of metanephric blastema



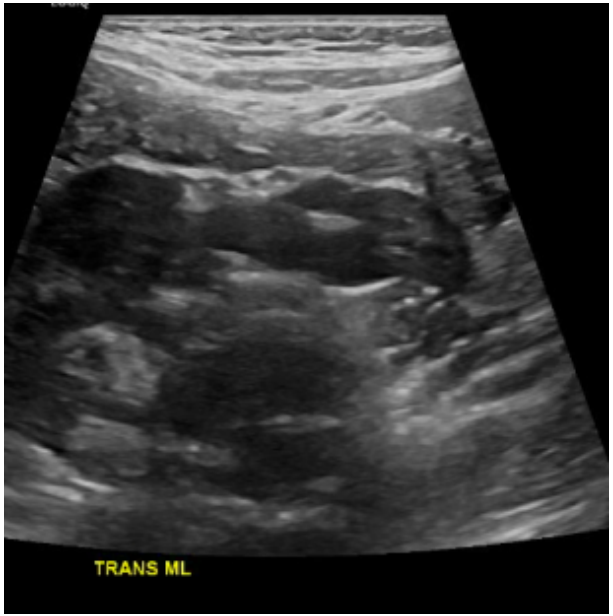
Ectopic (pelvic) kidney

- Failure to ascent during week 6-8
- High risk of ureteral obstruction and stones
- May be associated with GU anomalies:
  - Vaginal atresia
  - Imperforate hymen
  - Hypoplastic uteri
  - Rudimentary fallopian tube/ovary



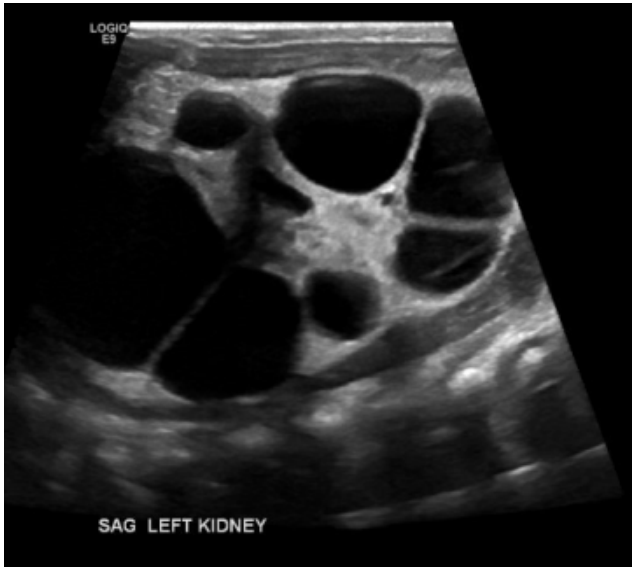
“United kidneys at birth” (horseshoe kidney, cross fused renal ectopia)

- 1:500
- Male 2:1
- 70% are left-dominant
- Mostly benign, but are associated with urological sequelae including stones
- Susceptibility to midline trauma and vascular anomalies
- Higher frequency of rare renal cancers



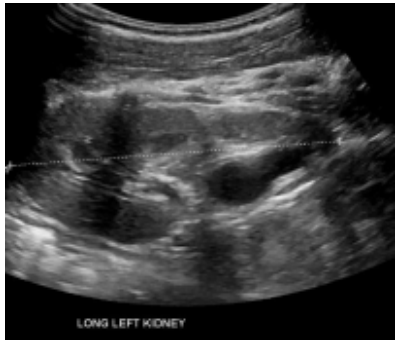
MCDK

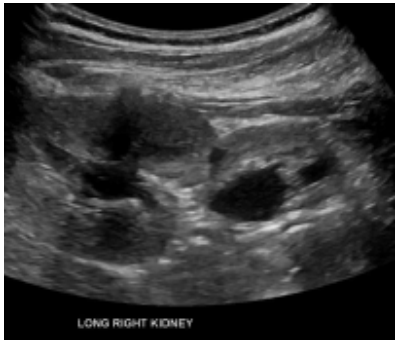
- 1:2000-4000 live births
- Males > females
- L > R
- Multiple cysts of various sizes
- Usually non-functional w/ atretic ureter
- 60% involute by age 10 years

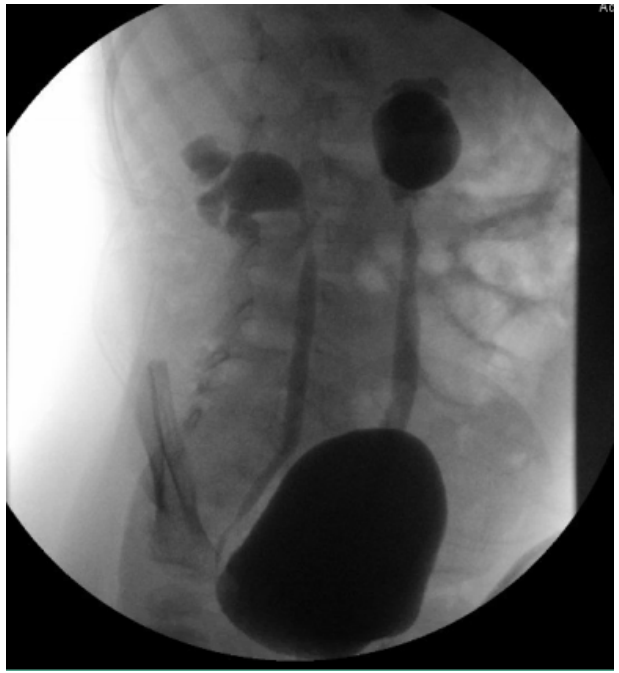


“I have four kidneys”: Duplex kidney

- 1:100
- More susceptible to reflux and obstruction

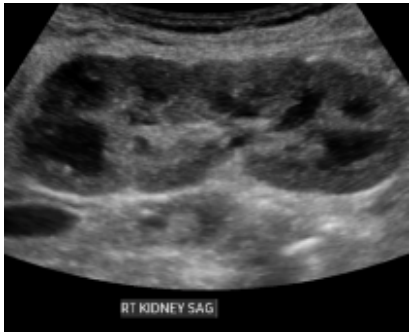




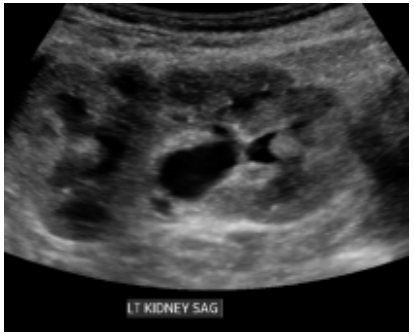


“Water in the kidney” Hydronephrosis/pylectasis/pelviectasis

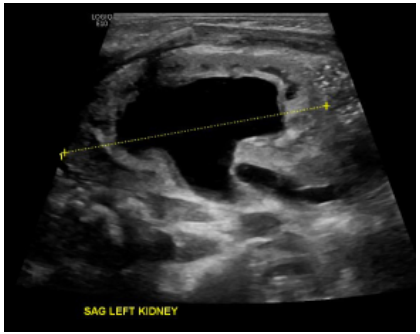
Normal



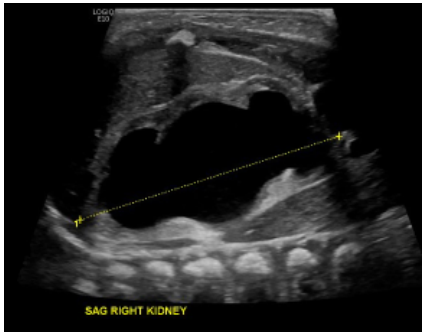
Mild



Moderate



Severe



3 possible causes:

1. VUR
2. Obstruction (UVJ, UPJ, PUV)
3. Non-refluxing, non-obstructed dilation (megaureter or physiologic)

50-75% transient or physiologic

Grading is key

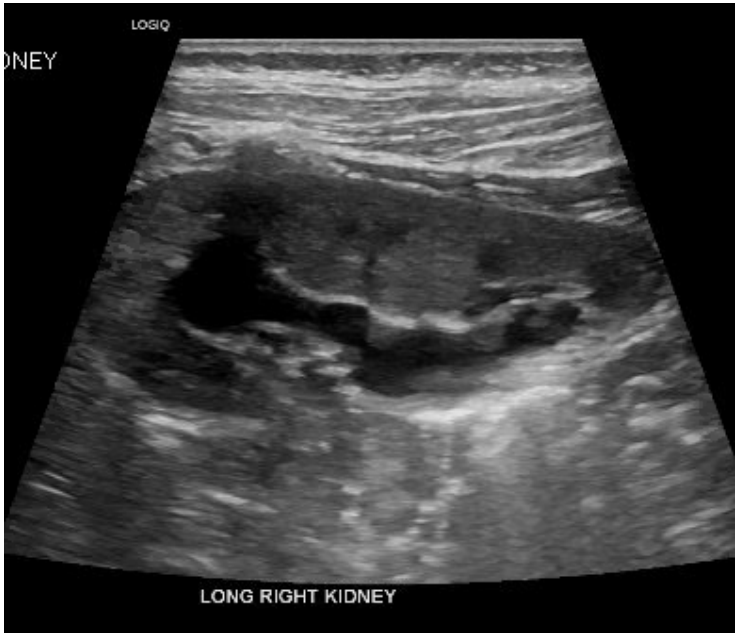
Hydronephrosis grading systems

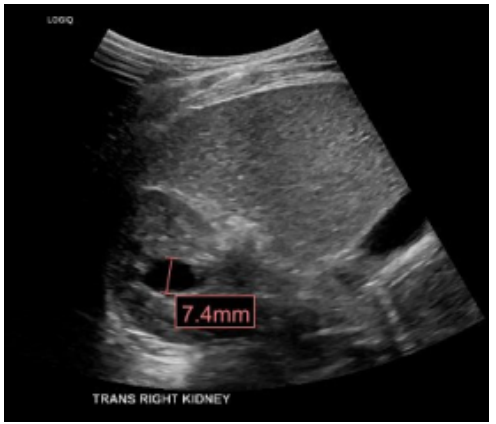
System	Publication	Stakeholders
AP diameter		Utilized widely by OB/gyn and fetal medicine teams
Urinary Tract Dilation (UTD)	Nguyen et al, Journal of Pediatric Urology, 2014	American College of Radiology American Institute of Ultrasound in Medicine American Society of Pediatric Nephrology The Society for Fetal Urology The Society for Maternal-Fetal Medicine The Society for Pediatric Urology The Society for Pediatric Radiology The Society of Radiologists in Ultrasounds
Society of Fetal Urology (SFU)	Fernbach SK, Maizels M, Conway JJ. Pediatric Radiology, 1993	
Onen	Onen A. Journal of Pediatric Urology, 2007	

Hydronephrosis grading systems

- Factors:
  - Anterior-posterior renal pelvic diameter (APRPD):
    - Dependent on position, hydration, phase of voiding, respiration
  - Calyceal dilation
  - Renal parenchymal thickness
  - Renal parenchymal appearance
  - Bladder abnormalities
  - Ureteral abnormalities
  - Based on gestational age and whether the UT dilation is detected prenatally or postnatally

AP diameter





Prenatal imaging

Classification for antenatal hydronephrosis and risk of postnatal uropathy			
Grade	**APD**		**Risk of uropathy** (95% CI)
	2nd trimester	3rd trimester	
Mild	4 to <7 mm	7 to <9 mm	11.9 (4.5 – 28)
Moderate	7 to 10 mm	9 to 15 mm	45.1 (25.3 – 66.6)
Severe	>10 mm	>15 mm	88.3 (53.7 – 98)

- Fernbach et al, 1993
- Lee RS et al, 2006
- Nguyen HT et al, 2012

Prenatal imaging

- **Equity of maternal care**
  - Race-based
    - Severe maternal morbidity is 2.1x higher in Black women and 1.4x higher in Hispanic women compared to White women, regardless of insurance type
    - PA Medicaid: White and Asian women more likely to receive prenatal and postnatal care
    - Black and Latinx women report 2x more barriers to prenatal care than White women
  - Rural – urban inequality

-Brown et al, 2021
-Fryer et al, 2021
-Parekh et al, 2019
-Wang et al, 2020

Diagnosis

Postnatal ultrasound?

- Non-invasive
- No sedation
- Cost: $400-500
- ***Timing matters***
  - DOL 1-2: low UOP, physiologically vol depleted
  - Can underestimate dilation
  - If unilateral and low risk: wait until feeding/voiding established (1-2 weeks)

-Used with parental permission

Diagnosis

Postnatal ultrasound?

- **Urgent** if high risk for significant kidney anomaly or there are concerns for follow-up
  - Oligohydramnios:
    - <500 mL of amniotic fluid
    - AFI <5-6
  - Suspected CAKUT and no void > 24 hours
  - Severe (>10mm 2nd trimester, >15mm 3rd trimester) hydro, especially if bilateral
  - Concern for PUV in a male:
    - Bilateral moderate to severe hydronephrosis
    - Unilateral moderate to severe hydroureteronephrosis
    - Distended bladder
    - Dilated posterior urethra

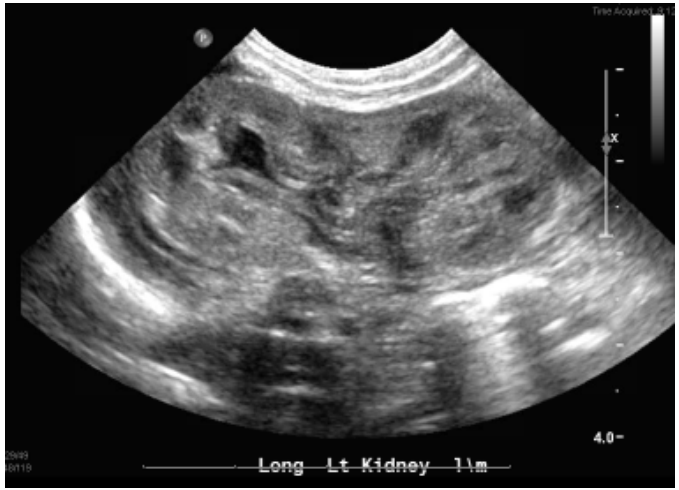
Management

Postnatal counseling

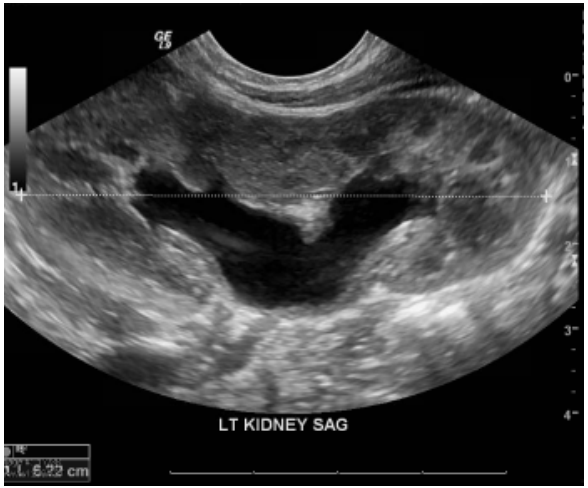
- More severe dilation -> greater the likelihood of a condition requiring surgical intervention, either UPJ obstruction or VUR
- Antibiotic prophylaxis and voiding cystourethrogram (VCUG) indicated for infants with persistent moderate or severe hydronephrosis after birth
- Severity of dilation **does not correlate** well with severity of VUR; those with resolved hydronephrosis may have VUR
- Consensus guidelines for fetal hydronephrosis recommend **discussion with families about risk and benefits of antibiotics and the VCUG in these cases**

Hydration matters

DOL1

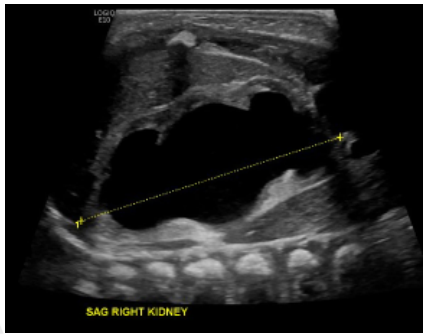


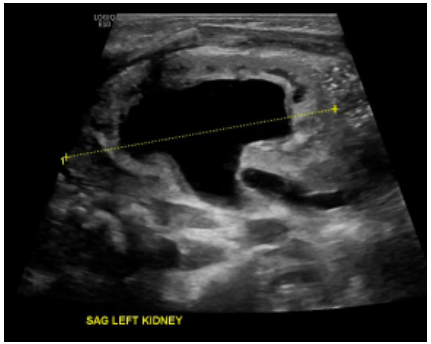
DOL40

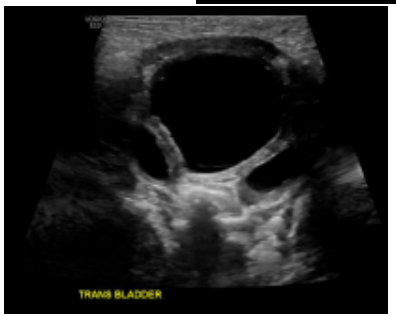


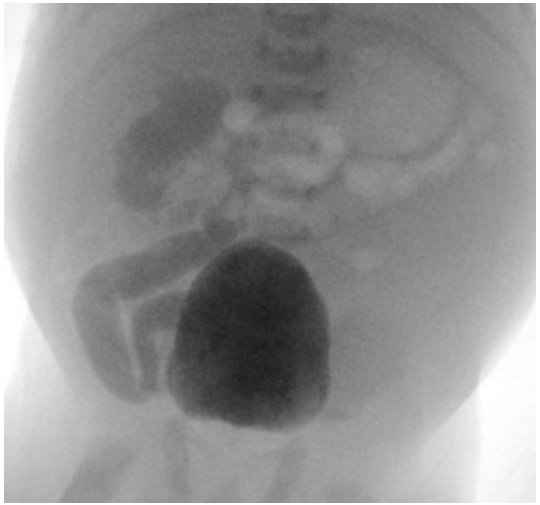
Repeating US at DOL 7-14 may be indicated

“Water in the kidney”
Hydronephrosis/pylectasis/pelviectasis

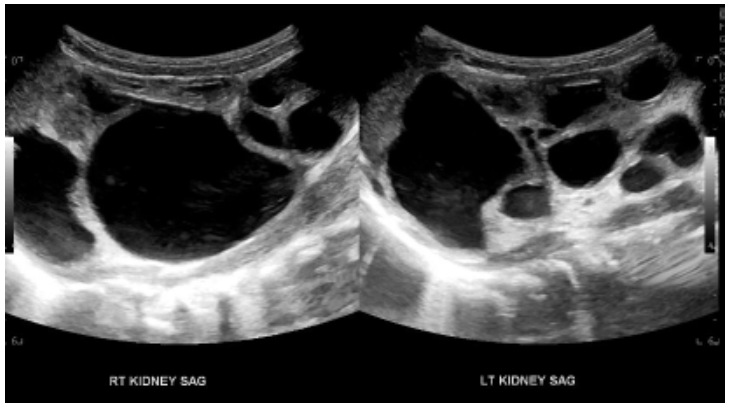


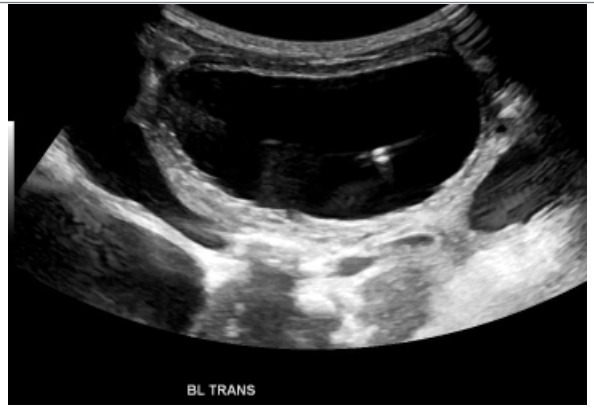


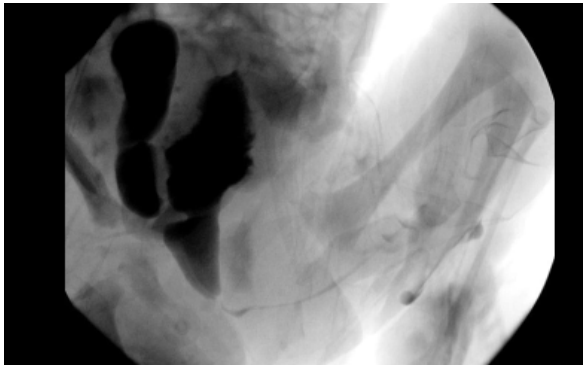




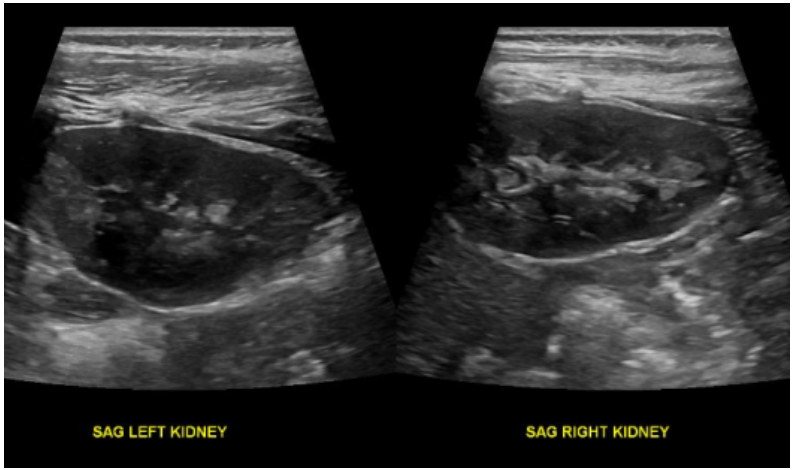
Posterior urethral valves

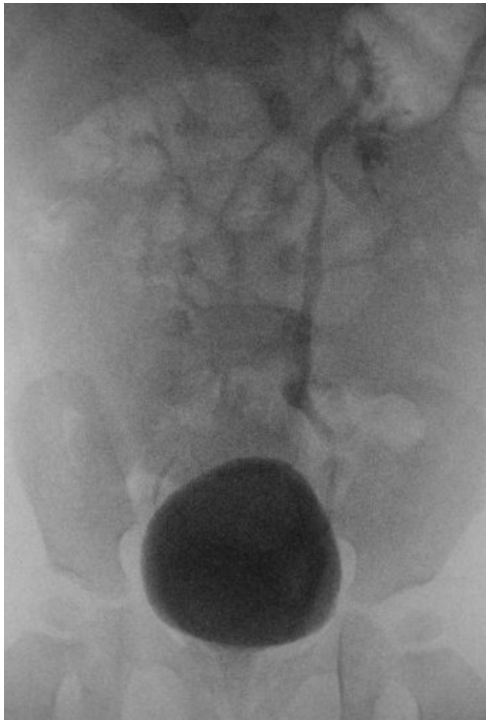






Vesicoureteral reflux





Postnatal ultrasound ASAP? YES if high risk

- Oligohydramnios with any suspected CAKUT
- Suspected CAKUT and no void > 24 hours
- Severe (>10mm 2nd trimester, >15mm 3rd trimester) hydronephrosis, especially if bilateral
- Concern for PUV in a male:
  - Bilateral moderate to severe hydronephrosis OR
  - Unilateral moderate to severe hydroureteronephrosis OR Distended bladder OR
  - Dilated posterior urethra

Urgency of referral

EMERGENT (urology +/- nephrology)

- Evidence of PUV
- Moderate to severe CAKUT in a solitary kidney
- Ureterocele or urethral atresia
- Abnormal abdominal wall musculature consistent with Prune Belly Syndrome
- Other GU anomalies (imperforate anus, ambiguous genitalia, bladder exstrophy, cloacal exstrophy, spinal cord abnormality)

Check renal function, US and BP

Urgency of referral

URGENT (2-10 days)

- Mild prenatal hydronephrosis in solitary kidney
- Moderate to severe unilateral prenatal hydronephrosis

ROUTINE (within 4 weeks)

- Unilateral ectopic kidney
- Cystic kidney(s) with normal function
- Solitary kidney without hydronephrosis

Management

Uncomplicated unilateral hydronephrosis:

- Repeat renal / bladder ultrasound 7-14 days after birth
- Counsel on UTI prevention, symptoms, testing, antibiotics
- Follow US every 6 months for 2 years, then annually until 6 years old
- Refer to Urology AND Nephrology if:
  - Increasing hydronephrosis (moderate or severe)
  - Urinary tract infection
  - Flank pain
  - Gross hematuria
  - Poor growth, HTN or any other concerns

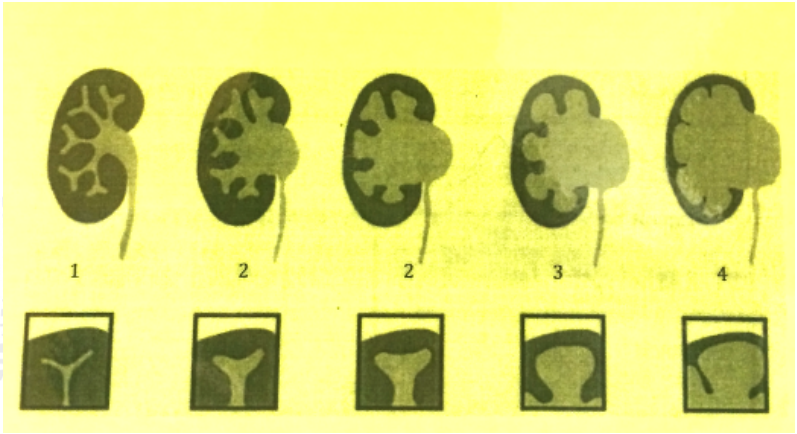
Management

When to pursue imaging?

Grade	Renal pelvis	Renal cortex
0	No splitting	Normal
1	Urine in pelvis barely splits sinus	Normal
2	Urine fills intrarenal pelvis	Normal
2+	Urine fills extrarenal pelvis, major calyces dilated	Normal
3	SFU grade 2 and minor calyces dilated and parenchyma preserved	Normal
4	SFU grade 3 and parenchyma thin	Diminished

Management

VCUG and/or MAG3



Standard Diagnostic Algorithm for Congenital Hydronephrosis

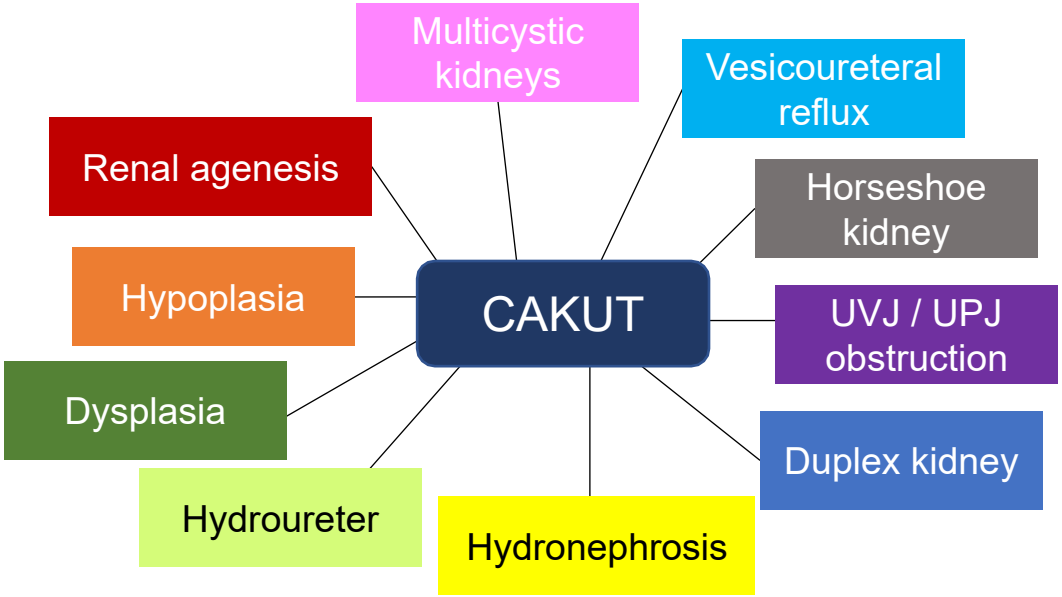
Grade	Study	Initial Visit	6 mos	12 mos	18 mos	24 mos	36 mos
1							
	US	X					
	VCUG	Optional*					
2							
	US	X	X	Optional	Optional		
	VCUG	X					
3							
	US	X	X	X	X	X	X
	VCUG	X					
	Mag-3	X	X	Possible*	Possible	Possible	Possible
4							
	US	X	X	X	X	X	X
	VCUG	X					
	Mag-3	X	X	X	Possible	Possible	Possible

For patients with reduced DRF <35-40 % and obstructive drainage curve, recommend pyeloplasty.
For patients with good DRF ≥40% DRF and either a flat (T-1/2 ≥ 100 minutes) or rising curve, recommend 1 follow-up scan in 6 months.
*Optional: It is up to the treating physician's discretion whether this test is needed.
*Possible: Evaluate sonogram first and obtain MAG-3 lasix only if hydronephrosis is grade 3 or grade 4.

-Pohl 2010

Management

CAKUT



-Choi YH et al, 2016
-Rodriguez M, 2012

Management

Case: Baby L

Labor & Delivery Data:

Maternal Antibiotics in Labor: None

Delivery type: Cesarean

Time of ROM: 6/29/2020 4:14 PM
Time of Delivery: 6/29/2020 9:37 PM

ROM duration: 5h 23m

APGARS: 9 at 1 minute, 9 at 5 minutes

Resuscitation: Tactile Stimulation,

Maternal Temperatures: Temp (72hr
Avg:98.3 °F (36.8 °C), Min:97.8 °F (36
C), Max:98.6 °F (37 °C)
Presentation: Vertex

Fluid color: Clear
Cord: 3 vessels
Cord complications: None
Anesthesia: Epidural

Case: Baby L

Pediatrician: “Anything concerning on your prenatal ultrasound?”

Mom: “They said there was water in the kidneys!”

Maternal problem list: “Abnormal prenatal ultrasound”

☑ Prenatal pelviectasis - Monitor UOP. Per prenatal ultrasound 5/2020 - "KNOWN BILATERAL HYDRONEPHROSIS AND HYDROURETERS ARE VISUALIZED. LT RENAL PELVIS AP DIAMETER MEASURES 1.5 CM; RT RENAL PELVIS DIAMETER MEASURES 1.4 CM"

Renal ultrasound

Radiology:
Us Renal Kidney Bladder Complete

Result Date: DOL 1
1. Severe right greater than left hydroureteronephrosis with debris. Question left-sided cysts versus dilated calyces as well. 2. Bilateral cortical thinning, also right greater than left. 3. Posterior bladder wall thickening. Recommend VCUG for further evaluation. Please also note that the degree of renal dilatation may still be underestimated if the patient is dehydrated and less than birth weight.

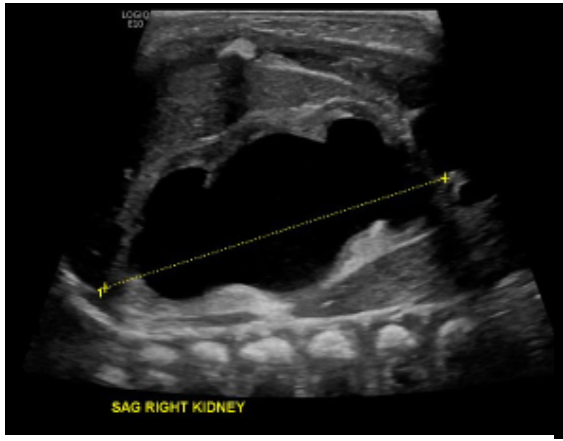
Management

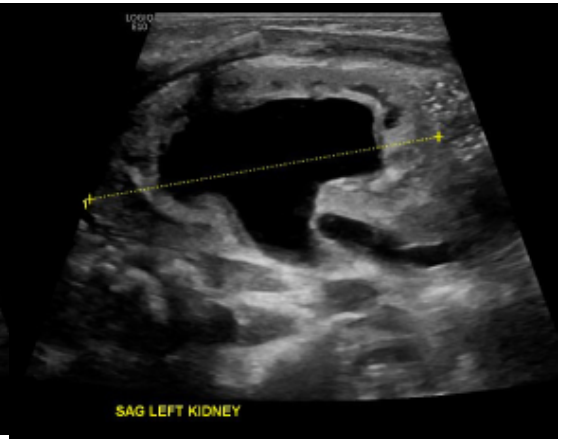
- Severity? (>15 mm APD)
- Bilateral versus unilateral?
- Gestational age?
- Urologic lower tract or upper tract?
- Isolated or syndrome-related?
- If prenatally detected: risk assessment of fetal outcome?

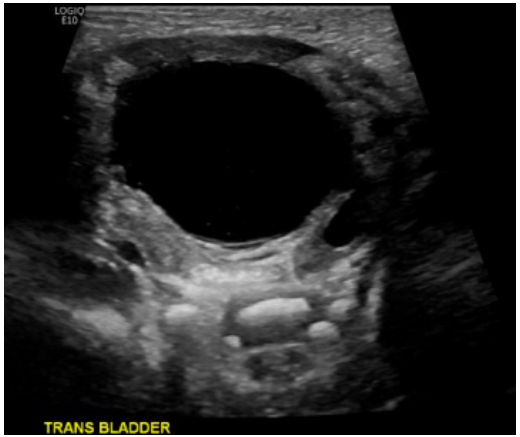
Management

- Obtain RBUS

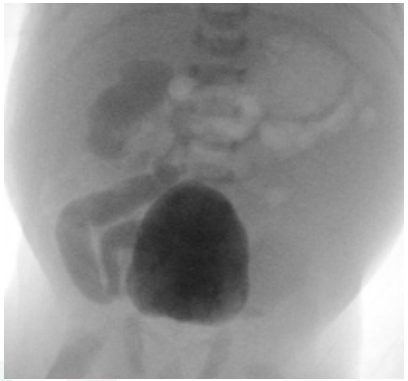
“Water in the kidney”/hydronephrosis







- Counseled parents
- Prophylactic antibiotics
- VCUG -> PUV
- Consulted urology and nephrology



Management

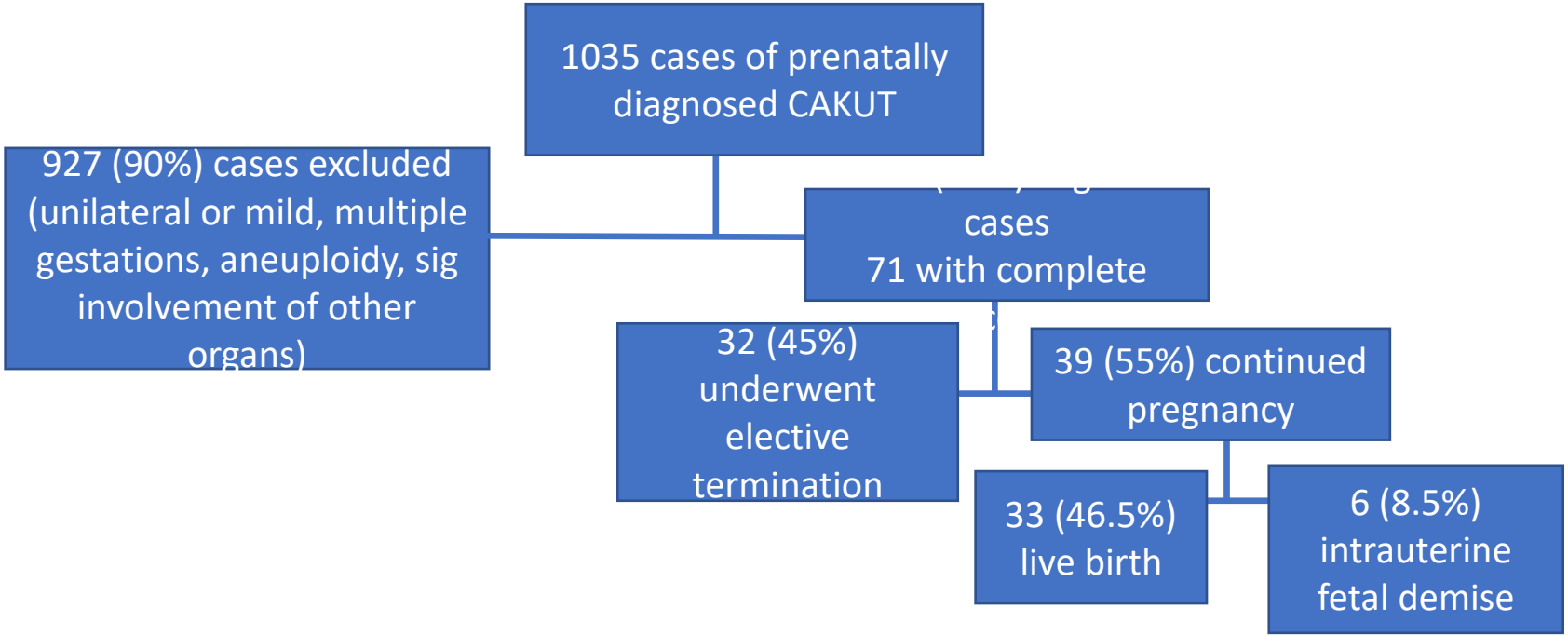
- Begins with prenatal counseling
  - Maternal fetal medicine multidisciplinary team
- Thorough physical exam
- Renal ultrasound postnatally
  - If high risk -> in neonatal period
  - If low risk -> after feeding established
- Consider renal function panel, BP measurement
- Consider genetics

Management

How should we counsel families?

- "Severe" defined as:
  - Bilateral
  - Documented concern for significant renal insufficiency
- Danziger et al: Severe congenital anomalies of the kidney and urinary tract: epidemiology can inform ethical decision-making. *J Perinatology* 2016
- Retrospective cohort study to "improve perinatal counseling and decision-making for families facing such diagnoses"

Study patients and outcomes



-Danziger et al, 2016

Predictors of poor postnatal renal function

- Oligohydramnios
- Renal cortical appearance
- Gestational age <24 weeks

Predictors of survival

- Survivors had better Apgar scores and presence of spontaneous respirations at birth (p=0.02)
- Survivors tended to be older and bigger (NS)
- Cause of death in non-survivors predominantly respiratory failure

Outcomes

Outlook

“If your child has kidney dysplasia in one kidney, their outlook is typically good. The child may have a few health problems, such as increased risk of UTIs, but will mostly likely live a normal life.

“If your child has kidney dysplasia in both kidneys, they may need dialysis and a kidney transplant as well as close monitoring.”

https://www.healthline.com/health/kidney-dysplasia#outlook

Complications and challenges

CAKUT patient follow-up

- More UTIs
- Require more antibiotics
- Had more surgeries
- More subspecialty follow-up
- More imaging
- Often needed more educational support (29 vs 11%) but did not require more neurodevelopmental follow-up
- Risk of progression to ESKD
  - Anemia, growth delay, metabolic bone disease, acidosis, hypertension

-Israel T et al, 2021

Changes you may wish to make in practice

1. Advocate for accurate communication of prenatal imaging and maternal risk factors
2. Consider timing of first antenatal imaging based upon risk factors
3. Communicate with your local pediatric nephrologist or urologist

In a perfect world…

- Comprehensive, accurate, succinct integrated EMR for mother-fetus-baby
- Thorough and accurate prenatal counseling given and absorbed
- Optimal and timely imaging available for newborn
- Perfect flow of accurate information from nursery to pediatrician's office
- Easy access to nephrology/urology if there is a problem

Resources for parents

- Healthychildren.org website
- Partnership between AAP, National Kidney Foundation and American Society of Pediatric Nephrology
- Relevant topics:
  - Posterior urethral valves
  - Children with a single kidney
  - Chronic kidney disease in children
  - Detecting urinary tract infections
  - Genitourinary reconstruction
  - Kidney cysts in infants and children

Summary

- CAKUT represent a common and heterogeneous spectrum of disease
- CAKUT is responsible for a sig proportion of ESRD in children
- Antenatal testing is important in counseling patients but is not perfect in predicting renal outcome
- Pulmonary outcomes at birth remain the most important predictor of survival
- Low risk: Antenatal ultrasound at 7-14 days of life
- High risk: Antenatal ultrasound before discharge +/- antibiotics, consult

References

- Choi YH et al. Ultrasonography of hydronephrosis in the newborn. Ultrasonography 35(3): 198-211, 2016.
- Dos Santos J et al. A New Grading System for the Management of Antenatal Hydronephrosis. Clin J Am Soc Nephrol 10(10):1783-1790, 2015.
- Fryer K, Munoz MC, Rahangdale L, Stuebe AM. Multiparous Black and Latinx Women Face More Barriers to Prenatal Care than White Women. J Racial Ethn Health Disparities. 8(1):80-87, 2021.
- Halima S Janjua, et al. Congenital anomalies of the kidneys, collecting system, bladder and urethra. Peds in Review 40: 619-626, 2019
- Harambat J et al. Epidemiology of chronic kidney disease in children. Pediatr Nephrol 27: 363-373, 2012.
- Israel, T., Tal, W., Pasternak, Y. *et al.* Long-term follow-up of congenital anomalies of the kidney and urinary tract diagnosed in utero: a longitudinal study. *J Nephrol,* 2021.
- Janjua HS et al. Congenital anomalies of the kidneys, collecting system, bladder and urethra. Peds in Review 40(12): 619-626, 2019.
- Kirkpatrick JJ, Leslie SW. Horseshoe Kidney. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing, 2021.
- Editor(s): Melissa H. Little, Kidney Development, Disease, Repair and Regeneration, Academic Press, 2016.
- Morris RK et al. Antenatal ultrasound to predict postnatal renal function in congenital lower urinary tract obstruction: systematic review of test accuracy. BJOG 116(10): 1290-9.
- Morris RK et al. Systematic review of accuracy of fetal urine analysis to predict poor postnatal renal function in cases of congenital urinary tract obstruction. Prenat Diagn 27(10): 900-11, 2007.
- Murugapoopathy V et al. A primer on congenital anomalies of the kidney and urinary tracts (CAKUT). CJASN 15: 723–731, 2020.

References

- Parekh N, Jarlenski M, Kelley D. Prenatal and Postpartum Care Disparities in a Large Medicaid Program. Matern Child Health J. 2018 Mar;22(3):429-437.
- Potter EL: Normal and abnormal development of the kidney, Chicago, IL, Year Book Medical Publishers, 1972.
- Queisser-Luft A et al. Malformations in newborn: results based on 30,940 infants and fetuses from the Mainz congenital birth defect monitoring system (1990-1998). Arch Gynecol Obstet 266(3): 163-7, 2002.
- Onen A. An alternative grading system to refine the criteria for severity of hydronephrosis and optimal treatment guidelines in neonates with primary UPJ-type hydronephrosis. *Journal of Pediatric Urology,* 2007
- Quirino IG et al. Clinical course of 822 children with prenatally detected nephrouropathies. Clin J Am Soc Nephrol 7: 444-451, 2012.
- Rad N et al. Cellular and molecular mechanisms of kidney development: From the embryo to the kidney organoid. Front. Cell Dev. Biol. 8:183, 2020.
- Rodriguez M. Congenital Anomalies of the Kidney and Urinary Tract (CAKUT). Fetal and Pediatric Pathology 22: 293-320, 2012.
- Vize PD, Woolf AS, Bard JBL, editors: The Kidney: From Normal Development to Congenital Disease, Cambridge, MA, Academic Press, 2003
- Wang Y, Liao R, Feng XL. Equity in Essential Maternal, Newborn, and Child Health Interventions in Northeastern China, 2008 to 2018. Front Public Health. 2020
- Walker KA et al. Kidney development: core curriculum. Am J Kidney Dis. 57(6): 948-58, 2011

Thank you!

My colleagues in neonatology, newborn nursery, OB/gyn, MFM, urology, radiology, gen peds, and nephrology: Dr. Margot Ahronovich, Dr. Karen Bodnar, Dr. Tracy Seo, Dr. Dana Block-Abraham, Dr. Hans Pohl, Dr. Nakul Jerath, Dr. Rasheda Amin, Dr. Davoud Mohtat, and Dr. Randala Lakkis

AAP experience OCTOBER 8–12, 2021
AAPEXPERIENCE.ORG | #AAP2021

1789 GEORGETOWN UNIVERSITY School of Medicine

UVA MEDICINE INOVA CAMPUS

Pediatric Specialists of Virginia

Children's National INOVA