ULTRASOUND OF THE FETAL GENITOURINARY TRACT

Jude P. Crino, M.D.

JOHNS HOPKINS MEDICINE
JOHNS HOPKINS HEALTH SYSTEM

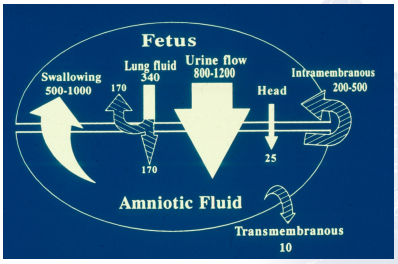
RENAL DEVELOPMENT
Nephron formation

- Pronephros (3rd-5th week)
  - nonfunctional
- Mesonephros (5th-12th week)
  - able to form urine
  - renin production
- Metanephros
  - final stage
  - mature metanephric kidney

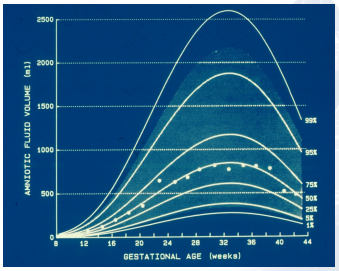
RENAL DEVELOPMENT
Metanephros

- Tubular function begins 9th-12th week
- Functional loop of Henle by 14th week
  - –tubular reabsorption
- New nephron formation through 36 wks

AMNIOTIC FLUID DYNAMICS
Determinants of AFV



AMNIOTIC FLUID DYNAMICS
normal amniotic fluid volume



NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys

- Visualization - transvaginal
  - earliest 9 weeks
  - 100% by 13 weeks
- Visualization - transabdominal
  - earliest 13-14 weeks
  - most patients by 16-18 weeks

NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys

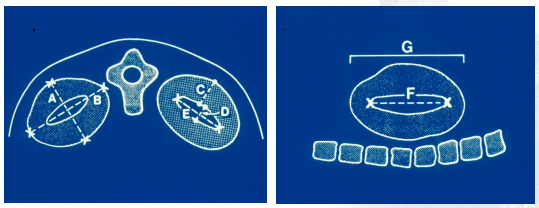
- Paraspinous
- Circular/ elliptical shape
- Hypoechoic
- Echogenic rim more prominent with advancing GA

NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys

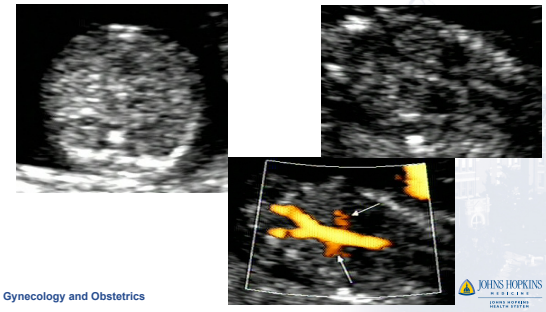
- Renal pelvis
  - slit-like, central, anechoic
- Medullae
  - hypoechoic
  - arranged in A-P orientation around pelvis
- Cortex
  - echogenicity similar to surrounding tissues

NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys

measurements

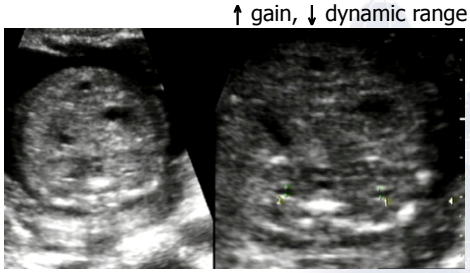


NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys – 13 weeks



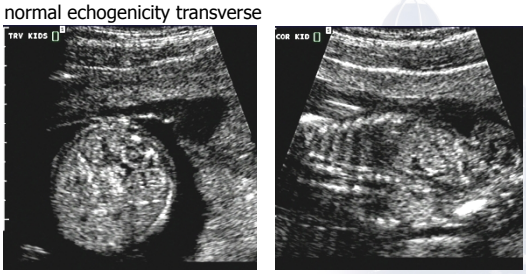
NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys – 18 weeks

↑ gain, ↓ dynamic range



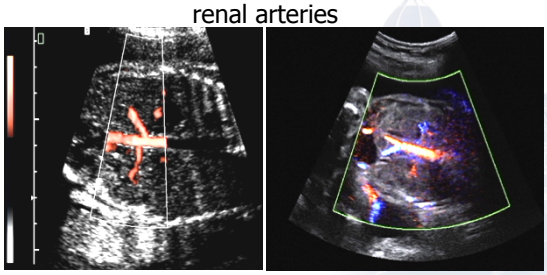
NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys – 18 weeks

normal echogenicity transverse



NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys – 18 weeks

renal arteries



NORMAL SONOGRAPHIC ANATOMY
Fetal Kidneys – 36 weeks

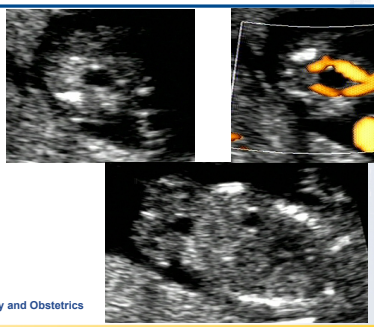
NORMAL SONOGRAPHIC ANATOMY
Fetal Bladder

- Visualization
  - earliest 10-12 wks (TA or TV)
  - almost 100% by 16 wks (TA)
- Appearance
  - rectangular, anechoic
  - thin wall

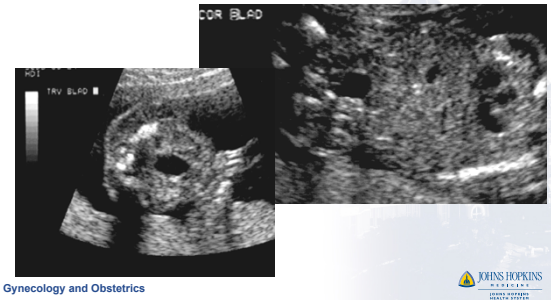
NORMAL SONOGRAPHIC ANATOMY
Fetal Bladder

- Level of iliac crest in transverse
- Int iliac arteries along lateral walls
  - can aid in identification
- Variation in volume
  - filling - emptying cycle 20-30 min

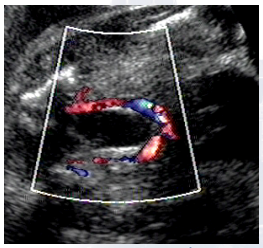
NORMAL SONOGRAPHIC ANATOMY
Fetal Bladder – 13 weeks



NORMAL SONOGRAPHIC ANATOMY
Fetal Bladder – 18 weeks



NORMAL SONOGRAPHIC ANATOMY
Fetal Bladder – 30 weeks



NORMAL SONOGRAPHIC ANATOMY
Fetal Genitalia

- Visualization GA, position dependent
- Must distinguish labia from scrotum
  - testicles descend 28-34 weeks
  - testicles in scrotum 100% reliable
- ID of penis provides further evidence
- Pitfalls: prominent clitoris, small penis, undescended testicles

FIRST TRIMESTER GENITALIA

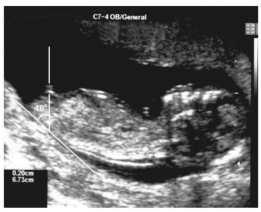


Figure 1 Male gender was assigned sonographically if the angle of the genital tubercle to a horizontal line through the lumbosacral skin surface was > 30°.

Figure 2 Female gender was assigned sonographically if the genital tubercle was parallel or convergent (< 10°) to a horizontal line through the lumbosacral skin surface.

 Ultrasound Obstet Gynecol 2006;27:619

FIRST TRIMESTER GENITALIA

Table 1 Gender identification according to crown–rump length (CRL)

Gestational age (weeks)	*CRL (mm)*	*Patients (n)*	*Gender identified by ultrasound (n (%))*	*Known gender at birth (n)*	*Lost to follow-up (n)*
12 to 12 + 3	55.4–62.5	180	153 (85)	135	18
12 + 4 to 12 + 6	62.6–67.9	218	209 (96)	194	15
13 to 13 + 6	68.0–83.9	258	251 (97)	226	25
Total		656	613 (92.6)	555	58

 Ultrasound Obstet Gynecol 2006;27:619

FIRST TRIMESTER GENITALIA

Table 2 Accuracy of sonographic determination of fetal gender

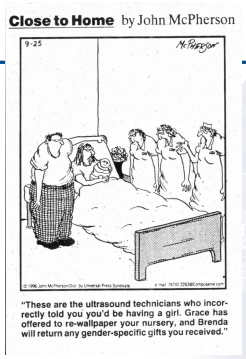
		Sonographically assigned male		*Sonographically assigned female*	
Gestational age (weeks)	*CRL (mm)*	*Male at birth (n (%))*	*Female at birth (n (%))*	*Female at birth (n (%))*	*Male at birth (n (%))*
12 to 12 + 3	55.4–62.5	64/64 (100)	0/64	65/71 (91.5)	6/71 (8.5)
12 + 4 to 12 + 6	62.6–67.9	105/106 (99)	1/106 (1)*	87/88 (99)	1/88 (1)†
13 to 13 + 6	68.0–83.9	113/113 (100)	0/113	113/113 (100)	0/113
Total		282/283 (99.6)	1/283 (0.4)	265/272 (97.4)	7/272 (2.6)

*CRL of the fetus was 63.5 mm. †CRL of the fetus was 62.6 mm.

 Ultrasound Obstet Gynecol 2006;27:619

FIRST TRIMESTER GENITALIA

MALE FEMALE



SECOND/THIRD TRIMESTER GENITALIA

MALE

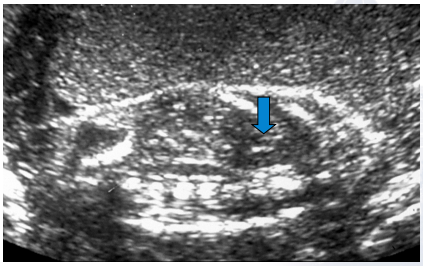
FEMALE

HYDROCELE

URINARY TRACT ABNORMALITIES Classification

- Severe hypoplasia/ agenesis
- Ectopia
- Dilatation/ obstructive uropathy
  - UPJ obstruction
  - UVJ obstruction
  - bladder outlet obstruction
- Renal cystic disease
  - cystic dysplasia
  - multicystic dysplastic kidney disease
  - polycystic kidney disease
  - syndromes with cysts
- Tumors
- Abnormal genitalia

BILATERAL RENAL AGENESIS



BILATERAL RENAL AGENESIS

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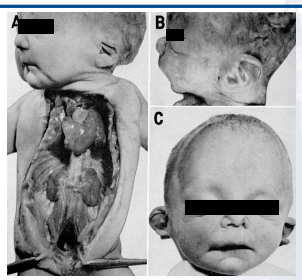
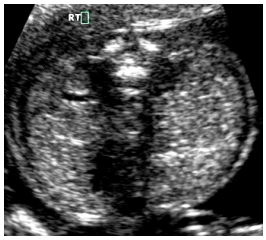
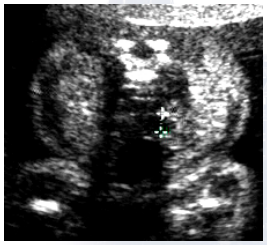


Potter, Pathology of the Fetus and the Newborn, 1952

PELVIC KIDNEY





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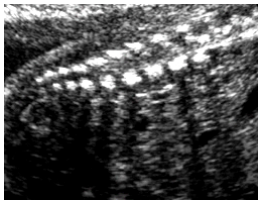

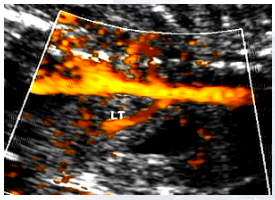

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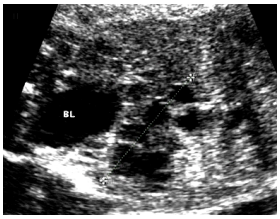
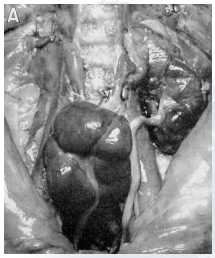
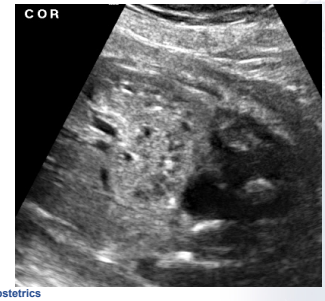




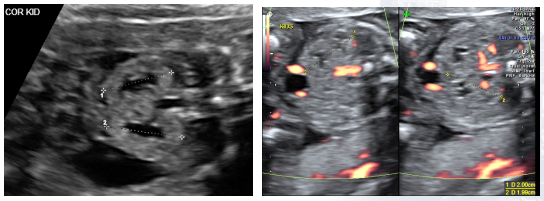
Potter, Pathology of the Fetus and the Newborn, 1952

CROSSED FUSED ECTOPIA

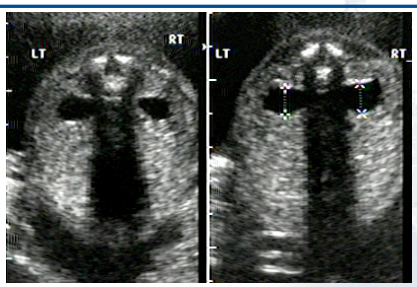
CROSSED FUSED ECTOPIA



HORSESHOE KIDNEY



URINARY TRACT DILATION



Urinary Tract Dilation Consensus Meeting

- March 14-15, 2014 in Linthicum, MD (AUA Headquarters)
- Participants:
  - 1 director and 12 panelists
  - Audience consisting of clinicians and researchers from the various specialties
  - Webinar for those not able to attend
- Format:
  - 1st day: current literature was reviewed and discussed
  - Evening: Panelists drafted a consensus statement
  - 2nd day: Statement presented to audience and discussed until the entire group arrived at consensus

J Pediatr Urol 2014;10:982

Participants

Prenatal

- Society for Maternal - Fetal Medicine
  - Anthony Odibo
  - Jude Crino
- American Institute of Ultrasound in Medicine
  - Bryann Bromley
- American College of Radiology
  - Beverly Coleman
- Society of Radiologists in Ultrasounds
  - Carol Benson

Postnatal

- Society for Fetal Urology and Society for Pediatric Urology
  - Anthony Herndon
  - Jeffrey Campbell
  - Christopher Cooper
- Society for Pediatric Radiology
  - Jeannie Chow
  - Kassa Darge
- American Society of Pediatric Nephrology
  - Michael Somers
  - Deborah Stein

J Pediatr Urol 2014;10:982

Goals of the UTD Classification System

- To propose a unified description of UT dilation that can be applied pre- and postnatally.
  - Simple but detailed enough to be meaningful for both clinical use and future research endeavors.
  - Allow for communication of information between specialists, providing consistent terminology.
- To propose standardized schema for the perinatal evaluation of these patients based on sonographic criteria
  - Intended to be a starting point for observation and study
  - Will be modified over time based on the accumulated evidence.

J Pediatr Urol 2014;10:982

Recommendation # 1: Terminology

- Discourage the use of non-specific terms in describing UT dilation (e.g. hydronephrosis, pyelectasis, pelviectasis, uronephrosis, UT fullness or prominence, pelvic fullness)
- Suggest the consistent use of the term " UT dilation"
- Further determination of the severity of UT dilation is characterized by specific sonographic findings, delineated by the UTD Classification System

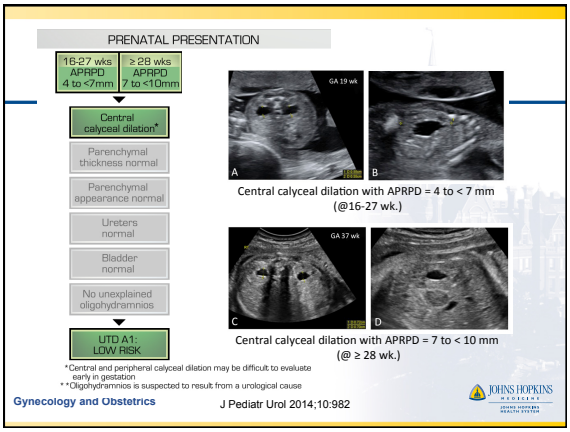
J Pediatr Urol 2014;10:982

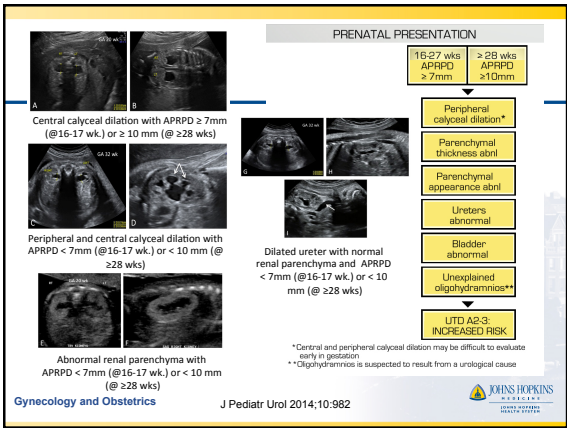
Recommendation #3: Defining Normal

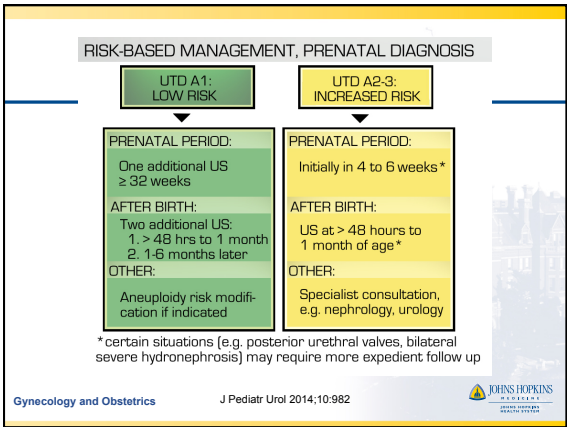
Ultrasound Findings	Time at Presentation		
	16-27[6]w	≥ 28w	Postnatal (> 48h)
Anterior posterior diameter	< 4mm	< 7mm	< 10mm
Calyceal dilation			
Central	No	No	No
Peripheral	No	No	No
Parenchymal thickness	Normal	Normal	Normal
Parenchymal appearance	Normal	Normal	Normal
Ureter (s)	Normal	Normal	Normal
Bladder	Normal	Normal	Normal
Oligohydramnios	No	No	NA

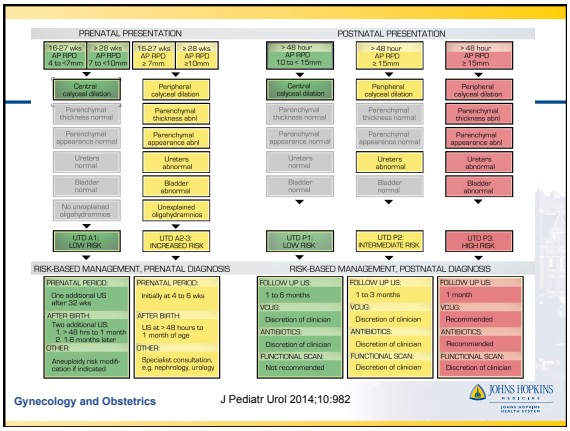
Recommendation #3: Stratification of Risk

- Risk of what ???
  - Defined as the presence of postnatal urological pathology
- Further research will be needed to correlate risk stratification to clinical outcomes (UTI, pain, stone, need surgery, renal function, urological pathologies)
- Propose follow up recommendation based on risk stratification









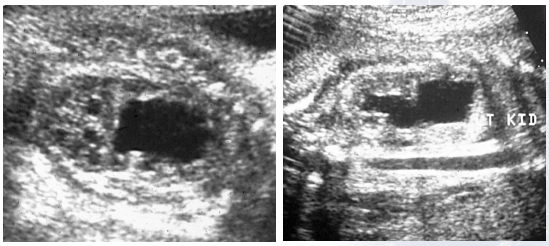
CAUSES OF URINE FLOW IMPAIRMENT

- UPJ anomaly
- UVJ anomaly
- Post urethral valves
- Duplex systems
- Ureterocele/ ectopic ureter
- Urethral atresia
- Cloacal anomaly
- Vesicoureteral reflux
- Megaureter
- Megacystis microcolon hypoperistalsis synd

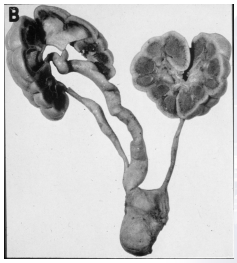
CAUSES OF URINE FLOW IMPAIRMENT

- Sacrococcygeal teratoma
- Hydrometacolpos
- Other pelvic masses

DUPLEX SYSTEM

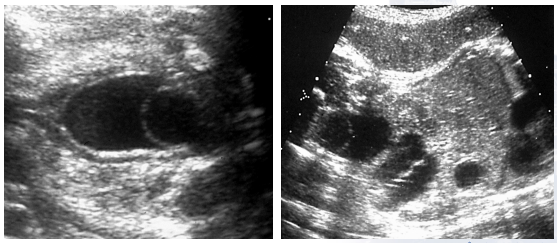


DUPLEX SYSTEM



Potter, Pathology of the Fetus and the Newborn, 1952

URETEROCELE



OBSTRUCTIVE UROPATHY Prognostic Factors

- Site of obstruction
- Degree of dilatation
- Cortical appearance
- Amniotic fluid volume
- Associated anomalies
- Urine biochemistry

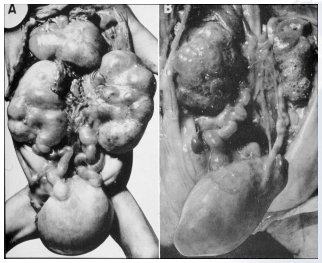
OBSTRUCTIVE UROPATHY
Evaluation & Management

- Look for associated anomalies
- Offer karyotype
- Patient counseling
- Pediatric subspecialty consultation
- If urethral level obstruction (LUTO):
  - consider urine biochemistry
  - consider vesicoamniotic shunt

LUTO – SONOGRAPHIC FINDINGS

- Urinary tract dilation
  - renal pelves ≥ 10 mm
- Hydroureter
- Dilated bladder
  - thick wall
  - "keyhole sign"
- ± signs of renal dysplasia

LUTO – PATHOLOGIC FINDINGS



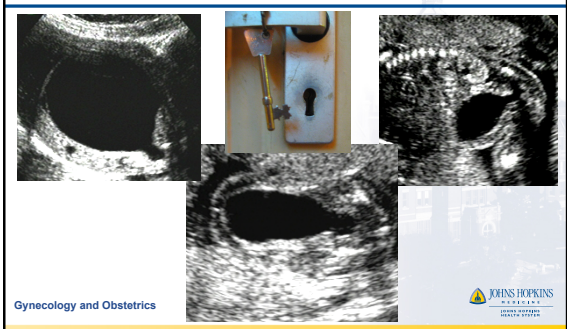
Potter, Pathology of the Fetus and the Newborn, 1952

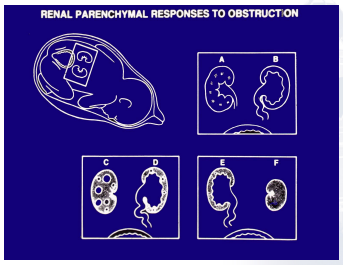
LUTO – PATHOLOGIC FINDINGS

Potter, Pathology of the Fetus and the Newborn, 1952

HYDROURETER

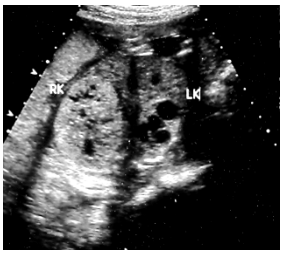
LUTO – "KEYHOLE" BLADDER

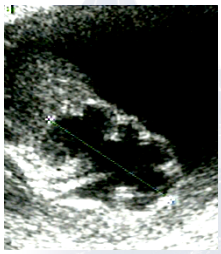




Nyberg, Diagnostic Imaging of Fetal Anomalies

LUTO – RENAL FINDINGS



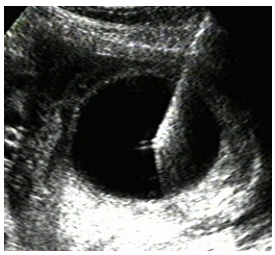


LUTO – URINE ASCITES WITH THICK-WALLED BLADDER

LUTO – EVALUATION

- Karyotype
  - amniotic fluid, fetal urine, fetal blood, chorionic villi
- Detailed sonography
- Serial urine testing
  - sodium, chloride, calcium, osmolality, total protein, β-2 microglobulin
  - at least 3 samplings 48-72 hrs apart

LUTO – BLADDER ASPIRATION



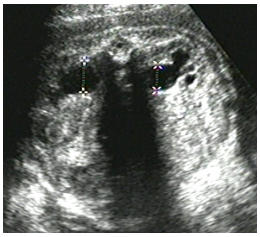
LUTO URINE VALUE THRESHOLDS

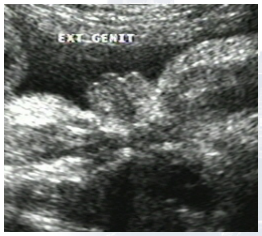
- Sodium < 100 mmol/L
- Chloride < 90 mmol/L
- Osmolality < 200 mOsm/L
- Calcium < 8 mg/dL
- ß-2 microglobulin < 6 mg/dL
- Total protein < 20 mg/dL

OBSTRUCTIVE UROPATHY
Criteria for in utero Rx

- Lower urinary tract obstruction (LUTO)
- Normal male karyotype
- Oligohydramnios or ↓ AFV
- No other significant anomaly
- Improving fetal urine values

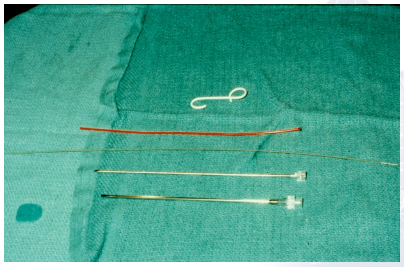
LUTO – CRITERIA FOR IN UTERO Rx
NORMAL MALE KARYOTYPE



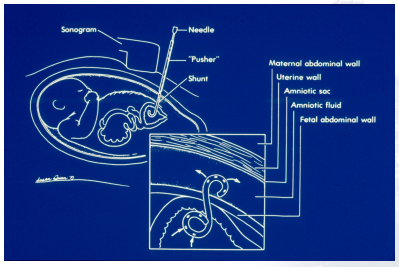


LUTO – CRITERIA FOR IN UTERO Rx
NORMAL MALE KARYOTYPE

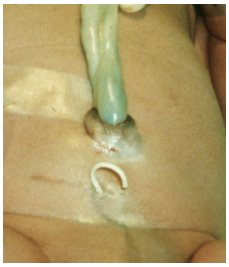
VESICOAMNIOTIC SHUNTING
IN FETAL LUTO: TECHNIQUE



VESICOAMNIOTIC SHUNTING
IN FETAL LUTO: TECHNIQUE



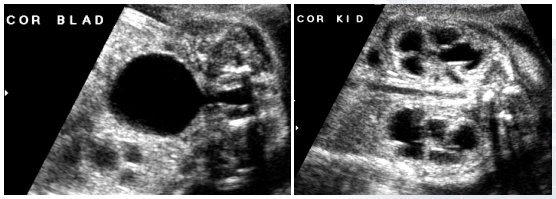
VESICOAMNIOTIC SHUNTING
IN FETAL LUTO: TECHNIQUE



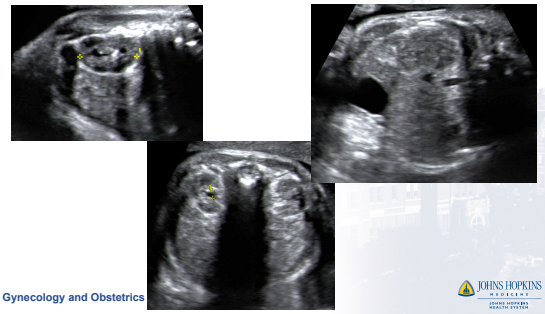
VESICOAMNIOTIC SHUNTING IN FETAL LUTO: PROBLEM AREAS

- Natural history is highly variable
- Limited accuracy of antenatal assessment of prognostic factors:
  - etiology
  - renal function
- Procedure related complications
- Poor quality of available evidence of efficacy

LUTO: CLINICAL EXAMPLE



LUTO: CLINICAL EXAMPLE



LUTO: IS A STENT JUSTIFIED?

- YES, with the following caveats:
  - antenatal assessment must be systematic and complete
  - patients must be thoroughly counseled and informed of both short term and long term outcomes
  - ideally should be included in a clinical trial or registry

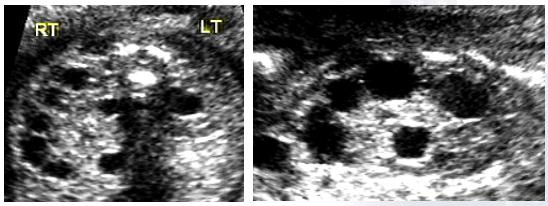
MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

- Complete proximal obstruction or atresia before 10 weeks
- Sonographic appearance
  - enlarged kidney, irregular contour
  - multiple cysts, various sizes
  - no communication between cysts

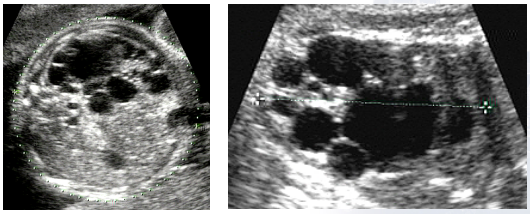
MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

- Dysplastic kidney nonfunctional
- May diminish in size or disappear
- 40% contralateral abnormality
  - UPJ most common
- Prognosis
  - good if unilat, other kidney nml
  - fatal if bilateral

MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

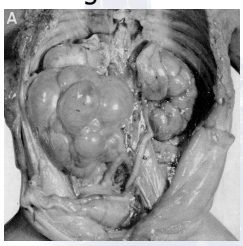


MULTICYSTIC DYSPLASTIC KIDNEY DISEASE



MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

Pathologic findings



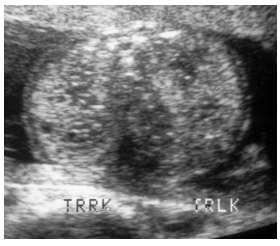
 Potter, Pathology of the Fetus and the Newborn, 1952

POLYCYSTIC KIDNEY DISEASE

- Autosomal recessive (infantile)
  - usually evident *in utero*
  - symmetrically enlarged, echogenic appearance
  - presentation depends on fraction of renal tubules affected
  - hepatic fibrosis inversely proportional to renal involvement

POLYCYSTIC KIDNEY DISEASE

autosomal recessive

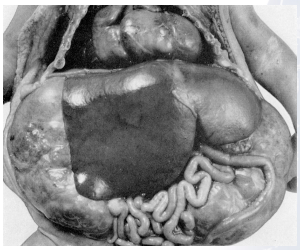


POLYCYSTIC KIDNEY DISEASE

autosomal recessive

POLYCYSTIC KIDNEY DISEASE

autosomal recessive



Potter, Pathology of the Fetus and the Newborn, 1952

POLYCYSTIC KIDNEY DISEASE

- Autosomal dominant (adult onset)
  - commonly presents in young adults
  - occasionally seen *in utero*
  - enlarged, echogenic kidneys, ± cysts
  - family history crucial

AMBIGUOUS GENITALIA

- Genitalia not typical for male or female
  - Cannot differentiate penis from clitoris
  - Cannot differentiate scrotum from labia
    - Empty scrotum resembles labia
    - Fused labia resemble scrotum
- Secondary structures rarely seen in fetus
  - Uterus, ovaries, undescended testes

AMBIGUOUS GENITALIA MORPHOLOGY

- Male
  - Hypospadias / epispadias
  - Microphallus
  - Chordee (ventral curvature of penis)
  - Cryptorchidism (undescended testes)
- Female
  - Clitoromegaly
  - Prominent or fused labia

AMBIGUOUS GENITALIA ETIOLOGY

- Congenital adrenal hyperplasia (CAH)
  - Treatable
- Female pseudohermaphrodism
  - 46,XX, fetal or maternal androgen source
- Androgen insensitivity syndrome
  - 46,XY, ↓ end organ testosterone effect
  - Complete – female external genitalia
  - Incomplete – ambiguous genitalia

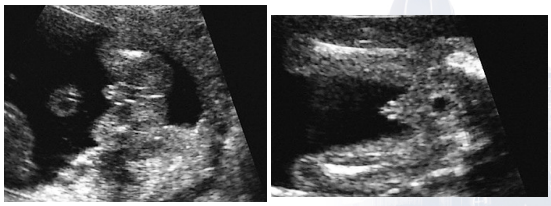
AMBIGUOUS GENITALIA ETIOLOGY

- Mixed gonadal dysgenesis
  - 45,X/46,XY
- Pure gonadal dysgenesis
  - Variable karyotype
- True hermaphrodism
- Aneuploidy
- Duplication and deletion syndromes

AMBIGUOUS GENITALIA EVALUATION

- Determine genetic sex
  - cfDNA, amniocentesis
- Evaluate for aneuploidy, duplication and deletion syndromes
  - Karyotype, microarray
- Evaluate for CAH if virilized female
  - Molecular genetics, amniotic fluid 17 OHP
  - Maternal dexamethasone if affected female

AMBIGUOUS GENITALIA



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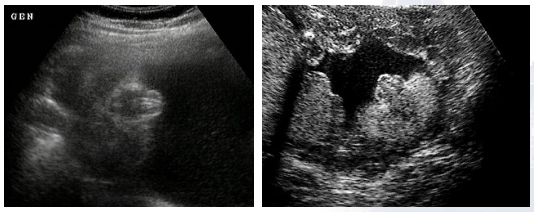
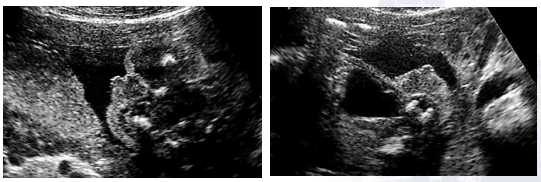


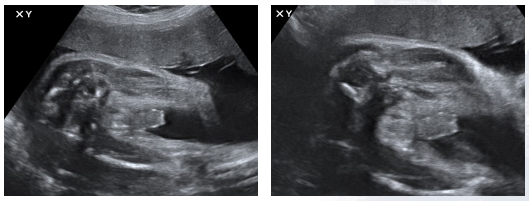
AMBIGUOUS GENITALIA



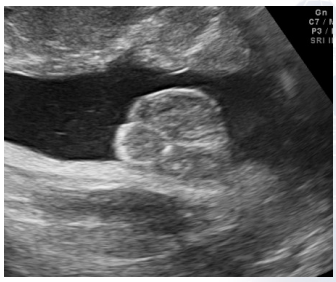
HYPOSPADIAS

- Urethral orifice on ventral side of penis
  - 50% anterior near glans
  - 30% middle
  - 20% posterior
- Blunt ended or bulbous penis
- “Tulip” sign – small penis between scrotal folds
- Other urogenital anomalies in 40%

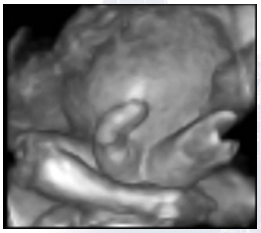
HYPOSPADIAS



HYPOSPADIAS



MEGALOURETHRA



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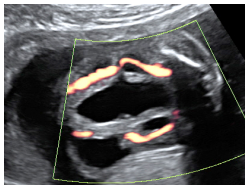
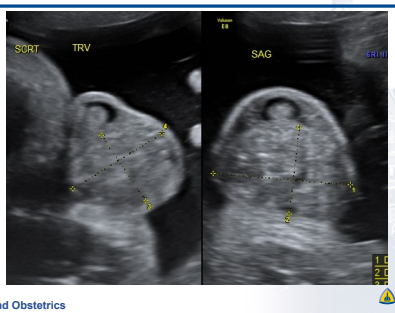


SCROTAL MASS

- Inguinal hernia
  - Indirect (bowel passes into scrotum through processus vaginalis)
  - Echogenic mass separate from testis
    - May see peristalsis – pathognomonic
- Testicular torsion
  - Variable echotexture, size, shape of testis
- Tumor (rare)

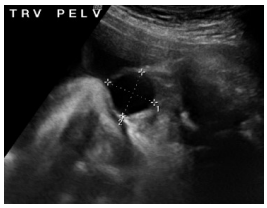
INGUINAL HERNIA

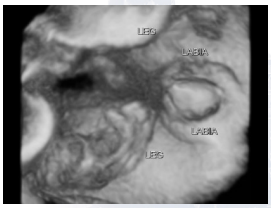


HYDROCOLPOS

- Vaginal obstruction
- Distension of vagina with secretions
- Unilocular retrovesicular cystic mass funneling to perineum
- Look for evidence of cloacal anomaly

HYDROCOLPOS

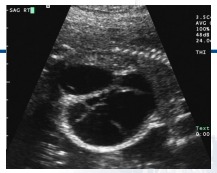




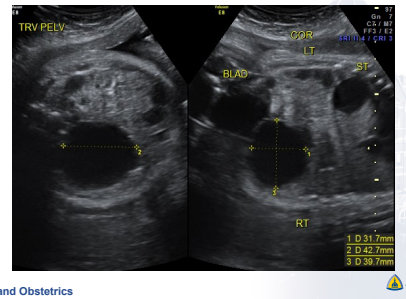
OVARIAN CYST

- Fetal ovarian response to maternal hormones
- Abdominal cyst in female fetus
  - Usually in lower abdomen / pelvis
  - Variable in size
  - May be simple, complex, septate
- GI and urinary tracts normal
- May resolve spontaneously
- Hemorrhage, torsion may occur

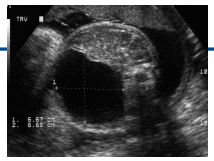
OVARIAN CYST

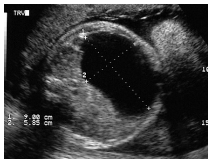


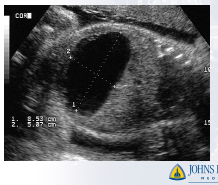
OVARIAN CYST



OVARIAN CYST





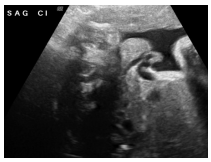


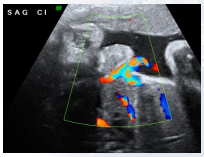
BLADDER EXSTROPHY

- Lower abdominal wall defect
- Exposed bladder
  - Soft tissue mass – posterior bladder wall
- Abdominal cord insertion at superior margin of exposed bladder
- Wide iliac wing angle, separated pubic symphysis
- Abnormal genitalia
  - Bifid penis, separated labia

BLADDER EXSTROPHY







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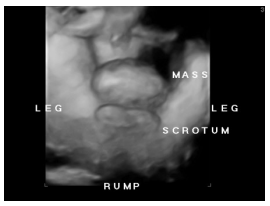

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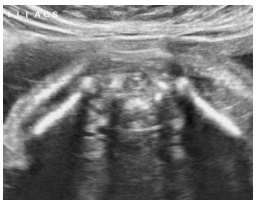


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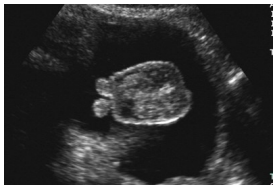
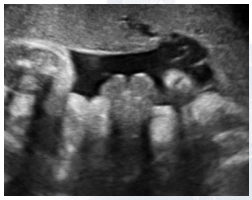
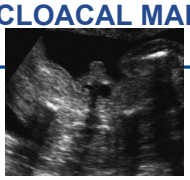
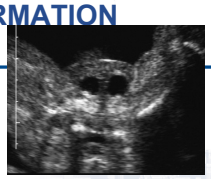
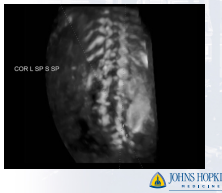



CLOACAL MALFORMATION

- Complex malformation – failure of cloacal division
- Spectrum of abnormal anatomy
- Septated retrovesicular mass with fluid-fluid level
- Genitourinary, bowel, spine anomalies common

CLOACAL MALFORMATION



PROTOCOL FOR GENITOURINARY ANOMALIES

- Genitourinary system evaluation
  - measure renal pelves, renal lengths
  - assess renal appearance (contour, echogenicity, cysts)
  - demonstrate renal artery blood flow (color or power Doppler), consider pulsed Doppler study
  - image bladder in transverse and coronal/ sagittal planes, measure bladder volume and/ or wall thickness if appropriate

PROTOCOL FOR GENITOURINARY ANOMALIES

- Genitourinary system evaluation (cont'd)
  - look for ureteral dilatation
  - if kidneys or bladder are enlarged, measure fetal abdominal circumference at maximum level in addition to standard level
- Evaluate amniotic fluid volume
- Complete anatomic survey
- Fetal echocardiography
- Consultation as appropriate (genetic counseling, pediatric urology, neonatology)

THANK YOU

JOHNS HOPKINS MEDICINE
JOHNS HOPKINS HEALTH SYSTEM