2018 ANNUAL MEETING
FRIDAY HANDOUTS:
ULTRASOUND 101
Introduction to Obstetric Ultrasound
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Maternal-Fetal Medicine
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Disclosures
• None

Objectives
• Discuss ultrasound background
• Review specific knobology
• Review the Alara principle, Mechanical and Thermal index and why they are important
• Discuss differences in probes
• Review how to optimize images
Background

• Ultrasound is the frequency of sound >20 KHz, which cannot be heard by humans (i.e. ultrasonic)
• Typical frequencies used in Ob/Gyn are between 3 and 10 MHz
• Audible sound is between 20 Hz and 20 KHz

Background

• Ultrasound waves are generated from tiny piezoelectric crystals which are packed into the ultrasound transducer.
• The crystals transform electric into mechanical energy (ultrasound) and vice versa
  • Returning ultrasound (mechanical energy) beams from the body are converted back into electric currents
• Gel is used to facilitate the transfer of sound from the transducer to the skin
  • Couples the transducer to the skin and permits the sound to go back and forth

Background

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Image generation

• An image is created by sending multiple pulses from the transducer at slightly different directions and analyzing the returning echoes received into a gray scale format
  • Tissues that are strong reflectors of the US beam (bone or air) produce strong electric current -> image appears hyperechoic
  • Weak tissue reflectors (fluid or soft tissue) result in weaker currents -> image appears hypoechoic or anechoic
• Since the US beam travels longitudinally, keeping the angle of incidence of the US beam perpendicular to the object of interest will produce the best quality image

Types of ultrasound modes

• A-mode (historic)
  • Amplitude mode
• B-mode
  • Brightness mode
  • 2-D imaging
  • Grey scale
  • Image is created based upon the intensity of the returning US beam which is reflected in variations in shades of grey that form the image
• M-mode
  • Motion mode
  • Originates from a single beam penetrating the body with a high pulse repetition frequency
  • Time is displayed on the image on the x-axis and depth on the y-axis
  • Used to assess motion of the fetal heart, evaluate arrhythmias, viability, etc.
Cont’d

• Spectral (pulsed) Doppler
  • Ultrasound with a specific frequency is used to insonate a certain blood vessel; the reflected frequency is directly proportional to the speed with which the rbcs are moving (velocity)
  • Frequency shift is highest during systole when the blood flow is fastest, and lowest during end diastole, when the blood flow is slowest
  • Frequency shift is also dependent on the cosine of the angle that the US beam makes with the targeted blood vessel
  • Utilizing the ratio of frequency shift, the Doppler indices are independent of the effects of the insonating angle of the US beam (such as s/d ratio of the umbilical artery)
  • Angle of insonation is more important in Doppler studies when a PSV is required, such as when MCA Dopplers are used to determine risk for fetal anemia
Cont’d

• Color Doppler
  • Color flow is superimposed on the B-mode image
  • Used to detect presence of vascular flow within the tissue being investigated
  • Flow towards the transducer is red and flow away from the transducer is blue

• Power Doppler
  • Sensitive mode of Doppler, helpful in detection of low velocity flow
  • Less affected by angle of insonation

Color Doppler

Vasa previa at 29 weeks with Doppler demonstrating FHR

Doppler Angle/Angle of Insonation

• Estimated by a process known as angle correction
  • Involves aligning an indicator on the duplex image along the longitudinal axis of the vessel
  • “Doppler effect”
    • The cosine of 90° is zero, so if the US beam is perpendicular to the direction of blood flow, there will be no Doppler shift and it will appear as if there is no flow in the vessel
    • Angle should be 60° or less; if the angle is >60°, there will be greater errors in angle correction since the cosine function has a steeper curve above this angle
Angle of Insonation

Ultrasound Safety

“Just for fun, do you want me to Photoshop in a few more before your husband gets here?”
Bioeffects of ultrasound

- Ultrasound is a form of mechanical energy
- Mode affects the output
  - B-mode has the lowest energy
  - Pulsed Doppler has the highest energy
- 2 indices used to measure the bioeffects of ultrasound
  - Thermal index (TI)
  - Mechanical index (MI)

Thermal index

- A measure of the absorption of the ultrasound wave’s energy by soft tissue and bone and its conversion to heat
- At TI of 1 means an increase in temperature of 1°C
- Reported in 3 forms:
  - TIS – Thermal index Soft tissue (should be used <10 wks)
  - TIB – Thermal index Bone (should be used ≥ 10 wks when bone ossification is evident)
  - TIC – Thermal index Cranial

Mechanical index

- Estimates the cavitation effect of ultrasound, which results from the interaction of sound waves with microscopic, stabilized gas bubbles in the tissues
- Concern for disruption of cell membranes
- Not likely to be relevant in obstetric imaging because of the relative absence of gas bubbles (air) in the fetus (Salvesen et al., 2011)
ALARA principle

- **As Low As Reasonably Achievable**

- Minimize use of Doppler in first trimester
- Use M-mode instead of spectral Doppler to document embryonic/fetal HR
- Keep track of the TI and MI values on the US screen (Output Display Standard)
  - Keep TI below 1 and MI below 1 or obstetrical ultrasound imaging

**ALARA Principle**

- Minimize risk
- Minimize exposure
- Use only when indicated
- Minimize exposure time
- Minimize exposure intensity
Ultrasound controls and Image Optimization
Transducer

- Frequency varies resolution and penetration
- Higher frequency transducers
  - Limited penetration
  - Better resolution
  - Good for superficial structures
- Lower frequency transducers
  - Better penetration for deeper structures
  - Worse resolution

Power

- Power output determines the strength of the pulse that is transmitted
- When the pulse is stronger, the returning echoes are stronger and the resulting image is brighter
- Higher power levels also produce sound pulses that will penetrate deeper
- Power output may be increased when sound attenuation limits penetration, even after adjusting for gain and transducer frequency
- But… changing power output will change the thermal and mechanical index
**Depth**

- Allows you to increase or decrease the depth of field
- Allows you to maximize the area of interest on your monitor

**Gain**

- Measure of the strength of the ultrasound signal
- Gain amplifies all signals by a constant factor, regardless of the depth, thereby increasing the overall brightness of the image
Gain

Time Gain Compensation

- Allows adjustment of brightness at a specific depth of the image
- Goal is to make the entire image look evenly "lit" from top to bottom
- In TA imaging, upper field gain knobs should be kept slightly to the left than lower field ones
  - Eye of the operator can focus on the deeper part of the screen where the area of interest is
- In TV imaging, opposite is true
- This is increasingly being automated on newer machines
Focal zone

• Varies the depth of the maximum beam focusing
• Should be placed at the level of interest on the ultrasound image in order to ensure best lateral resolution

• Usually indicated at the side of the image with an arrowhead
Field of view

• Field of view of a real-time image can be divided into depth and width
  • varies image size
• Trade off in altering depth or width is reduced frame rate

Freeze

• Allows the image to be frozen on the screen
  • While frozen, measurements can be taken and annotations can be made
  • Option to “cine” back to previous time frames
    • Assists in capturing previous frames during fetal movements
Trackball

- Used for moving objects on the monitor for scrolling back in freeze mode

Res/Zoom

- Allows magnification of areas of the ultrasound image
First Trimester Ultrasound

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Disclosures

• None

Objectives

• First trimester ultrasound
  • How to measure a CRL
  • First trimester anatomy
  • Anomalies that can be diagnosed in the first trimester
  • Utility of first trimester US in the age of cell free fetal DNA
Importance of first trimester US

- Establish location of pregnancy
- Viability
- Accurate dating
- Evaluate for the presence of multiples
  - Establish chorionicity
- Fetal anatomy
  - First trimester
  - Second trimester
- Aneuploidy screening

AIUM 2013

A. First trimester ultrasound examination

1. Indications:
   a. Confirmation of first trimester gestational age
   b. Evaluation of early pregnancy complications
   c. Confirmation of ongoing pregnancy
   d. Evaluation of early pregnancy wastage
   e. Diagnosis or evaluation of multiple gestations
   f. Confirmation of cardiac activity
   g. Assessment of normal fetal size and position
   h. Evaluation of maternal transfusion status
   i. Measurement of fetal and placental growth
   j. Diagnosis of fetal anomalies
   k. Measurement of maternal amniotic fluid volume

Early first trimester timeline (+/- 0.5 weeks)

- 5 weeks: Gestational sac
- 6 weeks: Embryo with cardiac activity
- 5.5 weeks: Yolk sac
- 7 weeks: Amnion
Diagnostic Criteria for Nonviable Pregnancy Early in the First Trimester

Assignment of gestational age by early ultrasound

- Prior to visualization of the embryo, mean sac diameter or visualization of the yolk sac may be used
- Once an embryo is visualized, CRL is most accurate

Crown rump length

- Measure from the top of the head to the bottom of the rump
- Should be in neutral position
- Calipers should NOT include the yolk sac or lower extremities
Caliper placement

AIUM Practice Parameter for first trimester ultrasound
• Presence, size, location and number of gestational sac(s)
• Presence or absence of a yolk sac
• Presence or absence of an embryo/fetus
• Demonstration of cardiac activity
• Evaluation of uterus, cervix, adnexa and cul-de-sac

First trimester anatomy
• Nuchal translucency
• Abdominal wall
• Head shape
• Presence of falx
• Extremities
Nuchal Translucency

- Fluid filled space behind the baby’s neck
- Accurate measurements taken 45 to 84 mm
- Increase NT associated with Down syndrome, other aneuploidies and other health concerns such as heart defects
- Detection rate for Down syndrome with NT alone is 70% with a 5% false positive rate (up to 90% with serum analytes)

Outcomes of Increased NT in chromosomally normal fetuses

<table>
<thead>
<tr>
<th>Nuchal Translucency</th>
<th>Cardiac Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;95th %</td>
<td>0.1%</td>
</tr>
<tr>
<td>2.5-3.4 mm</td>
<td>1%</td>
</tr>
<tr>
<td>3.5-4.4 mm</td>
<td>3%</td>
</tr>
<tr>
<td>4.5-5.4 mm</td>
<td>7%</td>
</tr>
<tr>
<td>5.5-6.4 mm</td>
<td>20%</td>
</tr>
<tr>
<td>&gt;6.5 mm</td>
<td>30%</td>
</tr>
</tbody>
</table>
Nasal Bone in 1st Trimester

- Association between absence of fetal nasal bone and Down syndrome
- A study of 701 fetuses with increased NT: nasal bone was absent in 73% of fetuses with DS and only 0.5% of unaffected fetuses (Cicero et al., 2001)

Nasal Bone Present

Nasal Bone Absent

Abdominal Wall (normal)
• Bony cranium beings to ossify at 9 weeks and presence of the falx should be visualized after 10 weeks
Head Shape (normal)

Choroids

Head Shape

Anencephaly  Acrania

Face

• By 11 weeks, evaluation of the lip/palate should be possible and nose/nasal bone/profile should be visualized
WX4790 – get prior first trimester face images

Falx

- Should be present by 9-10 weeks
- Choroid plexus should be visible within each of the lateral ventricles by the middle of the 9th week and fill the space by the 12th week
Presence of Falx (normal)

Absence of Falx

Single ventricle, fused thalami

Proboscis

Extremities
Cell free fetal DNA

- Uses cell free DNA from maternal serum to screen for common fetal aneuploidies with high sensitivity and specificity.

Circulating cell-free fetal DNA

- Comprises about 3-13% of the total cell free maternal DNA after 10 weeks gestation
- Measurable in maternal serum by 9-10 weeks
- Derived primarily from the placenta
  - Apoptosis of placental cells
  - Half life is < 20 minutes
  - Undetectable <2 hours postpartum
cffDNA Technology

- **Massive Parallel Sequencing**
  - "shot gun sequencing"
  - Simultaneously sequences amplified DNA from all chromosomes
  - Amplifies maternal and fetal DNA together

- **Targeted sequencing**
  - Amplifies selected regions only of chromosomes of interest (13, 18, 21, X and Y) to provide a risk score

- **Selection of polymorphic SNPs**
  - Utilizes single DNA base pair variations throughout the genome
  - Amplifies both maternal and fetal DNA
  - Desires a paternal sample for interpretation
  - Can detect triploidy, which other methods cannot
Implications of cffDNA results

- cffDNA results are lab-dependent
  - All results should be confirmed with diagnostic testing
- Positive results
  - Some labs simply say “elevated risk”
  - Others provide an actual risk score (>99/100)
  - Do not provide positive predictive value report
- Negative results
  - Some labs simply say “unlikely” or “negative”
  - Very few provide an actual residual risk score (ie. 1/10,000)
- Unreportable
  - “Result failures” typically related to low fetal fraction
  - For patients weighing more than 250 pounds, 10% or more may have a fetal fraction of less than 4%
  - Rates of aneuploidy as high as 23% (due to low fetal fraction or other unknown factors) have been reported for women who fail to receive an interpretable result from cell-free DNA testing.
  - Only 50-60% of repeat screens will provide a result

SMMFM/ACOG Committee Opinion #640, 2015

SMFM statement on cffDNA

- Recommended that NIPT is most appropriate for high-risk patients
  - Maternal age 35 years or older at delivery
  - Sonographic findings indicating an increased risk of aneuploidy
  - History of a prior pregnancy with a trisomy
  - Positive screening results for aneuploidy, including first trimester, sequential, integrated, or quadruple screen
  - Parental balanced Robertsonian translocation with increased risk for trisomy 13 or 21.
Why cffDNA is limited in the general population

- Results depend on the prevalence of the disease in a particular population

- Only screens for the 3 most common chromosomal disorders

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**Fig. 1.** Percentage of chromosomal defects detectable or not detectable by noninvasive prenatal testing based on maternal age. For numeric details, see Table 4.


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**Applicability to Clinical Practice**

<table>
<thead>
<tr>
<th>Chromosome</th>
<th>Sensitivity (95%)</th>
<th>Specificity (95%)</th>
<th>PPV (95%)</th>
<th>NPV (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trisomy 21</td>
<td>97.6</td>
<td>99.9</td>
<td>87</td>
<td>99.6</td>
</tr>
<tr>
<td>Trisomy 18</td>
<td>81.0</td>
<td>94.9</td>
<td>91</td>
<td>82</td>
</tr>
<tr>
<td>Trisomy 13</td>
<td>81.0</td>
<td>94.9</td>
<td>91</td>
<td>82</td>
</tr>
<tr>
<td>Sex chromosome (female)</td>
<td>95.2</td>
<td>99.2</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Positive predictive value** (defined as true positives/(true positives + false positives)) is directly related to the **prevalence** of the condition in the population screened.

Based on the sensitivity and specificity of the test, when a population with an overall prevalence of 1/1,000 for trisomy 21 is screened, the PPV of an abnormal result is 33% - only 1/3 women who get an abnormal result will have an affected fetus. If the prevalence is 1/75, the PPV is 87%
Conclusions

- First trimester ultrasound can provide a wealth of information
  - Accurate dating
  - Viability
  - Anomalies
  - Multiples
  - Correlate with aneuploidy screening
Antenatal Testing Using Ultrasound

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Disclosures

• None

Objectives

• Discuss the goals and indications for antenatal testing
• Describe the common forms of antenatal testing involving ultrasound
• Review basic biometry
Antenatal testing by ultrasound

- BPP
- Cord Dopplers
- Biometry

Goals

- Decrease the rate of stillbirth
- Decrease long term neurologic injury

- Limited evidence to demonstrate effectiveness
- May impact gestational age at delivery and mode of delivery

Indications for Antenatal Testing

- Diabetes
- Hypertensive Disorders
- Fetal growth restriction
- Multiple gestation
- Amniotic fluid abnormalities
- Postterm pregnancy
- History of prior stillbirth
- Decreased fetal movement
- Morbid obesity
- Advanced maternal age (>40)
- Coagulation defects
Limited Effectiveness

- The majority (>70%) of cases of neonatal encephalopathy arise prior to onset of labor
  - Only 4% of cases of encephalopathy can be attributed solely to intrapartum events
- BUT... most cases of CNS injury are not identified prenatally
- AP testing may be contributing to increase in rate of CP while decreasing stillbirth rate

Antenatal Testing

- Stillbirth and CP are both associated with
  - Extremes of maternal age and parity
  - Use of assisted reproductive technology
  - African American race
  - Smoking
  - Maternal medical disease
  - Obesity
  - Previously affected pregnancy
  - Fetal anomalies
  - Multiple gestation
  - Fetal growth restriction
  - Male fetal sex

Premise of Antenatal Testing

- There is a progressive series of physiologic adaptive signs as fetal hypoxemia or metabolic acidemia develops
Adaptive Signs during Hypoxemia

- Blood flow redirected to brain, heart, adrenals with decreased renal perfusion oligohydranmios
- Decrease fetal movement in effort to conserve energy
- Vagally-mediated reflex causing slowing of the FHR may appear as late decelerations

Adaptive Changes

- Loss of FHR reactivity
- Abnormal blood flow in umbilical artery
- Sequential changes in other fetal vessels
- Abnormalities in BPP parameters (breathing, AFI, movement and tone)

Progression of Doppler and biophysical findings in severe fetal growth restriction

Baschat et al., Ultrasound Obstet Gynecol 2001
Fetal movement counting

- Fetal movement decreases in response to hypoxemia
- Fetal movements first felt about 17-20 weeks; peak at about 38 weeks
- Difficult to measure/study
- Maternal sense of “change” from what is normal may be more important

Nonstress Testing

- FHR variability is controlled through the parasympathetic nervous system
- With exposure to prolonged periods of stress (uteroplacental insufficiency) there is a noradrenergic response mediated through epinephrine and norepinephrine
- As hypoxemia worsens, there is a decrease in FHR variability

Nonstress Testing

- NST only assesses well-being at the time of the test

- Rate of stillbirth for fetuses evaluated after a reactive NST was 1.9/1000 compared to 26/1000 after a nonreactive NST (Freeman et al., 1982)

- If performed 2x weekly, stillbirth after a reactive NST was reduced to 1.9/1000 compared with 6.1/1000 if done once weekly (Buxton et al., 1982)
Patients at risk for fetal distress

<table>
<thead>
<tr>
<th>Nonstress Testing</th>
<th>Once a week</th>
<th>Twice a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients eligible</td>
<td>1000</td>
<td>915</td>
</tr>
<tr>
<td>No. of patients included</td>
<td>661</td>
<td>517</td>
</tr>
<tr>
<td>Total # of stillbirths</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Corrected #*</td>
<td>7 (10.6/1000)</td>
<td>3 (5.8/1000)</td>
</tr>
<tr>
<td># of stillbirths with reactive NST</td>
<td>4 (6.1/1000)</td>
<td>1 (1.9/1000)</td>
</tr>
</tbody>
</table>

Boehm et al., Obstetrics and Gynecology, Vol. 67, No.4, April 1986

Nonstress Testing

- High inter- and intraobserver variability
- High false positive rate for abnormality
  - In at least 50% of fetuses with nonreassuring test, neonate is not acidotic (Black et al., 1997)
- Contraction stress test may be a better assessment of placental dysfunction
  - Freeman et al., 1982 reported a corrected perinatal death rate of 176.5/1000 for patients with a positive CST compared with 2.3/1000 for patients with a negative test

Intrapartum FHR Monitoring

- Utilized to determine if a fetus is well oxygenated
  - Poor inter- and intraobserver reliability
  - High false-positive rate
  - 63% of term pregnancies with fetal asphyxia had no known risk factors (Low et al., AJOG 2002)
Intrapartum FHR Monitoring

- Increased the overall cesarean delivery rate (RR 1.66; 95% CI 1.3-2.13)
- Increased the risk of both vacuum and forceps operative VD (RR 1.16; 95% CI, 1.01-1.32)
- Did NOT reduce perinatal mortality (RR 0.85; 95% CI 0.59-1.23)
- DID reduce the risk of neonatal seizures (RR 0.5; 95% CI 0.31-0.8)
- Did NOT reduce the risk of CP (RR 1.74; 95% CI 0.97-3.11)
  - The false positive rate for predicting CP is >99%

Alfirevic et al., Cochrane Reviews, 2006; Nelson et al., NEJM 1996

NICHD Guidelines for Nomenclature

- Baseline
- Variability
- Acceleration
- Early deceleration
- Late deceleration
- Variable deceleration
- Prolonged deceleration
- Sinusoidal pattern

Macones et al., Obstet Gynecol 2008

Three-Tiered Interpretation

- Category I
  - Normal
  - Baseline FHR 110-160
  - Moderate baseline variability
  - Accelerations/early decelerations may be absent OR present
  - Strongly predictive of normal fetal acid-base status AT THE TIME of observation

- Category II
  - Not predictive of abnormal acid-base status
  - Requires continued surveillance

- Category III
  - Sinusoidal FHR pattern OR absent baseline variability AND ANY: recurrent late decels, bradycardia or recurrent variable decels
  - Associated with abnormal fetal acid-base status AT THE TIME of observation
  - Requires prompt evaluation
Biophysical Profile

• Provides an assessment of multiple acute and chronic fetal physiologic parameters
• Reliable test of fetal well-being (Dayal et al., 1999)
  • Fetal tone
  • Fetal movement
  • Fetal breathing
  • Amniotic fluid volume
  • NST

• Each component is assigned 2 points if present, 0 points if absent
  • Normal ≥ 8/10 or 8/8 excluding NST
  • Equivocal 6/10
  • Abnormal ≤ 4/10
• Assesses both acute (NST, breathing, movements) and chronic (fluid) indicators of hypoxia
• Score is linearly correlated with fetal pH (Manning et al., AJOG 1993)

Progression of Fetal Growth Restriction
BPP Changes

Decreased fetal heart rate variability on the NST
  ▼
  Fetal breathing
  ▼
  Decrease in amniotic fluid volume
  ▼
  Fetal movement and tone
Biophysical Profile

• Whether or not the NST and BPP are independent predictors of normal outcome
• BPP is usually performed to lower the false positive rate of the NST
  • However, the false positive rate of a BPP ranges from 75% for a score of 6 to 20% for a score of 0 (Inglis et al., 1993)
  • Vibroacoustic stimulation can be used to reduce the false positive rate

Modified BPP

• AFI is a measure of chronic placental function
• Modified BPP (NST with AFI)
• Rate of stillbirth after a reassuring BPP OR modified BPP is 0.8/1000
• Perinatal outcomes worsen as the BPP score decreases (<4)

Risk of Stillbirth with Antenatal Tests

<table>
<thead>
<tr>
<th>Antenatal Test</th>
<th>Risk of Stillbirth per 1000</th>
<th>Negative Predictive Value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>NST (once a week)</td>
<td>6.1</td>
<td>NS</td>
</tr>
<tr>
<td>NST (twice a week)</td>
<td>1.9</td>
<td>99.8</td>
</tr>
<tr>
<td>BPP</td>
<td>0.8</td>
<td>&gt;99</td>
</tr>
<tr>
<td>Modified BPP</td>
<td>0.8</td>
<td>&gt;99</td>
</tr>
</tbody>
</table>

Thompson et al., Obstetrical and Gynecological Survey, 2012
### Antenatal Testing Methods

<table>
<thead>
<tr>
<th>Name</th>
<th>Comments</th>
<th>Scoring</th>
<th>False Negative Rate</th>
<th>False Positive Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST</td>
<td>Continuous FHR</td>
<td>≥3 ctx in 10 mins</td>
<td>Negative</td>
<td>0.04%</td>
</tr>
<tr>
<td>CST</td>
<td>Continuous FHR</td>
<td>≥3 ctx in 10 mins</td>
<td>Positive</td>
<td>0.2 to 0.65%</td>
</tr>
<tr>
<td>NST</td>
<td>Continuous FHR</td>
<td>≥32 weeks</td>
<td>Negative</td>
<td>0.07-0.08%</td>
</tr>
<tr>
<td>NST</td>
<td>Continuous FHR</td>
<td>≥32 weeks</td>
<td>Positive</td>
<td>0.2 to 0.65%</td>
</tr>
<tr>
<td>BPP</td>
<td>NST</td>
<td>≥32 weeks</td>
<td>Normal: reactive NST and AFI &gt;5 cm</td>
<td>0.0%</td>
</tr>
<tr>
<td>BPP</td>
<td>NST</td>
<td>≥32 weeks</td>
<td>Abnormal: nonreactive NST and/or AFI ≤5 cm</td>
<td>0.0%</td>
</tr>
<tr>
<td>Modified BPP</td>
<td>NST</td>
<td>≥32 weeks</td>
<td>Normal: reactive NST and AFI &gt;5 cm</td>
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</tr>
<tr>
<td>Modified BPP</td>
<td>NST</td>
<td>≥32 weeks</td>
<td>Abnormal: nonreactive NST and/or AFI ≤5 cm</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

### Doppler Velocimetry

- Used in monitoring a pregnancy once FGR is diagnosed
  - Not useful as a diagnostic or screening tool
  - In contrast to NST and BPP, effectiveness has been confirmed by RCTs and meta-analyses (umbilical artery)

- Helps to determine if delivery is needed (versus expectant management)

- Has been found to reduce interventions and improve fetal outcomes in pregnancies with FGR
  - Most helpful in cases when FGR is associated with placental dysfunction

### Doppler Velocimetry

- Systolic-to-diastolic ratio
  - Frequency shift obtained during systole/frequency shift obtained during diastole
    - Umbilical artery and MCA

- Pulsatility index
  - Difference between frequency shift in systole and diastole/mean frequency shift
    - Maternal uterine artery and MCA

- Resistance index
  - Difference in frequency shift between systole and diastole/frequency shift in systole
    - MCA
Umbilical Artery

• Assesses blood flow from the fetus to the placenta
  • Reflects placental vessel resistance
• Most commonly used Doppler surveillance in the setting of FGR (Abuhamad, 2008; Davies et al., 1992)
• Helpful in distinguishing growth restriction from constitutionally small
• Gestational age specific norms
• Use free floating loop of cord
  • Fetal breathing can influence waveform
  • Values obtained close to placental end have more end-diastolic flow (lower ratios) than those obtained closer to abdominal wall

Umbilical Artery

• As gestational age increases the systolic-to-diastolic ratio normally decreases (due to an increase in end-diastolic flow)
  • Due to placental maturation which causes an increase in the number of tertiary stem villi
  • A decrease in end-diastolic velocity becomes evident when 30% of the placental vasculature is affected
• Once 60 to 70% of the vasculature is affected, absent and then reverse end-diastolic flow results (Baschat, 2010)

Umbilical Artery

• Perinatal mortality increases with progression from absent to reverse end-diastolic flow
  • OR of 4.0 and 10.6, respectively, when compared with cases with positive end-diastolic flow (Karsdorp et al., 1994)
  • Abnormal Dopplers can be present up to 1 week before acute deterioration
  • Can be associated with acidosis in up to 40% of fetuses (Ferrazzi et al., 2002; Figueras et al., 2011)
Absent and Reversed End-Diastolic Velocity in the Umbilical Artery and Perinatal Outcome
(From 1126 reported cases)

<table>
<thead>
<tr>
<th>Perinatal Outcome</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perinatal mortality</td>
<td>45%</td>
<td>17-100%</td>
</tr>
<tr>
<td>Gestational age</td>
<td>31.6 weeks</td>
<td>29-33 weeks</td>
</tr>
<tr>
<td>Birth weight</td>
<td>1056 gms</td>
<td>910-1481 gms</td>
</tr>
<tr>
<td>Small for gestational age</td>
<td>68%</td>
<td>53-100%</td>
</tr>
<tr>
<td>Cesarean section for fetal distress</td>
<td>73%</td>
<td>24-100%</td>
</tr>
<tr>
<td>Apgar score at 5 min &lt; 7</td>
<td>26%</td>
<td>7-69%</td>
</tr>
<tr>
<td>Admission to NICU</td>
<td>84%</td>
<td>77-97%</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>10%</td>
<td>0-24%</td>
</tr>
<tr>
<td>Anoxia bility</td>
<td>6.4%</td>
<td>0-18%</td>
</tr>
</tbody>
</table>


Umbilical Artery Waveforms

Normal
- Decreased end-diastolic flow
- Increased s/d ratio

Absent end-diastolic flow

Reverse end-diastolic flow

Middle Cerebral Artery
- Normally, cerebral circulation is high impedance circulation with continuous forward flow throughout cardiac cycle
- When fetus is hypoxic, central redistribution of blood flow results in increased flow to the brain, heart and adrenals
  - Decreased flow to peripheral circulation
  - Brain sparing reflex
- As FGR progresses, end-diastolic velocity through the MCA increases → decrease in the s/d ratio and low PI
  - Compensatory cerebral vasodilation secondary to fetal hypoxiasia
  - Present up to 2 weeks before acute deterioration (Ferrazzi et al., 2002; Cosmi et al., 2005)
- Cerebroplacental ratio
  - MCA PI/umbilical artery PI <5th percentile for EGA is consistent with brain sparing
MCA Dopplers

Middle Cerebral Artery

- Umbilical artery Dopplers have a better positive predictive value compared to MCA Doppler
  - Better predictor of adverse outcome than MCA Doppler
- MCA Doppler has a better negative predictive value
  - Normal MCAs can help to identify fetuses without adverse perinatal outcomes

Ductus Venosus

- Doppler interrogation of the DV detects alterations in cardiac function
  - Reflects status of the right ventricle
- Has the highest forward velocity in the venous system
  - Blood flow is antegrade throughout the cardiac cycle
  - As umbilical artery resistance increases, there is increased shunting through the DV
    - Leads to increase in volume through the right heart
    - Leads to increased shunting to the left ventricle
    - Leads to increased end-diastolic pressure in the right ventricle and decreased cardiac compliance
    - Leads to changes in flow through the DV (Berkley et al., 2012)
Ductus Venosus

- Normal ductus venosus waveform is biphasic
  - Continuous flow throughout the cardiac cycle in normal fetuses
  - First peak corresponds with systole
  - 2nd peak corresponds with diastole
  - Followed by a nadir (a-wave) which occurs during atrial contraction

- Absent or reversed DV a-wave indicates myocardial impairment, increased ventricular end-diastolic pressure from an increase in RV afterload
  - Can be a sign of acidemia or impending death (Baschat et al., 2003; Huisman et al., 1993)

- Abnormalities in DV occur in late stages of fetal compromise
  - May precede BPP changes by only 48 to 72 hours

Take at the level of the origin from the umbilical vein

Normal
Decreased a-wave
Absent a-wave
Reversed a-wave
Investigational Doppler Studies

• Uterine artery
• Fetal descending aorta
• Fetal renal artery

Biometry

• Biparietal diameter
• Head circumference
• Abdominal circumference
• Femur length
• Humerus length

Gestational age versus EFW

• BPD and/or HC and FL -> gestational age (after 14 weeks)
• Add the AC to evaluate fetal weight/growth
Obstetric and Gynecologic Ultrasound Curriculum and Competency Assessment in Residency Training Programs: Consensus Report

Alfred Abuhamad, MD, Katherine K. Minton, MA, RDMS, RDCS, Carol R. Benson, MD,Trish Chudleigh, PhD, Lori Crites, BS, RDMS, Peter M. Doubilet, MD, PhD, Rita Driggers, MD,Ann Falcó, MD, Beryl R. Benacerraf, MD

Journal of Ultrasound in Medicine, January 2018

Biparietal Diameter

- Axial plane of head
- Symmetric appearance of cerebral hemispheres
- Midline falx imaged
- Thalami imaged
- Cavum septi pellucidi imaged
- No cerebellum seen
- Near caliper on outside edge of bone
- Far caliper on inside edge of bone
- Measurement at widest diameter
- Measurement perpendicular to falx
Head circumference

- Same level/image as the BPD
- Place ellipse on outer margin of the bone

Abdominal circumference

- Axial plane of abdomen
- Abdomen as circular as possible
- Spine imaged in cross-section in 3- or 9-o’clock position if possible
- Stomach bubble imaged
- Intrahepatic portion of umbilical vein imaged in short segment
- No more than one rib visible on each side laterally
- Kidneys not visualized
- Surrounding skin seen in entirety if possible
- Measurement of circumference ellipse on outside edge of skin
Abdominal Circumference

Femur length

- Whole femur diaphysis imaged
- Ultrasound beam perpendicular to long axis of femur
- Calipers placed at each end of ossified diaphysis
- Longest visible diaphysis is measured
- Spur artifacts on end of diaphysis not included in measurement
Humerus length

Thank you!
Ultrasound in Twin Gestations
William Goodnight, MD, MSCR
Associate Professor | Maternal-Fetal Medicine
University of North Carolina at Chapel Hill

• No disclosures or conflicts of interest in the presentation to report

• Objectives
  » Describe the timing, components, and frequency of ultrasound evaluation in twin pregnancy
  » Review importance of and determination of chorionicity
  » Discuss the ultrasound approach to complicated monochorionic twin pregnancy

How to respond to the question "Are they twins?" by twindadman.com
Etiology of twining

Monozygotic
- Possible shared placenta
- Separate placentas

Dizygotic

60% – multiple follicles
30%

Zygosity influences placentation

Diologic
Dichorionic Diamniotic
Monochorionic Diamniotic
Monochorionic Monoamniotic

MZ Twining - placentation

30%
60%
1-5%
<1%
EARLY PREGNANCY | FIRST TRIMESTER US IN TWINS

All twins: US 11-14 weeks
- Chorionicity
- Confirm EGA
- Aneuploidy screening

Gestational age determination

- **Determination:**
  - Embryo transfer
  - LMP
- **Confirm with US**
  - Ideal 7-10 weeks EGA
  - CRL

If EGA US discrepancy from clinical EGA:
- Use smaller CRL for determination of EDC if difference between CRLs is < 10mm
- Use larger CRL for EDC if difference is > 10 mm


Chorionicity matters!

Monochorionic twins
- Increased risk:
  - sIUGR
  - Growth discordance
  - Discordant fetal anomalies
  - Twin-twin transfusion syndrome
  - Neurologic morbidity
  - Fetal death:
    - <24 weeks: 12.7% (2.5% DC)
    - >24 weeks: 4.9% (2.8% DC)
- Require specific pregnancy monitoring
Chorionicity

- Risk stratification/monitoring
- Near 100% accurate in first trimester
  - Ideal 7-10 weeks
  - 10% inaccurate if done in 2nd trimester
  - # of gestational sacs = # of chorion

Ultrasound Determination of Chorionicity

- Optimal time is 11-14 weeks
  - T-sign and T-sign
- Discordant gender — dichorionic
- Separate placentas
  - USE CAUTION
- Second trimester
  - Membrane thickness
    - > 2 mm c/w dichorionic
    - 3-4 layers vs 2 layers
- IF UNSURE — MANAGE AS MONOCHORIONIC

Sonographic markers of chorionicity

- Lambda sign - DADC
- T – sign - MCDA
Ultrasound/ fetal assessment in twin pregnancy

- All twins: US 11-14 weeks
  - Chorionicity
  - Confirm EGA
  - Aneuploidy screening
    - MC: maternal age risk
    - DC: 2x maternal age risk
  - Combined serum and nuchal translucency screening at 11-14 weeks EGA
  - Maternal serum screen at 15-20 weeks EGA
  - CVS at 11-14 weeks
  - Amniocentesis at > 15 weeks
    - Cell free fetal DNA currently not recommended in twins
    - MSS < 4-6 weeks from twin loss not recommended

Second and third trimester – twin pregnancy US

Ultrasound/ fetal assessment assessment in twin pregnancy

- Dichorionic twins:
  - Fetal anatomy survey 18-20 weeks EGA
    - Determine PCI for each twin
    - Velamentous/previa insertion more common
    - Fetal echo if IVF pregnancy
    - Institution specific cervical length assessment
  - US q 3-4 weeks for fetal growth
  - Abnormal growth defined as EFW < 10th % tile; discordant EFW > 20%
Ultrasound/fetal assessment in twin pregnancy

- Monochorionic twins:
  - US for MVP of amniotic fluid q 2 weeks from 16 weeks EGA
    - Abnormal AFV defined as MVP < 2 cm and/or MVP > 8 cm
      - Prompt referral to fetal center with twin pregnancy experience
    - Fetal anatomy survey
      - 18-20 weeks EGA
      - Fetal echo
    - EFW assessment q 3-4 weeks
    - Weekly fetal testing
      - 32 weeks
  - Abnormal growth defined as EFW < 10th % tile or discordant EFW > 20%

Congenital Anomalies

- Singleton 0.6%
- DZ twin 1%
- MZ twin 2.7%
- MZ higher rates anomalies than DZ
  - Early malformations – midline defects
    - Anencephaly
    - CHD
    - Cloacal exstrophy
    - VATER
    - Sacrococcygeal teratoma
    - Conjoined twins

Monochorionic twin pregnancy conditions
Twin-twin transfusion syndrome

- 10-15% of MC twins
- Defined
  - Monochorionic
  - Polyhydramnios (> 8cm) and oligohydramnios (< 2 cm)
  - Growth discordance +/-
  - Historic dx – 5 gm/dl Hgb difference
Arterio-venous Anastomosis
Twin B → Twin A

Arterio-venous Anastomosis
Twin B → Twin A

Arterio-venous Anastomosis
Twin B ← Twin A

Arterio-arterial Anastomosis
Twin B ↔ Twin A


• High vascular resistance
• Hypovolemia
• Release of mediators
  - Endothelin 1
  - Angiotensin II

OLIGOHYDRAMNIOS

• Increased preload
• Transferred vasoactive mediators

POLYHYDRAMNIOS

MYOCARDIAL REMODELING

Ultrasound based Quintero Staging for TTTS

Stage I
Poly (+ 5 cm MVP) / Poly (- 2 cm MVP)

Stage II
- Non-vizualization of bladder - donor

Stage III
- Critical Doppler: AR EDF UA
- DV ARI ≥ twin
- UV pulsations

Stage IV
Hydrops

Stage V
IUFD
CV scoring

- Physiologically based; may upgrade stage – direct treatment
  - CHOP scoring
    - Right ventricle more commonly affected, most common abnormal values include ventricular hypertrophy, TR, single peak tricuspid inflow
  - Cincinnati scoring - Mild, mod, severe, based on TR regurgitation, RV/LV wall thickness, MPI cardiomyopathy

UA – UV in TTTS

Abnormal e/a wave in tricuspid and mitral valve inflow: Doppler obtained with pulse wave Doppler gate placed distal to the AV valve (2 mm gate). E wave represents passive filling in the ventricle, a wave corresponds to atrial contraction (normal in Donor). With cardiac dysfunction, single e/a wave is noted (recipient)

CV score TTTS
CV score TTTS

- Cardiothoracic ratio – area of heart/area of chest: Obtain transverse view of fetal chest at 4-chamber view (apical or subcostal 4-chamber). Measure circumference of thorax and chest in same image, calculate area from ellipse. CA/TA ratio < 0.3 is abnormal

- Ventricular wall measurements – obtain apical of subcostal 4-chamber view of heart. Measure ventricular free wall and interventricular septum thickness just inferior to AV valves. Measurement > 4 mm = thickened.

MPI/TEI

\[ \text{MPI/TEI} = \frac{\text{Isovolumetric contraction time} + \text{Isovolumetric relaxation time}}{\text{ejection time}} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>MC without TTTS</th>
<th>TTTS recipient</th>
<th>TTTS donor</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/D</td>
<td>0.31(0.15-0.48)</td>
<td>0.38(0.14-0.54)</td>
<td>0.78(0.61-0.85)</td>
<td>0.35(0.27-0.45)</td>
</tr>
<tr>
<td>TEI</td>
<td>0.29(0.10-0.56)</td>
<td>0.26(0.12-0.57)</td>
<td>0.69(0.56-0.79)</td>
<td>0.33(0.24-0.46)</td>
</tr>
<tr>
<td>p vs control</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.001</td>
<td>NS</td>
</tr>
</tbody>
</table>

TTTS – CV score

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grade I (0-5)</th>
<th>Grade II (6-10)</th>
<th>Grade III (11-15)</th>
<th>Grade IV (16-20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiomegaly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventricular hypertrophy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac dilatation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventricular dyskinesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR inflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MR inflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A wave</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A wave reverse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulsations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Score:
- Grade I (0-5)
- Grade II (6-10)
- Grade III (11-15)
- Grade IV (16-20)
<table>
<thead>
<tr>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No treatment</strong></td>
</tr>
<tr>
<td>80-90% mortality</td>
</tr>
<tr>
<td><strong>Serial amnioreduction</strong></td>
</tr>
<tr>
<td>Easy</td>
</tr>
<tr>
<td>Widely available</td>
</tr>
<tr>
<td>Less successful</td>
</tr>
<tr>
<td>&lt; 50% survival</td>
</tr>
<tr>
<td>Septostomy</td>
</tr>
<tr>
<td><strong>Laser photocoagulation</strong></td>
</tr>
<tr>
<td>Fetoscopy</td>
</tr>
<tr>
<td>Select centers</td>
</tr>
<tr>
<td>Selective</td>
</tr>
<tr>
<td>Nonelective</td>
</tr>
<tr>
<td>53-56%</td>
</tr>
<tr>
<td><strong>Fetal cord occlusion</strong></td>
</tr>
<tr>
<td>Umbilical cord ligation</td>
</tr>
<tr>
<td>Termination</td>
</tr>
<tr>
<td>50% survival</td>
</tr>
</tbody>
</table>

**TTTS follow up following laser**
- Both twins: MVP, BPP (as viability indicates), MCA PSV Doppler, UA S/D
  - Weekly following procedure x 6 weeks; rare complications after 28 weeks EGA
  - TAPS (twin anemia-polycythemia) – 2-13%.
  - Reversed TTTS (2-14%)/recurrent TTTS – polyhydramnios/oligohydramnios
    - If TAPS:
      - < 26 weeks, accessible, repeat laser
      - > 26 weeks, not accessible, PUBS/IUT, delivery
    - If recurrent TTTS – manage as based on GA with repeat laser, amnioreduction, selective reduction, or delivery

**28 weeks EGA (MoDi twins)**
- Twin A: EFW 1023 grams (28th % tile) – US Doppler normal
- Twin B: EFW 743 grams (7% tile) – UA Doppler S/D > 95% ile

**MCA PSV**
- 0.61 MoM
- 1.65 MoM
28 weeks EGA
Twin A: EFW 1023 grams (28th % tile) – US Doppler normal
Twin B: EFW 743 grams (7% tile) – UA Doppler S/D > 95% ile

- MCA Doppler PSV 0.61 MoM
- UA Doppler – normal
- DV normal
- MVP: 4.6 cm
- Thickened placenta
- Echogenic kidneys
- 'Starry sky' liver appearance

Twin B: EFW 743 grams (7% tile)
- MCA Doppler PSV 1.65 MoM
- UA Doppler S/D ratio 3.93 (> 95th % tile)
- DV - suppressed but present a-wave
- MVP: 2.8 cm
- Pericardial effusion noted on today's US

Diagnosis?

polycythemic

anemic
TAPS – twin anemia polycythemia sequence

- Small number of vascular anastomoses
  - Gradual, slow flow (5-15 ml in 24 hours)
  - 3-4 AV anastomoses (< 1mm)
  - Rare and small (< 1mm) AA anastomoses
  - Slow transfusion w/o hormonal imbalance

- Abnormal placental share
  - Donor has larger placental share

- Spontaneous (3-5% of MC pregnancies)
  - > 26 weeks EGA

- Post laser TTTS (2-16% of laser tx TTTS)
  - Former recipient becomes anemia
  - 1-5 weeks post laser

• Diagnosis:
  - Neonatal – hgb difference w/o poly/oligo
    - Increased reticulocyte in donor ratio > 1.7
    - < 1 mm AA anastomoses on placenta
  - Prenatal (no poly/oligo) – 40-60% of cases
    - MCA PSV < 1.0 MoM and > 1.5 MoM
    - MCA PSV MoM discordance > 0.5 MoM
    - Enlarged placenta in hydropic donor (anemic)
    - 'starry-sky' liver - polycythemic

TAPS

<table>
<thead>
<tr>
<th>Stage</th>
<th>Perinatal survival</th>
<th>Need for post natal transfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83%</td>
<td>40%</td>
</tr>
<tr>
<td>2</td>
<td>80%</td>
<td>67%</td>
</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>90%</td>
</tr>
<tr>
<td>4</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>33%</td>
<td>100%</td>
</tr>
</tbody>
</table>
TAPS

- Monitoring – MCA Doppler
  - Post laser for TTTS ~ 6 weeks
  - ? All MC twins every 2 weeks – not recommended
- Treatment
  - Expectant tx
  - IUT (donor) – intraperitoneal preferred – slower absorption
  - IUT (donor) + PET (in recipient)
  - Repeat laser coagulation of vessels
**Acardia – TRAP**

**Twin reversed arterial perfusion**
- 1% MC twins
- Arterial-arterial communication between umbilical arteries
- Pump twin/recipient twin
  - Poorly oxygenated blood perfusing recipient twin
  - 50% mortality

**TRAP**
- Normal twin (pump twin)
  - Support acardiac twin
  - No placental share
  - Large AA anastomosis
  - Retrograde flow of deoxygenated blood into the acardiac twin
  - Perinatal mortality 55%
- Aneuploidy 9%
- Dx
  - First trimester – min Doppler flow often visible; document reversed flow in UA

**TRAP**
- EGA delivery ~ 29 weeks
  - EFW of pump twin:
    - \( g = 1.2 \times L^2 - (1.66 \times L) \) (g) = [width x height x length (cm)] x 0.523
    - 1 ml = 1 mg
  - Mortality greater with weight acardiac/pump > 70%
    - <=50% - survival rate 88%

<table>
<thead>
<tr>
<th>Weight %</th>
<th>PTB</th>
<th>Poly</th>
<th>CHF pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 70%</td>
<td>90%</td>
<td>40%</td>
<td>30%</td>
</tr>
<tr>
<td>&lt; 70%</td>
<td>75%</td>
<td>30%</td>
<td>15%</td>
</tr>
</tbody>
</table>
MVP twin A = 7 cm

sIUGR

- 15-25% MC pregnancies
- Dx:
  - EFW of < 10th % ile
  - EFW discordance >= 25%
- Pathogenesis
  - Unequal placental share
  - Large (> 2 mm) AA anastomoses
- Ultrasound assessment
  - MVP for amniotic fluid
  - UA Doppler s/d ratio; MCA Doppler PSV
  - DV waveform
  - Absent a-wave occurs with fetal compromise
sIUGR

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
<th>EGA at del</th>
<th>EFW discord</th>
<th>mortality</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Positive EDF in UA</td>
<td>35.4 wk</td>
<td>29%</td>
<td>- 2.6%</td>
<td>Weekly Doppler - Del 35-36 wk</td>
</tr>
<tr>
<td>II</td>
<td>Persist AREDF in UA</td>
<td>31.6 wk</td>
<td>38%</td>
<td>- 14% US brain injury in sIUGR twin</td>
<td>venous Doppler evaluation</td>
</tr>
<tr>
<td>III</td>
<td>Intermittent AREDF in UA</td>
<td>31 wk</td>
<td>36%</td>
<td>- 15% unexpected IUFD</td>
<td>Venous Doppler evaluation</td>
</tr>
</tbody>
</table>

Predictors of mortality – type II (OR 28.9 vs type I), EFW < 3rd % tile, oligohydramnios

Cyclic UA Doppler – type III sIUGR

- Latency of Doppler deterioration ~ 10 weeks
- Weekly Doppler evaluation
  - UA
  - DV
  - MCA
  - UV
- Delivery
  - Abnormal venous Doppler
    - UV pulsations
    - UV absent/reverse a wave
- Selective reduction – 80% favorable outcome for co-twin
Monoamniotic

- 1:10,000 pregnancies
  - 1-5% of monozygotic pregnancies
- Complications
  - Perinatal mortality – 23%
  - Cord entanglement – 66%
  - Congenital anomalies – 10-26%; 4% CHD
  - Discordant birth weight – 20%
- US
  - Absence of intervening amnion
  - Yolk sac can be 1 or 2
  - US monitoring as in monochorionic/diamniotic

Monoamniotic Twins - Management

- Increased risk for IUFD
  - Cord entanglement
  - UV notching on Doppler
- Monitoring 24-26 weeks EGA
  - Delivery at 32-34 weeks
- Inpatient vs outpatient
  - No IUFD in inpatient, 14% in outpatient
  - Inpatient = increased GA at delivery, birthweight and decreased neonatal morbidity
Conjoined twins

-pagus
Cephalopagus: 11%
Thoracopagus: 19%
Omphalopagus: 18%
Ischiopagus: 11%
Conjoined twins

- Keys to conjoined twins
  - Monoamniotic twin pregnancy
  - Twins hold same position relative to each other
  - Prognosis based on degree and sites of fusion
  - 40% thoracopagus
  - Vascular Doppler helpful at determination of shared circulations/organisms

Twins US Summary: Chorionicity matters!

- Monochorionic twins
  - Anatomy US and fetal echo 18-20 weeks
  - 16 weeks to delivery
    - Q 2 weeks US for MVP; q 3-4 weeks fetal growth
    - Poly/oligo, or discordant MVP
      - MCA Doppler for PSV MoM
      - UA/SV Doppler
      - MFM referral; Cardiac Doppler
    - IUGR or discordant EFW
      - UA Doppler

- Dichorionic twins
  - Anatomy US 18-20 weeks
    - Fetal growth US q 3-4 weeks
    - IUGR or discordant EFW
    - UA Doppler
Complicated monochorionic twin pregnancy ultrasound evaluation

Suspected abnormal US for monochorionic twin pregnancy

Targeted anatomy US, fetal echo if not previously completed; confirm chorionicity

EFW, MVP each twin

MVP > 8 cm AND MVP < 2 cm

MFM referral

Twin twin transfusion syndrome*
ID twin as 'donor' (oligo) and 'recipient' (poly)

Discordant fetal anomalies

Individualize care, TTTS, sIUGR may be present; monitoring, RFA/cord coag based on anomaly, EGA

Yes No

Acardiac twin

Yes

Twin reversed arterial perfusion

Yes No

Obtain/report multivessel Doppler; CV evaluation each twin

^UA (s/d ratio % tile; normal, absent, or reversed diastolic velocity)
MCA PSV and RI/PI
Ductus venosus (normal, absent, reversed a-wave; s/a ratio % tile)
Recipient Tricuspid regurgitation (presence, absence); 'e,' 'a' wave evaluation
Cardiothoracic ratio (CA/TA); ventricular wall thickness
UV pulsations

Selective IUGR*

Obtain/report:

Pump twin UA Doppler s/d %tile, normal or AREDF, amnionicity, MVP DV a-wave (normal, absent, reversed)

Hydrops Acardiac twin

EFW gram = width (cm) x length x height x 0.523, % weight of pump twin

No

MVP > 8 OR MVP < 2

MCA PSV > 1.5 MoM and < 1.0 MoM

EFW < 10th %tile, growth discordance > 20%, or both

Yes No

TAPS* – twin anemia, polycythemia sequence

Obtain/report:

UA Doppler (s/d ratio % tile; normal, absent, reversed or intermittent EDF)
DV (normal, absent, reversed a-wave; s/a ratio % tile)
BPP as indicated

*hybrid lesions may occur – consider management based on cardiovascular findings on evaluation

^see Doppler in Twin Pregnancy outline

Management (individuate)

by stage:
I: weekly assessment; amnioreduction (AR) for maternal s/s

stage I TTTS trial enrollment

II: referral for laser photocoagulation 16–26 weeks; AR after 26 weeks; BMZ > 23 weeks

III: referral for laser photocoagulation 16–26 weeks; AR after 26 weeks; BMZ > 23 weeks

IV: referral for laser photocoagulation 16–26 weeks; AR after 26 weeks; BMZ > 23 weeks

V: EGA fetal testing, consider MRI on remaining twin for CNS injury (EGA dependent)

SIUGR classification

Type I: UA Doppler normal, elevated s/d, forward diastolic velocity

Type II: AREDF UA

Type III: iAREDF UA

Report Quintero stage; comment on CV status TVCL

See Epic flow for management PD X
### Ultrasound twins

<table>
<thead>
<tr>
<th>Indication</th>
<th>Timing</th>
<th>Notes</th>
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<tbody>
<tr>
<td>EGA estimation</td>
<td>First trimester</td>
<td>CRL 7-10 weeks</td>
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<tr>
<td>Chorionicity</td>
<td>First trimester</td>
<td>Near 100% accuracy &lt; 2nd trimester</td>
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<tr>
<td>NT screening</td>
<td>10-13 weeks</td>
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<tr>
<td>Anatomic evaluation; baseline cervical length</td>
<td>Second trimester</td>
<td>Color Doppler for PCI</td>
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<tr>
<td>Placental evaluation</td>
<td>Second trimester</td>
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<tr>
<td>Fetal growth</td>
<td>Second/third</td>
<td>Q 3-4 week after 24-26 weeks</td>
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<tr>
<td>Serial surveillance</td>
<td>Second/third</td>
<td>DCDMA</td>
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<td>• q 2 week US from 16 weeks</td>
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<tr>
<td></td>
<td></td>
<td>• ANT from 32 weeks</td>
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<tr>
<td></td>
<td></td>
<td>• Daily from viability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• DCDA</td>
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<tr>
<td></td>
<td></td>
<td>• A/ANT from 32 weeks</td>
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### Twin pregnancy US monitoring

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<th>Week</th>
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<th>MVP</th>
<th>EFW</th>
<th>MVP</th>
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<td>10</td>
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<td>14</td>
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<td>26</td>
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<td>38</td>
<td>US</td>
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</table>
Title Abnormalities of the placenta & umbilical cord

David Stamilio, MD, MSCE
Professor, Division of Maternal-Fetal Medicine
Department of Obstetrics & Gynecology
April 20, 2018
NC OB/GYN Society Annual Meeting

Disclosure

- Dr. Stamilio has no relevant financial interests to disclose.

Objectives

- Identify the sonographic findings and understand the risks and management of the following placental and umbilical cord abnormalities:
  1. Placenta:
     a. Placenta previa
     b. Placental implantation abnormalities (accreta, increta, percreta)
     c. Velamentous cord insertion
     d. Vasa previa
     e. Placental abruption
     f. Choriangioma
  2. Umbilical cord:
     a. Single umbilical artery
     b. Umbilical cord cyst
     c. Umbilical vein varix
PLACENTA PREVIA

Risk Factors

• Multiparity
• Advanced maternal age
• Multiple gestation
• Prior uterine surgery
• Uterine abnormality
• Smoking
• Cocaine Use

Placenta previa on Ultrasound

Complete previa - TA & TV US

Low lying placenta (<2 cm) TVUS
Maternal-Fetal Risks

- Antepartum hemorrhage
- Need for peripartum hysterectomy
- Morbidly adherent placenta
  - Accreta
  - Increta
  - Percreta
- Intrapartum hemorrhage
- Blood transfusion
- Post partum hemorrhage
- Septicemia
- Thrombophlebitis

Placenta Previa - management

- >90% resolved when seen in early 2nd trimester
- 3rd trimester ultrasound
  - Assess for persistence
  - Accreta / MAP?
- Always assess for previa with antenatal bleeding
- Delivery
  - Placenta >2 cm from the os → SVD ok
  - Placenta <1 cm from the os → cesarean
  - Placenta 1-2 cm from the os “individualize”

MORBIDLY ADHERENT PLACENTA (ACCRETA SPECTRUM)

Aka; Placental implantation abnormality = “PIA”
Risk Factors

- Previous uterine surgery
- Risk increases with increasing # of Cesareans
- Placenta previa
- AMA
- Increasing parity
- Endometrial defects (Asherman syndrome)
- Submucosal leiomyomata

---

Risk of accretia with cesarean

<table>
<thead>
<tr>
<th>Cesarean #</th>
<th>MFMU 2006 (n=143)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
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<td>One</td>
<td>0.3%</td>
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<td>Two</td>
<td>0.6%</td>
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<tr>
<td>Three</td>
<td>2.1%</td>
</tr>
<tr>
<td>Four</td>
<td>2.3%</td>
</tr>
<tr>
<td>Five or more</td>
<td>6.7%</td>
</tr>
</tbody>
</table>

Silver RM et al. Obstet Gynecol 2006

---

Risk of accretia with previa

<table>
<thead>
<tr>
<th>Cesarean #</th>
<th>Clark 1985 (n = 29)</th>
<th>MFMU 2006 (n=91)</th>
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<tbody>
<tr>
<td>None</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>One</td>
<td>24</td>
<td>11</td>
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<tr>
<td>Two</td>
<td>47</td>
<td>40</td>
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<tr>
<td>Three</td>
<td>40</td>
<td>61</td>
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<tr>
<td>Four or more</td>
<td>67</td>
<td>67</td>
</tr>
</tbody>
</table>

Clark SL et al. Obstet Gynecol 1985
Silver RM et al. Obstet Gynecol 2006
Maternal & Fetal Risks

**Maternal Risks**
- Massive hemorrhage
- DIC
- ARDS
- Renal failure
- Death
- Need for peripartum hysterectomy

**Fetal Risks**
- Little information on perinatal outcomes
- Increased risk of:
  - Preterm birth (PTB)
  - Small for gestational age (SGA) infants

Ultrasound diagnosis of PIA

- Look for previa
- Loss of hypoechoic retroplacental myometrial zone
  - Thickness ≤ 1 mm
- Disruption of hypoechoic uterine serosa-bladder interface
- Lacunar vascular spaces
- Hypervascularity
  - Bridging vessels

Ultrasound diagnosis of PIA

- Vascularity between placenta & bladder (†)
  - Bridging vessels
- Turbulent flow in lacunae (†)
### Placenta Accreta Index

<table>
<thead>
<tr>
<th>PAI</th>
<th>Prob invasion, % (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0</td>
<td>5 (1 - 15)</td>
</tr>
<tr>
<td>&gt;1</td>
<td>10 (4 - 22)</td>
</tr>
<tr>
<td>&gt;2</td>
<td>19 (10 - 32)</td>
</tr>
<tr>
<td>&gt;3</td>
<td>33 (22 - 47)</td>
</tr>
<tr>
<td>&gt;4</td>
<td>51 (36 - 66)</td>
</tr>
<tr>
<td>&gt;5</td>
<td>69 (50 - 83)</td>
</tr>
<tr>
<td>&gt;6</td>
<td>83 (63 - 93)</td>
</tr>
<tr>
<td>&gt;7</td>
<td>91 (73 - 97)</td>
</tr>
<tr>
<td>&gt;8</td>
<td>96 (81 - 99)</td>
</tr>
</tbody>
</table>

N = 184; 54 (29%) with MAP on histology

* Better predictor than just cesarean rate
* At >4 cutoff sensitivity 72%, False = 15%

---

**VELAMENTOUS CORD INSERTION**
Risks
- IUGR
- Vasa Previa

Management
- Fetal growth US
- Intrapartum fetal monitoring
- Increased risk for cesarean

Vasa Previa

Type 1:
- Velamentous cord insertion
- Previa & low-lying placenta at risk
- Majority of cases (60%)

Type 2:
- Succenturiate lobe with bridging vessels to main lobe
- Occurs in 1/2500 pregnancies
- 20% seen early in pregnancy can resolve

Image obtained from: http://www.kohtukuolema.fi
Fetal Risks

- Rupture of a fetal vessel is rare, but can quickly lead to fetal death
- Important to check for presence of fixed pulsating vessels near the cervix (<2 cm) – which may represent vasa previa

US diagnosis of vasa previa

These authors recommend triage w/ cervical length & placental edge thickness:

- Low lying placenta 1-2cm: Cesarean at 37-38 weeks if thick edge or CL <25mm
- Placenta previa: Earlier cesarean if thick edge or CL <15mm
- Vasa Previa: Cesarean 35-36 wks if CL >25mm; Hospitalize if CL <25mm; Consider delivery if CL <15mm

SMFM et al AJOG 2015
Practice guidelines

• Screen at the anatomy US: placental location, PCI
• If previa / low lying placenta repeat TV US at 32 weeks
• If vasa previa:
  » Consider corticosteroids at 28-32 weeks
  » Consider hospitalization ~30-34 weeks
  » Cesarean scheduled 34-37 weeks or if PPROM/PTL
  » Delivery at a center capable of neonatal transfusion

SMFM, AJOG 2015

PLACENTAL ABRUPTION

Abruption Risk Factors

• Smoking
• Cocaine
• Multiple gestation
• PROM
• Chronic hypertension
• Preeclampsia
• Oligohydramnios
• Chorioamnionitis
• Abdominal trauma
Abruption

- Occurs in about 1% of deliveries
- 10-15% recurrence risk
- Clinical diagnosis
  - US not very sensitive
  - Classic Presentation
    - Painful, sudden pain
    - Non-clotting blood
    - Fetal compromise
    - DIC

Hematoma between chorion & uterine wall

Abruption

Retroplacental hematoma with subchorionic component

Hematoma between placenta & amnion

Resolving hematoma

CHORIOANGIOMA
Chorioangioma

- Most common placental tumor
  - Frequently near placental cord insertion
- Usually don’t impact pregnancy but increased perinatal risk if > 5 cm
  - IUGR
  - Hydrops
  - Polyhydramnios
  - Abruptio
  - Preterm delivery
- Differential diagnosis: hemorrhage, teratoma, partial mole, myoma, rare tumors/neoplasms
- Serial US if >4-5 cm

- SINGLE UMBILICAL ARTERY
Single umbilical artery

1-3% of pregnancies

SUA, aka 2-vessel cord

- Risk of structural defects
  - Renal 3x increase
  - Cardiac 20x increase
  - Thick NT
- IUGR 2x increase
  - If isolated?? OR 1.6 (1.0-2.6)
- Aneuploidy risk if non-isolated
  - T18, T13

- Management
  - Comprehensive anatomy US
  - Growth US 30-32 wks
  - If non-isolated, offer genetic counseling & screening or diagnostic testing
  - Good prognosis if isolated

UMBILICAL CORD CYST
Umbilical cord cyst

Sonoluscent area adjacent to the cord without blood flow

Zangen et al, Ultrasound Obstet Gynecol 2010

Cord cyst

• No adverse pregnancy outcome if resolve by 14 weeks
• If persists into 2nd/3rd trimester, increased risk for:
  » Structural abnormalities (cardiac, abd wall defect)
  » IUGR
  » Chromosome abnormalities (if not isolated)
• If persists, detailed fetal anatomy ultrasound
• If IUGR or co-existing defects, offer genetic screening/testing
UMBILICAL VEIN VARIX

Umbilical vein varix

- 1/1000; in the fetus or cord
- Definition = >9mm diameter or > 2SD for EGA or >50% larger than non-dilated portion
- Differential Dx: stomach, bladder, GB, intra-abdominal cysts (eg, mesenteric), cord cysts
- Associated defects (20%), IUGR, chromosome abnormalities (5-20%)
- Usually isolated ONLY NON-ISOLATED UVV

- Intra-abdominal varix
- Must use color and pulse wave Doppler to confirm the diagnosis

- di Pasquo et al 2017
Umbilical vein varix

- Extra-abdominal varix
- Management of UVV
  - Comprehensive US
  - Offer genetic amnio if other anomalies seen
  - Growth US 30-32 wks
  - Antenatal fetal testing?
    - IF IUGR

Any questions?

2018 ANNUAL MEETING
April 20-22, 2018 | Omni Grove Park Inn Resort | Asheville, NC

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References


