Obstetrical Doppler to evaluate the at risk fetus: Basic to Advanced

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Lecture Outline

- Doppler principle
- Optimization techniques
- Discuss Doppler interrogation of various fetal vessels and normal and abnormal waveforms
- Understand Cerebroplacental ratio and its potential applications
- Review fetal venous circulation and discuss Doppler applications

I have no disclosures
Christian J. Doppler (1803-1853)

- Austrian mathematician and physicist
- 1842 (age 38) published work: observed frequency of a wave depends on the relative speed of the source and the observer
- Later coined “Doppler effect”

Doppler Equation

\[ fd = \frac{2(fc \cos A \cdot V)}{c} \]

- \( fd \): Doppler effect (Doppler shift)
- \( fc \): transmitted frequency
- \( A \): cosine angle of incidence between ultrasound beam and the direction of blood flow
- \( V \): speed of red blood cells
- \( c \): speed of sound propagation in tissue

Doppler Equation: Angle of Insonation

<table>
<thead>
<tr>
<th>Angle</th>
<th>Cosine</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 degrees</td>
<td>1</td>
</tr>
<tr>
<td>60 degrees</td>
<td>0.5</td>
</tr>
<tr>
<td>90 degrees</td>
<td>0</td>
</tr>
</tbody>
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Magnitude of the shift depends the angle!

Maulik, Doppler Ultrasound in Obstetrics and Gynecology, 2nd ed., 2006

Doppler Indices

- Peak forward velocity during ventricular systole: **S-wave**
- Peak forward velocity during early diastole: **D-wave**
- Time averaged max velocity: **M**

Maulik, Doppler Ultrasound in Obstetrics and Gynecology, 2nd ed., 2006
Pulsatility index = S-D/M
Resistive index = S-D/S
Systolic/Diastolic ratio = S/D

Doppler Optimization Techniques

Doppler Optimization Tips:

- Insonation angle
- Absence of fetal movement and breathing
- Optimize sweep speed
- Adjust wall filter
- Measurements should be reproducible
- Avoid inverting Doppler display
- Update frequently

Record Doppler in Absence of Fetal Breathing

Correct: Fetal movements and breathing
Sweep speed

Slow sweep speed  Fast sweep speed

Better: Sweep speed 4-6 waveforms (no more than 8-10)

Pulse repetition frequency and Baseline

Incorrect: Aliasing, sweep speed

Increased PRF
Adjust PRF, baseline, sweep speed appropriately

- Baseline shift
- Sweep speed 4-6 waveforms (no more than 8-10)

Wall motion filter
Eliminates noise from movement of vessel walls
Should be set as low as possible (~60 Hz)

Wall motion filter
Incorrect WMF (too high)
Mimicking absent end diastolic flow

Avoid using Doppler invert
Use conventional color Doppler settings
Obstetrical Doppler Applications:

- Growth delay
- Fetal anemia
- Hydops
- Monochorionic twins
- Fetal echocardiography

Doppler assessment is the only non-invasive in utero method for assessing fetal/placental hemodynamic status.

Uterine Artery Doppler

Placental/Uterine Anatomy

- Uterine artery supplies blood to the uterus
- Arises from the anterior division of the internal iliac artery
- Crosses anterior to the ureter, through cardinal ligament, through the inferior portion of the broad ligament to reach the uterus
Placental/Uterine Vasculature

- Physiologic changes are complete by 24 weeks gestation converting the utero-placental circulation from a high to a low resistance system.
- Failure of this process beyond 24-26 weeks results in high resistance blood flow in the utero-placental circulation and is associated with the development of preeclampsia, SGA, and IUGR.
- Abnormal uterine artery Doppler is a marker for defective remodeling of the spiral arteries.

ACOG/SMFM does not recommend any screening to predict pre-eclampsia beyond taking a medical history……

- Addition of serum and ultrasound markers yielded a Low PPV
- Cost/benefit to additional screening/testing (parental anxiety, additional appts, increased surveillance, etc)

Indications for UtA Doppler

- Abnormal serum analytes
- History of severe pre-eclampsia
- Abnormal placenta
- IUGR

Uterine artery Doppler technique:

- Start in a sagittal orientation at the lower uterine segment
- Sweep laterally to visualize the right/left side of the uterus
- Use color Doppler to visualize the uterine artery (UtA) as it crosses the external iliac artery
- PW Doppler gate should be placed at UtA “take off”
Uterine artery Doppler technique

- Normal uterine artery waveform
  - High diastolic velocities (low PI)
  - Absence of early diastolic notch

- Measure PI (manual or auto trace)
- Report both measurements independently for right and left sides
- Presence of notching should be noted
- Normal PI < 1.6

(UOG 2001; 18: 441-449)
Abnormal Uterine Artery Waveform (beyond 24-26 weeks)

- Elevated PI
- Early diastolic notch

Normal for comparison

Abnormal UtA Doppler:
Diastolic notch

- Subjective interpretation
- Notch is characteristic of vessels having resistance

Case: “G”

- 24 yo G2P1 at 30 weeks
- LMP dated and confirmed by first trimester ultrasound
- Prior outside ultrasounds at 24 and 28 weeks with progressively lagging growth profile
- Elevated inhibin 4.79 MoM
- History of one prior term delivery at 37 weeks (4 lb infant!)
- Normal screen for T21, T18
- Of note, patient is small - 97 lbs

Patient “G”
Abnormal Uterine Artery Waveform
30 weeks GA

RT PI= 1.91
LT PI= 1.64
Growth ???

Abnormal….

symmetric IUGR; EFW <3%

Umbilical Artery Doppler

- Assess resistance to fetoplacental blood perfusion
- Normal low impedance circulation with progressive increasing end diastolic flow
- Maternal/placental conditions may obliterate small arteries in placental tertiary stem villi
- Severe disease may lead to progressive decrease in end diastolic flow — Absent — REDV

Primary monitoring tool when FGR is suspected

Umbilical artery Doppler

- Value
- Range
- Age
- GP
- AFI normal = 12 cm
1. Placental end = highest diastolic flow velocity = lowest impedance

2. Free loop => *most measure here for ease and consistency

3. Fetal end => highest impedance (abnormalities typically occur here first)
   - Reference ranges for each site have been published
   - Avoid compression between extremities or uterine wall

UA Doppler Technique:

- Select free floating loop
- Color box
- Place the Doppler gate over UA (adjust gate size to include only UA)

Normal UA Doppler during pregnancy

- Low resistive waveform
- Forward flow in diastole
- Diastolic flow increases as pregnancy progresses

20 wks
26 wks
36 wks

Absent/reverse end diastolic flow reflects substantial placental vascular pathology:

UA Doppler indices become critically abnormal when ~60-70% of the placental vascular tree is not functioning

Abnormal UA Progression

28 wks normal S/D 3.3

30 wks elevated S/D 5.06

32 wks absent EDF

33 wk REDV

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Patient “G” UA Doppler
30 weeks GA (>95%)

S/D = 5.06
PI = 1.66

Middle Cerebral Artery Doppler
MCA

- Most accessible cerebral vessel
- Carries >80% cerebral blood flow
- Normal high-impedance with forward flow throughout the cardiac cycle
- Peak systolic velocity used to predict moderate-severe fetal anemia
- Fetal hypoxia causes redistribution of blood flow to the brain -“brain sparing”

**Anatomy of the Middle Cerebral Artery**

- MCA
- PCA
- ACA

**MCA technique**

- Obtain transverse plane of the fetal head including the thalamus and sphenoid bones
- Avoid excess pressure on the fetal head

**TIP:** use directional independent Doppler
MCA technique

Angle of incidence ~ close to 0 degrees as possible!

MCA technique

- Magnify image
- Place Doppler gate at the proximal portion of the vessel

MCA Interpretation

- The waveforms should be similar to each other
- Normal high resistance waveform
- Record at least 3 waveforms, but less than 10
- MCA - PSV for detection of fetal anemia - 100%
- Decreased RI/PI can be used to assess for brain sparing

UOG 2013; 41: 233-239
TIP: Avoid unnecessary pressure on the fetal head

**CORRECT:**

w/o pressure:  
PSV 35.16 cm/s

**INCORRECT:**

with pressure:  
PSV 45.40 cm/s

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**Case “G”**

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**Patient “G”: MCA Doppler**

- Brain Sparing
- Decreased RI/PI

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**Cerebroplacental Ratio (CPR)**

- Normal for comparison

- UA Doppler 30 weeks
What is the cerebroplacental ratio (CPR)?

Short answer:

- Middle Cerebral Artery Pulsatility Index / Umbilical Artery Doppler Pulsatility Index
- Predicts fetuses at risk for adverse outcomes using MCA and UA together rather than as separate variables

What is a normal CPR?

Short answer:

≥ 1

Longer answer:

- CPR studied in various scenarios
- Normal has been defined in multiple ways
- Normograms exist
- Cutoff of 1 correlates well with outcomes
In IUGR, abnormal CPR is associated with:

1. Lower gestational age at birth
2. Lower mean birthweight
3. Lower birthweight centile
4. Birthweight < 10th centile
5. Higher rate of C/S for fetal distress in labor
6. Higher rate of Apgar scores less than 7 at 5 minutes
7. Increased rate of neonatal acidosis
8. Increased rate of NICU admissions
9. Higher rate of adverse neonatal outcome
10. Greater incidence of perinatal death


When should CPR be obtained?

- In IUGR fetuses as part of serial screening Doppler studies
- In normally grown fetuses ???

Case 1

- 25 yo G1P0 with asymmetric IUGR (5th percentile), oligo (AFI 4), and increased UA S/D ratio at 24 weeks
- Elevated inhibin 2.69 MoM
- Negative NIPT
- Developed intermittent absent end diastolic flow at 26w5d
- Declined inpt monitoring until 28 weeks
- US: 3 x weekly Dopplers, BPP
- Reversed end diastolic flow at 30w1d prompting delivery

Normal CPR of 1.31 at 28w5d, IAEDF

MCA PI= 2.08

UA PI= 1.59

AFI = 3.5 cm
BPP = 8/8
Abnormal CPR of 0.89 w/ IAEDF at 29w5d

Abnormal CPR of 0.89 w/ IAEDF at 29w5d

PI = 1.44
PI = 1.62

BPP = 8/8
AFI = 3.5 cm

No CPR calculated; this scan prompted delivery at 30w1d

No CPR calculated; this scan prompted delivery at 30w1d

MCA
PI = 1.83

UA
IREDF

AFI = 1.5 cm
BPP = 6/8
Frequent decels

Outcome

- Delivered by c/s at 30w1d, weighed 1021g
- Placenta small, hypermature, <10th percentile; thrombotic vasculopathy
- Intubated x 4 days
- nCPAP until DOL 21
- Oxygen via nasal cannula until DOL 47, diagnosed w/ chronic lung disease
**Outcome**

- D/C home on oxygen at 7 weeks old; 1979g
- 9 months chronological age F/U:
  - 2 x/ week early intervention/developmental support program
  - Growth: normal
  - Below average speech and language skills
  - Suspicious findings on neurological assessment

Now almost 2 years of age (no recent assessment due to insurance issues)

**Case 2**

- 35 year old G11P1273 diagnosed with IUGR at 25 week ultrasound (3rd percentile)
- History of severe preeclampsia
- Bilateral abnormal ut artery Doppler at 22 weeks
- No analytes
- Negative NIPT
- Admitted for IUGR (< 1st percentile) with elevated S/D ratio at 28 weeks

**IUGR + Lagging growth over serial scans + abnormal Dopplers**

Patient admitted after this scan

**CPR 1.04 at 28 wks**
Delivered at 28w4d for IREDF and NRFHT – no CPR calculated

Outcome

- Delivered by cesarean at 28w4d weighing 941g
- Placenta small, hypermature, <10th percentile; decidual vasculopathy
- Intubated x8 days, then CPAP until DOL 50
- Anemic - received transfusions in NICU

Outcome

- Discharged to home at 11 weeks old, weight of 2844g, on nasal cannula 02 until 10 months of age
- Follow up w/ pulmonology - dx chronic lung disease
- Now almost 2 years chronological age:
  - Normal growth, neurological exam
  - Average cognitive and motor skills

Ductus Venosus Doppler
**Ductus venosus**

- Short, funnel shape
- Located at the junction of the portal sinus
- Functions to shunt highly oxygenated UV blood flow directly to the heart

Mavrides et al, JUM 18: 598-604, 2001

**DV Doppler Technique**

- Mid-sagittal longitudinal plane or transverse plane through the upper fetal abdomen
- Use color Doppler
- Velocity scale should be lowered (~30-50 cm/sec)
- Aliasing can be a good thing

**DV Doppler Technique**

- DV normally shunts 20-50% of UV flow away from the liver and towards the heart
- Pulsatility index decreases w/ advanced gestation
- Fetal stress (hypoxemia or placental insufficiency) - DV shunts a greater portion away from the liver
  - Adaptive mechanism to preserve highly oxygenated blood streaming toward LA/LV

Mavrides et al, JUM 18: 598-604, 2001

Decrease scale = 35 cm/sec
Color scale = 77 cm/sec

Aliasing can be a good thing......
Place Doppler gate within DV at “take off”

Normal Ductus Venosus
Continuous forward flow throughout the cardiac cycle

S= Ventricular systole
D= Early Diastole
A= Late Diastole (atrial kick)

Abnormal Ductus Venosus Doppler
Decreased, absent, or reversed A wave flow may represent:
- Myocardial impairment
- Increased right ventricular afterload due to increased RV end diastolic volume (CHD)
- Seen in IUGR fetuses

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Patient “G” DV Doppler at 30 weeks

OUTCOME

- Admitted for BMZ course and evaluation for preeclamsia, TORCH titers
- Discharged 30 6/7 weeks: 2 X weekly NST and Doppler
- Patient did not realize she was supposed to do Dopplers so she never got them……
- 32 weeks sent to L&D for oligo and NRFHT

OUTCOME

- Delivered by c-section at 32 weeks due to NRFHT and oligohydramnios
- Infant weighed 876 g
- Admitted to NICU, RDS requiring intubation x 2 day, CPAP x 2 days
- Normal head ultrasound, hearing exam
- Discharged at 6 weeks old, 2020 grams

OUTCOME

- Now 2 years old
- Several upper respiratory infections
- Below average language, cognitive, fine motor scores
- OT/PT/Speech therapy
- Abnormal growth: failure to thrive (<1%)
Umbilical Vein Doppler

- Carries oxygenated blood from placenta to fetus
- Highest oxygen saturation in the fetal circulation
- In liver, UV branches into 1) ductus venosus and 2) portal vein

Gotsch, F. Doppler interrogation in the fetal circulation; Sonography in Obstet and Gyn., 7th ed. 2011

Umbilical Vein Technique

- UV can be sampled in a free floating loop or intra-abdominal portion
- Intra-abdominal portion should be sampled ~ 1 cm beyond ACI insertion site
- Sample UV in absence of fetal breathing

Umbilical Vein pulsations

- UV pulsations may be physiologically present in 1st trimester
- Transient pulsations can be seen in normal fetuses
- May be seen with fetal cardiac dysfunction, karyotype abnormalities, hydrops, hyper-coiled cord, brady/tachy arrhythmias
- If seen with IUGR or SGA: increased risk for IUFD, fetal acidemia, neonatal death

Gotsch F. Sonography in Obstet & Gynecol. 7th ed. 2011
Umbilical Vein Doppler Interpretation

- Qualitative assessment: Pulsations
  - Normal UV monophasic
- Quantitative assessment: Velocity
  - IUGR: Progressive reduction of UV flow over time

Conclusions

- Doppler assessment is the only non-invasive method to assess fetal well being
- Understanding normal anatomy and proper technique is important in order to obtain accurate Doppler waveforms
- Addition of fetal venous Doppler could help identify the critically ill fetus

Thank you!