Doppler in Obstetric Management: How to Interpret the Reports You Get

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Disclosures
• I have no disclosures to make

Outline
• Review of physics and physiology
• Uses in obstetrics:
  — IUGR
  — Fetal anemia
  — Twin-to-twin transfusion syndrome
  — Experimental Uses
    • IUGR or Preeclampsia Prediction
    • TAPS

Physics
Physics

Qualitative Doppler

Quantitative Doppler

Please note: the ‘squishing’ of the wave-fronts in the middle diagram and the stretching in the lower diagram are exaggerated. Realistically the Doppler shifts are so small in ultrasound you would hardly see any difference in the wave-fronts compared to the unshifted one on top. These are artists’ diagrams.
Fetal Circulation

Use of Doppler in IUGR

- Is IUGR due to placental insufficiency?
- Will this placental insufficiency lead to stillbirth?

- Placental insufficiency caused by loss of villous vasculature (microthrombi)
- Loss of villous vasculature -> increased placental resistance
- Umbilical artery resistance reflects placental resistance

Normal UA Doppler

Definitions

- PSV: Peak Systolic Velocity
- EDV: End Diastolic Velocity
- MDV: Mean Diastolic Velocity
- TAPV: Time Averaged Velocity
- S/D= PSV/EDV

- RI: Resistance Index
  = (PSV-EDV)/PSV
- PI: Pulsatility Index
  = (PSV-EDV)/TAPV
Placenta/Doppler Relationship

- 30% loss of villous vasculature -> ↑S/D ratio
- 60-70% loss of vasculature -> absent EDF
- Rigid placental circulation with elastic component -> reversed EDF

Doppler Dance

Normal UA Doppler

Umbilical Artery S/D Ratio: 2.2

Evolution Over Time
Evolution over time (PI)

![Graph showing evolution over time (PI)](image1)

Figure 3 Scatterplot of the mean uterine artery pulsatility index (PI) measured by transvaginal (○) and transabdominal (●) ultrasound examination vs. gestational age in our population. Estimated 5th, 50th and 95th centiles are shown.


Elevated S/D Ratio

![Image showing elevated S/D ratio](image2)

Umbilical Artery S/D Ratio: 4.9

Absent EDF

![Image showing absent EDF](image3)

Reversed EDF

![Image showing reversed EDF](image4)
Sequence of Doppler Abnormalities

- UA PI >90th percentile
- Cerebroplacental ratio or MCA PI >95th percentile
- Absent or reversed A-wave ductus venous
- Aortic outflow and ductus venous PI >95th percentile
- Pulsatile umbilical vein
- CTG and biophysical profile abnormalities
- Fetal acidemia and stillbirth

Doppler Evaluation of IUGR: Middle Cerebral Artery (MCA)

- Higher resistance circulation
- “Brain Sparing”
  - Preferential shunting of blood to the fetal brain leading to lower S/D ratios

MCA S/D Ratio: 4.7

Clinical Utility of Brain Sparing?

- CPR – Cerebro-Placental Ratio (MCA/UA PI)
  - Investigational
  - May better predict poor outcomes, but may also lead to more prematurity
  - Defined as CPR of <5th %ile for GA
- Reversal of Compensatory Flow
  - May be “terminal event”
  - Reported in case series

Neonatology 2015;108:269-276
Ductus Venosus

- From proximal umbilical vein into IVC
- Narrow aperture causes high flow of oxygenated blood into foramen ovale (and into left heart for circulation)

Sequence of Doppler Abnormalities

1. Absent end diastolic flow UA
2. Absent or reversed A-wave ductus venosus
3. Pulsatile umbilical vein
4. Aortic inhomus and ductus venosus PI > 90th percentile
5. Absent diastolic flow UA
6. Doppler and biophysical profile abnormalities
7. Atrial wave ductus venosus
8. Fetal anaemia and stillbirth

Ductus Venosus

<table>
<thead>
<tr>
<th>Finding</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal waveform</td>
<td></td>
</tr>
<tr>
<td>Absent a-wave</td>
<td>Abnormal late-diastolic filling</td>
</tr>
<tr>
<td>Reversed a-wave</td>
<td>Abnormal late-diastolic filling</td>
</tr>
</tbody>
</table>
Reasons for abnormal DV waveform

- (1) the massive increase in placental afterload
- (2) the decreased myocardial performance and compliance due to myocardial hypoxia
- (3) the autoregulatory increase in the DV diameter allowing an increase in the fraction of shunting

Utility of DV measurement

- No RCTs
- SMFM: “The umbilical artery is the preferred vessel to interrogate by Doppler flow velocimetry to guide management in pregnancies complicated by suspected IUGR, given lack of randomized trials using Doppler studies of other vessels”
- Awaiting TRUFFLE results

Risk of Stillbirth

<table>
<thead>
<tr>
<th>Perinatal outcome Measure</th>
<th>Number of Studies</th>
<th>Normal</th>
<th>Absent/Reversed EDF</th>
<th>Elevated DV index</th>
<th>Reversed DV A-wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adverse perinatal outcome 14</td>
<td>3.15 (0.19, 4.34)</td>
<td>1.9% (6/315)</td>
<td>5.9% (6/101)</td>
<td>25% (51/202)</td>
<td>24% (8/34)</td>
</tr>
<tr>
<td>Subgroups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antenatal</td>
<td>6</td>
<td>2.74 (1.70, 4.39)</td>
<td>0.58 (0.30, 1.06)</td>
<td>0.88 (0.50, 1.57)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Antepartum</td>
<td>5</td>
<td>3.08 (2.03, 4.64)</td>
<td>0.88 (0.50, 1.57)</td>
<td>0.34 (0.15, 0.78)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Stillbirth</td>
<td>2.8</td>
<td>3.08 (2.03, 4.64)</td>
<td>0.88 (0.50, 1.57)</td>
<td>0.34 (0.15, 0.78)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Perinatal mortality</td>
<td>6</td>
<td>4.21 (0.89, 18.08)</td>
<td>0.53 (0.25, 1.12)</td>
<td>0.34 (0.15, 0.78)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Neonatal death</td>
<td>3</td>
<td>2.05 (1.03, 3.98)</td>
<td>0.57 (0.25, 1.32)</td>
<td>0.34 (0.15, 0.78)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Interventricular hemorrhage</td>
<td>2</td>
<td>1.48 (0.06, 4.82)</td>
<td>0.09 (0.04, 1.46)</td>
<td>0.09 (0.04, 1.46)</td>
<td>0.09 (0.04, 1.46)</td>
</tr>
<tr>
<td>Nuchal translucency</td>
<td>3</td>
<td>2.94 (1.26, 7.07)</td>
<td>0.58 (0.25, 1.32)</td>
<td>0.34 (0.15, 0.78)</td>
<td>0.34 (0.15, 0.78)</td>
</tr>
<tr>
<td>Nuchal translucency serial</td>
<td>3</td>
<td>1.56 (0.45, 5.37)</td>
<td>0.09 (0.04, 1.46)</td>
<td>0.09 (0.04, 1.46)</td>
<td>0.09 (0.04, 1.46)</td>
</tr>
<tr>
<td>Neonatal mortality</td>
<td>1</td>
<td>2.36 (1.08, 4.82)</td>
<td>0.18 (0.08, 1.41)</td>
<td>0.09 (0.04, 1.46)</td>
<td>0.09 (0.04, 1.46)</td>
</tr>
<tr>
<td>Apgar 5 minutes &lt; 7</td>
<td>1</td>
<td>6.8 (1.39, 10.08)</td>
<td>0.79 (0.32, 1.99)</td>
<td>0.79 (0.32, 1.99)</td>
<td>0.79 (0.32, 1.99)</td>
</tr>
<tr>
<td>Apgar 1 minute &lt; 7</td>
<td>1</td>
<td>23.9 (7.17, 4.72)</td>
<td>0.79 (0.32, 1.99)</td>
<td>0.79 (0.32, 1.99)</td>
<td>0.79 (0.32, 1.99)</td>
</tr>
</tbody>
</table>

Cochrane Review:
29% reduction of perinatal death
(1.2% vs 1.7%, NNT: 203)

10% reduction in induction and cesarean

Ultrasound Obstet Gynecol 2004; 23 : 111 – 118
Alfirevic et al, Cochrane Database Syst Rev 2010
SMFM Algorithm

Doppler Surveillance in IUGR

- Frequency of repetition?
  - Weekly to q2-4 weeks
    - UCSF does weekly, as long as there is forward flow
  - More frequently (2-3x/week) if oligo, absent or reversed flow
    - Hospitalization? No guidance.
    - SMFM: reasonable if more than 3x/week NST
      - Twice weekly NST with weekly AFI

Uterine Artery Dopplers to identify pregnancies at risk for IUGR?

- SMFM: Not recommended
- RCOG: Performed at 20-24 weeks for “high risk patients”
  - 3+ risk factors, include: AMA, nulliparity, obesity, IVF
  - If abnormal (defined as a pulsatility index [PI] > 95th centile) and/or notching) then schedule serial US and Dopplers

Choosing Wisely

Society for Maternal-Fetal Medicine

Five Things Physicians and Patients Should Question

Don't screen for intrauterine growth restriction (IUGR) with Doppler blood flow studies.

Studies that have attempted to screen pregnancies for the subsequent occurrence of IUGR have produced inconsistent results. Furthermore, no standards have been established for the optimal definition of an abnormal test, best gestational age for the performance of the test or the technique for its performance. However, once the diagnosis of IUGR is suspected, the use of antenatal fetal surveillance, including umbilical artery Doppler flow studies, is beneficial.
MCA Dopplers in Anemia

Fetal Anemia

- Increase in cardiac output
- Increased blood velocity*
- Decrease in blood viscosity

*Measureable by Doppler velocimetry

MCA PSV

Angle = 0

MCA SV

PSV
Angle of insonation should be as close to 0 as possible

- Use angle correction if more than 10°, but this can introduce error
- Report should mention if angle correction used

Management of MCA PSV

<table>
<thead>
<tr>
<th>Categories</th>
<th>Cause</th>
<th>Potential causes of fetal anemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immune</td>
<td>RBC alloimmunization:</td>
<td>Rh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Atypical antigens</td>
</tr>
<tr>
<td>Infectious</td>
<td>Parvovirus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CMV</td>
<td>Toxoplasmosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Syphilis</td>
</tr>
<tr>
<td>Inherited</td>
<td>( \text{Lysosomal storage diseases (e.g., \text{Mucopolysaccharidosis type VII, Niemann-Pick disease, Gaucher disease})} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \text{Blackfan-Diamond anemia} )</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Anemia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTTS (Twin anemia-polyhydramnios sequence)</td>
<td></td>
</tr>
</tbody>
</table>

Management of Suspected Alloimmunization

- Maternal antibody titer (indirect Coombs) > critical value

  - **Fetus’ father’s genotype**
    - **Homzygous**
    - **Negative for antigen, certain paternity**
    - **Heterozygous or not available**
    - **No other test necessary**
    - Free fetal DNA testing for Rh (D) status or amnioncentesis for fetal Rh (D) genotyping

- **Fetus: antigen negative**
- **Fetus: antigen present**

**PSV MoM and Anemia**

Fig. 2. MCA-PSV in 111 fetuses at risk for anemia because of maternal red cell alloimmunization. Open circles indicate fetuses with either no anemia or mild anemia (0.80 MoM hemoglobin concentration). Triangles indicate fetuses with moderate or severe anemia (>0.50 MoM hemoglobin concentration). The solid circles indicate the fetuses with hydrops. The solid squares indicate the median MCA-PSV, and the shaded square indicates 1.6 MoM. Reproduced with permission from: Management of suspected alloimmunization. Pediatrics in Review 2004;25(10):342-348.
**Management of MCA PSV**

- TTTS (Twin-Twin Transfusion Syndrome)
  - Dopplers define Stage III:
    - absent/reversed EDV in the UA
    - reversed flow in a-wave of the DV
    - or pulsatile flow in the umbilical vein in either fetus.

- TAPS (Twin Anemia Polycythemia Sequence)
  - MCA PSV of >1.5 MoM in one, <1.0 MoM in another
  - Transfusion?

**Monochorionic Twins**

- **TTTS (Twin-Twin Transfusion Syndrome)**
  - Dopplers define Stage III:
    - absent/reversed EDV in the UA
    - reversed flow in a-wave of the DV
    - or pulsatile flow in the umbilical vein in either fetus.

- **TAPS (Twin Anemia Polycythemia Sequence)**
  - MCA PSV of >1.5 MoM in one, <1.0 MoM in another
  - Transfusion?


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**Uterine Artery Doppler?**


**Uterine Artery Dopplers for Preeclampsia Prediction**

**Preeclampsia Prediction?**

- Doppler Review
  - IUGR
    - Umbilical Artery
      - S/D Ratio, Absent/Reversed End Diastolic Flow
        - Follow SMFM algorithm
    - MCA
      - Brain sparing if S/D ratio is LOW, CPR reported
        - Informational, not to determine management
  - Ductus Venosus
    - Absent or reversed a-wave
      - May determine management, but not standardized

- Anemia
  - Middle Cerebral Artery
    - PSV >1.5 MoM (corrected for GA)
      - Determines need for PUBS, maybe transfusion
  - Twin Twin Transfusion Syndrome
    - UA, DV
      - Any abnormality = Stage III

- IUGR prediction
  - Uterine Artery in 2\textsuperscript{nd} trimester
- Preeclampsia prediction
  - Uterine Artery in 1\textsuperscript{st} or 2\textsuperscript{nd} trimester
- Twin Anemia Polycythemia Sequence
  - MCA PSV >1.5 MoM
  - Significance and management unclear

**Experimental Uses of Doppler**

- Prediction of Pre-eclampsia & Other Obstetric Complications by Serum Homocysteine & Doppler
  - Conditions: Pre-eclampsia; IUGR
  - Intervention: Drug; Aspirin; Drug; Placebo
- Prevention of Pre-eclampsia and SGA by Low-Dose Aspirin in Nulliparous Women With Abnormal First-trimester Uterine Artery Doppler
  - Conditions: Pre-eclampsia; Intra-uterine Growth Restriction
  - Interventions: Drug; Aspirin; Drug; Placebo
- Prediction of Pre-eclampsia and Intrauterine Growth Restriction With Drug Therapy in Pregnancies Complicated by Pre-eclampsia
  - Condition: Pre-eclampsia; Fetal Growth Restriction
  - Interventions: Drug; Aspirin; Drug; Placebo
Thank you!