The Fetus: Five Top “Do Not Miss Diagnoses”

Giancarlo Mari, MD, MBA
Professor and Chair
Department of Obstetrics and Gynecology
University of Tennessee Health Science Center
Memphis, TN
Five Top “Do Not Miss Diagnoses”

- Head Compression
- Fetal Anemia
- IUGR and Preeclampsia
- Ductal constriction
- Ductus venosus and impending fetal demise
A Few Concepts in Doppler Ultrasound
Christian J. Doppler was an Austrian physicist who described the Doppler effect in 1842.

Doppler Formula

\[ F_d = \frac{2(F_c \times V \times \cos \alpha)}{C} \]
From a transducer, ultrasounds are emitted at a frequency $F_c$. When they hit a structure that moves (for example, blood flow) they are backscattered and return to the transducer at a different frequency. This different frequency is the Doppler shift ($F_d$). The Doppler shift increases as the velocity of the blood flow increases ($V$) and as the cosine of the angle ($A$) between the ultrasound beam and the direction of the blood flow increases. $C$ is a constant (velocity of the ultrasound in water: 1540 m/sec).
The Doppler shift arrives to the transducer. The information is analyzed, and it is presented as waveforms.

On the y-axis, there is the velocity value. Some of the old ultrasound equipment reported the Doppler shift on the y-axis.
There are 4 types of Doppler ultrasound

- Spectral Doppler. There are two types of spectral Doppler: Pulsed and Continuous
- Color flow Doppler
- Power Doppler
- Tissue Doppler shows tissue motion such as the cardiac wall movements
Direction of Blood Flow Toward the Transducer

The waveforms are represented above the baseline
Direction of Blood Flow
Away from the Transducer

The waveforms are represented below the baseline
Does the velocity value reported on the y-axis of this set of waveforms reflect the real velocity of the blood flow?

Based on what we said about the angle and the velocity, the answer is: “We do not know.” If the angle between the ultrasound beam and the direction of the blood flow was 0°, the answer is YES.

If the angle was not close to 0°, the answer is NO.
This slide shows the \( \cos \alpha \) values (horizontal lines) at different angles. When the angle is \( 90^\circ \), the \( \cos \alpha = 0 \). Therefore, the value of the Doppler shift becomes 0. If this value is 0, there is no waveform generated, and no velocity can be measured.

\[
F_d = \frac{2(F_c \times V \times \cos \alpha)}{C}
\]
It is not always easy to get an angle of $0^\circ$ between the ultrasound beam and the direction of the blood flow; therefore, the velocity cannot be accurately measured in all of the cases. This is the reason why we often use angle-independent indices to quantify the waveforms.
Angle-Independent Indices

\[
\frac{A}{B} = \text{A/B ratio (Stuart et al, 1980)}
\]

\[
\frac{A - B}{B} = \text{Resistance index (Pourcelot, 1974)}
\]

\[
\frac{A - B}{\text{Mean}} = \text{Pulsatility index (Gosling and King, 1975)}
\]
These indices are independent of the angle. Therefore, the values do not change significantly when the angle changes.

The following slides provide a few examples.
Angle Dependence

Angle 45°

Angle close to 0°
Angle Dependence

\[ fd = c \]

Flow is perpendicular to angle of incidence (\( \cos 90^\circ = 0 \))
Five Top “Do Not Miss Diagnoses”

Head Compression
MCA and Reversed Flow
Reversed flow at the MCA often is not pathologic; rather, it is due to compression of the transducer on the fetal head.

Causes of Reversal of Flow in the MCA

Excessive Transducer pressure

Impending fetal death

Cardiac anomalies (unpublished data)

Following fetal heart rate decelerations
Late and variables
Five Top “Do Not Miss Diagnoses”

Fetal Anemia
Doppler waveforms obtained in the same fetus at: A, middle cerebral artery; B and C, middle cerebral artery and anterior cerebral artery at their origin from the internal carotid artery; D and E, anterior cerebral artery; F, posterior communicating artery; G, posterior cerebral artery. The values indicate the pulsatility index.

The most studied artery of the Circle of Willis is the middle cerebral arterial (MCA).
Fetal middle cerebral artery velocimetry

The middle cerebral artery can be easily sampled with an angle of $0^\circ$, and the true velocity of the blood flow can be obtained. The peak systolic velocity (PSV) is the highest point of the waveform. Therefore, for the MCA, we can easily obtain the PI (angle independent) and the PSV (an angle close to $0^\circ$ is needed).
Middle Cerebral Artery Peak Systolic Velocity

Steps for the correct sampling of middle cerebral artery peak systolic velocity. The use of an angle corrector increases the intra- and inter-observer variability. Therefore, its use is not recommended.
Where Do We Need to Sample the MCA?
The sample volume should be taken soon after the origin of the middle cerebral artery from the internal carotid artery. The artery should be visualized for its entire length, and an angle corrector should not be used.

Middle Cerebral Artery

This graph represents the reference range of the middle cerebral artery PSV throughout gestation.

Gestational Age (weeks)
16 18 20 22 24 26 28 30 32 34 36
Hemoglobin (gr/dl)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
95
50
5
Moderate Anemia
Severe Anemia
Severe Anemia with risk of Hydrops
Mild Anemia


The graph shows the relationship between MCA-PSV (cm/s) and gestational age (weeks). The line indicates that a MCA-PSV of 1.5 MM is achieved at approximately 36 weeks of gestation.
Prospective Study on an Intention to Treat

- Multicenter study in 5 tertiary referral centers
- 125 fetuses at risk for anemia
- MCA-PSV used for timing a cordocentesis

Five Top “Do Not Miss Diagnoses”

Prediction of Preeclampsia and IUGR
Normal flow velocity waveforms of the uterine artery obtained in a normal pregnancy at 22 weeks’ gestation. We consider normal a pulsatility index $\leq 1.41$ at 20-24 weeks’ gestation.

By ~18 weeks, trophoblasts:
• Invade the inner 1/3 of the myometrium
• Migrate through spiral arterioles
• Spiral arterioles lose the elastic layer
• Vessels become maximally dilated

Brosens et al. Obstet Gynecol Annu 1972, 1:177
Pijnenborg et al. Placenta 1980; 1:3
Utero-Placental Vessels

Normal pregnancy

Preeclamptic and/or IUGR pregnancy

A, Normal. B, Abnormal. The arrows indicate the notching that is considered abnormal. However, the following slides will clarify why an index is preferable to the notching.

Q: What is the difference between A and B?

Q: What is the difference between A and B?

A: Speed of recording. Same patient shown; however, a notch appears in B but not in A.

1) At what GA should we perform Uterine artery Doppler?
   20-24 weeks’ gestation; 1st trimester

2) How do we evaluate the results?
   NPV very high
   PPV better for high risk patients

### Meta-analysis (1866 citation-18 studies)

55974 women

1st trimester uterine artery - Preeclampsia and IUGR

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>Early PE</td>
<td>48% (39-56)</td>
<td>92% (89-95)</td>
</tr>
<tr>
<td>Early IUGR</td>
<td>39% (26-54)</td>
<td>93% (91-95)</td>
</tr>
<tr>
<td>Any PE</td>
<td>26% (22-31)</td>
<td>93% (90-95)</td>
</tr>
<tr>
<td>Any IUGR</td>
<td>15% (12-19)</td>
<td>93% (91-95)</td>
</tr>
</tbody>
</table>

L Velauthar, et al UOG 2014;43:500-507
Five Top “Do Not Miss Diagnoses”

Ductal constriction
Indomethacin

- Ductal constriction and tricuspid regurgitation
- Oligohydramnios
Ductus Arteriosus Constriction

- It occurs in 50% of patients treated with indomethacin.
- In 10% of the cases, the effect is severe.
- The ductal constriction is reversible.

IUGR

• Breathing
• Transitional phase
• Umbilical vein and Ductus venosus
• Ductus venosus and sovrahepatic veins
Flow velocity waveforms of the umbilical artery in a normal fetus from 11 to 40 weeks. Note the diastole that increases with advancing gestation. This indicates that the placental vascular resistance decreases in the normal fetus with advancing gestation.

Reference ranges for the umbilical artery RI, A/B ratio, and PI.
Umbilical Artery: High placental vascular resistance
Gestational age (weeks)

MCA pulsatility index

MCA Waveforms at 24 Weeks

A = Normal

B = “Brain sparing effect”
Central Venous Circulation

Ductus Venosus

- Biphasic Doppler Waveform
- First phase ~ ventricular systole
- Second phase ~ early diastole
- Nadir ~ late diastole (atrial kick)
Ductus venosus

Hemodynamically, these phases (S, D, a) reflect the rapid chronologic change in pressure gradients between the umbilical vein and the right atrium.
Fetal Breathing
Umbilical Vein
What are the arrows pointing to?
Central Venous Circulation

**Ductus Venosus**

- Doppler index is S/A or S-A/A
- Reflect RV preload
Ductus Venosus
Is Ductus venosus reversed flow an indication for delivery?
DV Transitional Phase

DV RF

1 hour later

DV Transitional Phase

- Forward Flow
- Transitional Phase
- Reversed Flow

DV RF 21 days before IUFD

DV RF 9 days before delivery
What is the difference among the different sets of waveforms?
a. What is the SIA index and
b. What does it indicate?

a. Peak systolic velocity
Isovolumetric relaxation +
 a-wave

b. Myocardial function

Picconi et al J Ultrasound Med 2008;27:1283