ISUOG Basic Training
Umbilical and Uterine Artery Doppler Studies

Juriy Wladimiroff
Learning objectives

At the end of the lecture you will be able to:

• describe how to perform, assess and report an umbilical artery Doppler examination correctly

• describe how to perform, assess and report a Doppler examination of the uterine arteries correctly
Key questions

1. What technique is required to perform a clinically useful Doppler examination of the umbilical artery?

2. What are the main pitfalls to be aware of when using Doppler to sample the umbilical artery?

3. What technique is required to perform a clinically useful Doppler examination of both uterine arteries?

4. What are the main pitfalls to be aware of when using Doppler to sample the uterine arteries?
ISUOG Education Committee recommendations for basic training in obstetric and gynecological ultrasound

- umbilical and uterine Doppler

Second and third trimesters
- Determination of fetal position
- Assessment of fetal wellbeing, including fetal movements
- Amniotic fluid volume estimation and conditions associated with abnormal amniotic fluid volume
- Placental assessment, including relation to the internal cervical os
- Standard fetal biometry (biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur diaphysis length (FL)) and estimated fetal weight calculation
- Fetal growth and typical causes of abnormal fetal growth
- Fetal head (intact cranium, head shape, midline falx, cerebral ventricles, cavum septi pellucidi, cerebellum, cisterna magna) and typical anomalies
- Fetal face (orbits, nose and mouth in different planes) and typical anomalies
- Fetal thorax (lung morphology and relationship to heart size) and typical anomalies
- Fetal heart (situs, four-chamber view, outflow tracts, three-vessel view) and typical anomalies
- Fetal abdomen (stomach, liver with umbilical vein, kidneys and urinary bladder, diaphragm, bowel, abdominal wall and cord insertion) and typical anomalies
- Fetal spine in longitudinal and transverse planes and typical anomalies
- Fetal limbs (arms, hands, legs, feet) and typical anomalies
- Umbilical and uterine artery Doppler
ISUOG Practice Guidelines: use of Doppler ultrasonography in obstetrics

Some general rules before you start

- know your US equipment
- have some knowledge of fluid dynamics
- have some knowledge of hemodynamics
- have some knowledge of fetal physiology
- know what you want to measure
- know which indices to use
- know when and when not to use Doppler
Fetal circulation

- high heart rate
- low blood pressure
- low peripheral resistance (placenta)
- placental circulation constant (does not respond to vasoactive substances)
- with advancing gestation fetal BP and arteriolar placental bed flow increase, peripheral resistance decreases
Fetal and maternal vessels

Fetal side

- umbilical artery
- middle cerebral artery
- ductus venosus
- umbilical vein

Maternal side

- uterine arteries

Basic training
Indications for Doppler in pregnancy

Placentation
• trophoblast invasion of spiral arteries

Fetal well-being
• hypoxaemia
• anaemia
• chromosomal anomalies (1\textsuperscript{st} trimester)
• heart anomalies (heart function)
• MC twins
• placental abruption
• post-term pregnancies
• diabetes
Umbilical artery Doppler
1. visualise the cord, select a free loop, not too close to the fetal cord insertion or the placental insertion
2. zoom up/magnify the area of cord
3. switch on the colour Doppler modality (not compulsory)
3a. optimize the colour flow mapping (CFM) scale
Umbilical artery Doppler

4. place the sample gate on the umbilical artery
Umbilical artery Doppler

5. start the pulsed Doppler function
Umbilical artery Doppler

Laurin 1987
2D/pulsed Doppler

- 2D image in freeze mode provides better Doppler signals
Irregular umbilical artery flow velocity pattern due to fetal breathing movements
Umbilical cord Doppler

16 weeks

24 weeks

32 weeks

40 weeks

Resistance in the placenta falls progressively with advancing gestation.
Umbilical artery in pathological pregnancies

- high PI
- absent end diastolic flow
- reversed end diastolic flow
Abnormal UA findings

Elevated UA index

**Graph:**
- **Equation:**\[ y = -0.0246x + 1.7791 \]
- **Correlation coefficient:** \[ r^2 = 0.4025 \]

**Legend:**
- Positive EDV
- AEDV
- REDV

30% of villous vessels are underperfused
50% of villous vessels are underperfused
70% of villous vessels are underperfused

**References:**
Variation in umbilical artery waveforms

- there is a significant difference in Doppler indices when measured at the fetal end, in a free cord loop or at the placental end of the umbilical cord

- for the sake of simplicity and consistency, measurements should be made in a free cord loop

- in multiple pregnancies, and/or when comparing repeated measurements longitudinally, recordings from fixed sites (fetal end, placental end or intra-abdominal portion) may be more reliable

- reference ranges used should be appropriate for the site of interrogation
When is umbilical artery assessment indicated?

- reduced fetal growth velocity/fetal growth restriction (FGR)
- MC twins
- fetal hydrops
- EDF (+ve, absent or reversed) more sensitive than PI
Uterine artery Doppler
New doppler technique for assessing uteroplacental blood flow.
Campbell S, Díaz-Recasens J, Griffin DR, Cohen-Overbeek TE, Pearce JM, Willson K, Teague MJ.

Abstract
Gated, pulsed, doppler ultrasound was used to study blood flow velocity profiles in the uterine vessels (arcuate arteries) during the second and third trimesters of pregnancy. A frequency index profile nomogram was constructed from 30 normal pregnancies; this demonstrated high diastolic velocity and low pulsatility. Among 31 pregnancies with complications 14 showed waveform changes suggesting raised vascular resistance; these pregnancies were complicated with a high frequency of proteinuric hypertension, poor fetal growth, and fetal hypoxia. This non-invasive technique may give early warning of impaired uteroplacental perfusion and can be used to evaluate methods of improving uterine blood flow.

PMID: 6132039 [PubMed - indexed for MEDLINE]
Trophoblast invasion

Non-pregnant

Normal pregnancy

Preeclampsia

NK cell

Endometrium

Myometrium

Spiral Artery

ENV

EVT

Decidua

Placenta

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Uterine artery Doppler - technique

• trans-abdominally, the probe is placed longitudinally in the lower lateral quadrant of the abdomen, and angled medially

• colour flow mapping is useful to identify the uterine artery as it appears to cross the external iliac artery

• sample volume is placed ~1 cm downstream from the crossover point

• if the uterine artery branches before the intersection of the external iliac artery, the sample volume should be placed on the main artery just before the bifurcation
Uterine artery measurement
Normal uterine artery waveform
Abnormal uterine artery waveform

note notch (arrow) implying increased resistance in the uterine artery
Normal range uterine artery PI

Normal impedance to flow the uterine arteries in 1º trimester

Normal impedance to flow the uterine arteries in early 2º trimester

Normal impedance to flow the uterine arteries in late 2º and 3º trimester
Uterine artery screening at 22-24 wks

low risk for PE and IUGR

high risk for PE and IUGR
Abnormal uterine artery waveforms after 20-24 weeks
Uterine artery
Clinical applications
Constitutionally Small

no increased perinatal death or morbidity

AC < 10\textsuperscript{th} centile

Doppler

FGR

uteroplacental insufficiency
hypoxemia, acidosis

Soothill, 1999

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Doppler is associated with a 38% reduction in perinatal deaths

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment n/N</th>
<th>Control n/N</th>
<th>Peto Odds Ratio</th>
<th>Weight (%)</th>
<th>Peto Odds Ratio 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chester 1992</td>
<td>1/338</td>
<td>4/326</td>
<td></td>
<td>4.0</td>
<td>0.80 [ 0.05, 1.72]</td>
</tr>
<tr>
<td>Dublin 1992</td>
<td>4/241</td>
<td>3/235</td>
<td></td>
<td>5.6</td>
<td>1.30 [ 0.29, 5.78]</td>
</tr>
<tr>
<td>Edinburgh 1993</td>
<td>12/1132</td>
<td>16/1197</td>
<td></td>
<td>22.2</td>
<td>0.79 [ 0.38, 1.67]</td>
</tr>
<tr>
<td>Leeds() 1990</td>
<td>3/250</td>
<td>3/250</td>
<td></td>
<td>4.8</td>
<td>1.00 [ 0.20, 4.99]</td>
</tr>
<tr>
<td>London(Guys) 1994</td>
<td>11/236</td>
<td>14/231</td>
<td></td>
<td>19.1</td>
<td>0.76 [ 0.34, 1.70]</td>
</tr>
<tr>
<td>Maastricht</td>
<td>2/74</td>
<td>3/76</td>
<td></td>
<td>3.9</td>
<td>0.68 [ 0.12, 4.03]</td>
</tr>
<tr>
<td>Oxford 1991</td>
<td>4/438</td>
<td>8/459</td>
<td></td>
<td>9.5</td>
<td>0.53 [ 0.17, 1.67]</td>
</tr>
<tr>
<td>Perth() 1991</td>
<td>9/275</td>
<td>9/270</td>
<td></td>
<td>14.0</td>
<td>0.98 [ 0.38, 2.51]</td>
</tr>
<tr>
<td>Sweden</td>
<td>0/214</td>
<td>3/212</td>
<td></td>
<td>2.4</td>
<td>0.13 [ 0.01, 1.28]</td>
</tr>
<tr>
<td>Sydney 1987</td>
<td>1/127</td>
<td>5/162</td>
<td></td>
<td>4.7</td>
<td>0.32 [ 0.06, 1.65]</td>
</tr>
<tr>
<td>Tygerberg</td>
<td>6/108</td>
<td>7/104</td>
<td></td>
<td>9.9</td>
<td>0.82 [ 0.27, 2.50]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>3433</strong></td>
<td><strong>3532</strong></td>
<td></td>
<td><strong>100.0</strong></td>
<td><strong>0.71 [ 0.50, 1.01]</strong></td>
</tr>
</tbody>
</table>

Total events: 53 (Treatment), 75 (Control)
Test for heterogeneity chi square = 5.31 df = 10 p = 0.85 P = 0.00%
Test for overall effect z=1.88  p=0.06

Neilson JP The Cochrane library 2005, Issue 1
When are uterine artery measurements indicated?

- suspicion of placental insufficiency / FGR
- FGR in previous pregnancy
- mothers with LES, factor V Leiden or other factors related to poor placentation
Repeatability of transabdominal uterine artery measurement

Table 1: Studies assessing repeatability of uterine artery Doppler during pregnancy

<table>
<thead>
<tr>
<th>Reference</th>
<th>n</th>
<th>Doppler technique</th>
<th>Doppler index</th>
<th>Repeatability</th>
<th>Statistical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraobserver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schulman et al. 1986^10</td>
<td>NR</td>
<td>CW</td>
<td>S/D</td>
<td>4%</td>
<td>NR</td>
</tr>
<tr>
<td>Mulders et al. 1988^11</td>
<td>21</td>
<td>PW</td>
<td>PI</td>
<td>6.4%</td>
<td>CV</td>
</tr>
<tr>
<td>Gagnon et al. 1988^12</td>
<td>11</td>
<td>CW</td>
<td>S/D</td>
<td>6.1%</td>
<td>CV</td>
</tr>
<tr>
<td>Long et al. 1988^13</td>
<td>20</td>
<td>CW</td>
<td>PI</td>
<td>6%</td>
<td>CV</td>
</tr>
<tr>
<td>Oosterhof et al. 1992^14</td>
<td>15</td>
<td>PW</td>
<td>PI</td>
<td>10.8%</td>
<td>CV</td>
</tr>
<tr>
<td>Bower et al. 1993^15</td>
<td>5</td>
<td>Color</td>
<td>RI</td>
<td>7%</td>
<td>CV</td>
</tr>
<tr>
<td>Ferrier et al. 1994^16</td>
<td>5</td>
<td>Color</td>
<td>RI</td>
<td>4%</td>
<td>CV</td>
</tr>
<tr>
<td>Weissman et al. 1995^8</td>
<td>20</td>
<td>TV, CW</td>
<td>S/D</td>
<td>5%</td>
<td>CV</td>
</tr>
<tr>
<td>Chan et al. 1995^17</td>
<td>9</td>
<td>CW</td>
<td>PI</td>
<td>5.9%</td>
<td>CV</td>
</tr>
<tr>
<td>Harrington et al. 1997^18</td>
<td>10</td>
<td>TV, Color</td>
<td>PI</td>
<td>2.6%</td>
<td>CV</td>
</tr>
<tr>
<td>Liberati et al. 1997^19</td>
<td>5</td>
<td>Color</td>
<td>RI</td>
<td>5.1%</td>
<td>CV</td>
</tr>
<tr>
<td>Interoobserver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trudinger et al. 1985^20</td>
<td>10</td>
<td>CW</td>
<td>S/D</td>
<td>No difference</td>
<td>CV</td>
</tr>
<tr>
<td>Schulman et al. 1986^10</td>
<td>NR</td>
<td>CW</td>
<td>S/D</td>
<td>4%</td>
<td>NR</td>
</tr>
<tr>
<td>Mulders et al. 1988^11</td>
<td>13</td>
<td>PW</td>
<td>PI</td>
<td>11.1%</td>
<td>CV</td>
</tr>
<tr>
<td>Oosterhof et al. 1992^14</td>
<td>10</td>
<td>PW</td>
<td>PI</td>
<td>10.1%</td>
<td>CV</td>
</tr>
<tr>
<td>Bower et al. 1993^21</td>
<td>10</td>
<td>CW</td>
<td>RI</td>
<td>−0.24 to 0.28</td>
<td>95% prediction interval</td>
</tr>
<tr>
<td>Bewley et al. 1993^22</td>
<td>20</td>
<td>CW</td>
<td>RI</td>
<td>−0.18 to 0.22</td>
<td>93% prediction interval</td>
</tr>
<tr>
<td>Ferrier et al. 1994^16</td>
<td>8</td>
<td>Color</td>
<td>RI</td>
<td>6.6%</td>
<td>CV</td>
</tr>
<tr>
<td>Yan et al. 1995^23</td>
<td>20</td>
<td>TV, CW</td>
<td>S/D</td>
<td>−0.24 to 0.16</td>
<td>95% prediction interval</td>
</tr>
<tr>
<td>Weissman et al. 1995^8</td>
<td>20</td>
<td>TV, CW</td>
<td>S/D</td>
<td>8%</td>
<td>CV</td>
</tr>
<tr>
<td>Chan et al. 1995^17</td>
<td>8</td>
<td>CW</td>
<td>RI</td>
<td>13.6%</td>
<td>CV</td>
</tr>
<tr>
<td>Liberati et al. 1997^19</td>
<td>10</td>
<td>Color</td>
<td>RI</td>
<td>7.4%</td>
<td>CV</td>
</tr>
</tbody>
</table>

NR, not reported; CW, continuous wave; PW, pulsed wave; Color, color-flow Doppler; TV, transvaginal; S/D, systolic/diastolic ratio; PI, pulsatility index; RI, resistance index; CV, coefficient of variation.
Second-trimester uterine artery Doppler screening in unselected populations: a review

A. T. Papageorghiou, C. K. H. Yu, S. Cicero, S. Bower and K. H. Nicolaides

Harris Birthright Research Centre for Fetal Medicine, King’s College Hospital, London, UK

Table 2 Results of uterine artery Doppler screening studies for the prediction of pre-eclampsia, providing data on the definition of pre-eclampsia used, screen-positive rate, prevalence, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Screen-positive rate (%)</th>
<th>Prevalence (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albaiges et al., 2000</td>
<td>7.3</td>
<td>3.7</td>
<td>45</td>
<td>94</td>
<td>23</td>
<td>98</td>
</tr>
<tr>
<td>Aquilina et al., 2001</td>
<td>9.8</td>
<td>5.5</td>
<td>60</td>
<td>93</td>
<td>33</td>
<td>98</td>
</tr>
<tr>
<td>Papageorghiou et al., 2001</td>
<td>5.1</td>
<td>1.4</td>
<td>41</td>
<td>95</td>
<td>12</td>
<td>99</td>
</tr>
</tbody>
</table>

Increased impedance to flow in the uterine arteries in pregnancies attending for routine antenatal care identifies approximately 40% (L.R. 6) of those who subsequently develop PE and approximately 20%(L.R. 3,5) of those who develop fetal growth restriction.
Pre-eclampsia screening

Table 1: Pooled and single estimates for uterine artery Doppler ultrasonography in predicting pre-eclampsia in patients at low risk or unspecified risk, by Doppler index, trimester and severity of pre-eclampsia

<table>
<thead>
<tr>
<th>Doppler index*</th>
<th>No. of studies</th>
<th>No. of women</th>
<th>Sensitivity (95% CI), %</th>
<th>Specificity (95% CI), %</th>
<th>Positive likelihood ratio (95% CI)</th>
<th>Negative likelihood ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second trimester</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall pre-eclampsia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance index (~ 0.58 or 90th centile)</td>
<td>11</td>
<td>3,778</td>
<td>74 (62.86)</td>
<td>79 (71.87)</td>
<td>3.5 (2.2-4.8)</td>
<td>0.33 (0.18-0.48)</td>
</tr>
<tr>
<td>Resistance index (~ 0.70 or 95th centile)</td>
<td>1</td>
<td>346</td>
<td>41 (18.67)</td>
<td>88 (84.91)</td>
<td>3.4 (1.7-5.7)</td>
<td>0.67 (0.42-0.90)</td>
</tr>
<tr>
<td>Pulsatility index</td>
<td>7</td>
<td>38,230</td>
<td>42 (25.58)</td>
<td>91 (86.96)</td>
<td>4.5 (1.7-7.3)</td>
<td>0.64 (0.47-0.82)</td>
</tr>
<tr>
<td>Bilateral notching</td>
<td>17</td>
<td>36,969</td>
<td>43 (26.60)</td>
<td>93 (90.97)</td>
<td>6.5 (4.3-8.7)</td>
<td>0.61 (0.44-0.79)</td>
</tr>
<tr>
<td>Unilateral notching</td>
<td>6</td>
<td>8,016</td>
<td>39 (23.55)</td>
<td>92 (88.95)</td>
<td>4.6 (1.3-7.9)</td>
<td>0.67 (0.48-0.86)</td>
</tr>
<tr>
<td>Any notching</td>
<td>8</td>
<td>4,205</td>
<td>74 (60.87)</td>
<td>84 (76.92)</td>
<td>4.6 (2.0-7.3)</td>
<td>0.31 (0.15-0.48)</td>
</tr>
<tr>
<td>Resistance index or notching</td>
<td>7</td>
<td>8,151</td>
<td>79 (62.95)</td>
<td>83 (73.92)</td>
<td>4.5 (2.6-6.5)</td>
<td>0.26 (0.08-0.44)</td>
</tr>
<tr>
<td>Resistance index and notching</td>
<td>5</td>
<td>1,654</td>
<td>72 (48.96)</td>
<td>87 (79.96)</td>
<td>5.6 (3.1-8.1)</td>
<td>0.32 (0.07-0.58)</td>
</tr>
<tr>
<td>Pulsatility index or notching</td>
<td>2</td>
<td>18,563</td>
<td>47 (44.51)</td>
<td>92 (88.96)</td>
<td>5.7 (2.9-8.4)</td>
<td>0.57 (0.53-0.62)</td>
</tr>
<tr>
<td>Pulsatility index and notching</td>
<td>1</td>
<td>1,757</td>
<td>23 (14.35)</td>
<td>99 (98.99)</td>
<td>7.5 (5.4-10.2)</td>
<td>0.59 (0.47-0.71)</td>
</tr>
<tr>
<td>S/D ratio</td>
<td>2</td>
<td>672</td>
<td>76 (68.84)</td>
<td>71 (62.80)</td>
<td>2.6 (1.8-3.5)</td>
<td>0.34 (0.22-0.46)</td>
</tr>
<tr>
<td>A/C ratio</td>
<td>3</td>
<td>1,284</td>
<td>74 (62.86)</td>
<td>82 (71.92)</td>
<td>4.0 (2.4-5.7)</td>
<td>0.32 (0.20-0.43)</td>
</tr>
<tr>
<td>Notch index</td>
<td>2</td>
<td>819</td>
<td>12 (9.15)</td>
<td>86 (81.90)</td>
<td>0.8 (0.5-1.2)</td>
<td>1.00 (0.96-1.10)</td>
</tr>
<tr>
<td>S/D or notching</td>
<td>2</td>
<td>1,083</td>
<td>28 (18.37)</td>
<td>88 (84.92)</td>
<td>2.4 (1.2-3.5)</td>
<td>0.82 (0.70-0.94)</td>
</tr>
</tbody>
</table>

Basic training

Cnossen JS et al 2008
Uteroplacental failure
- sequential well being changes

Growth ↓

Cerebral blood flow ↑ (MCA)
Fetal size <5th centile (HC/AC)
Umbilical artery PI ↑

Moderate/severe Redistribution (MCA↓)
Abnormal venous blood flow (DV)

↓ AFI
Oligohydramnios
Take home messages

- Doppler investigations give insight into fetal and pregnancy pathophysiology
- Doppler is one of the major breakthroughs in Fetal Medicine
- Doppler can be used in all trimesters for different indications
- It can be used as a screening or a diagnostic tool, according to the circumstances
- In the 2nd and 3rd trimesters it can indicate abnormal placentation, fetal hypoxemia, fetal anemia and impending heart failure
- Operators should use it skillfully and with knowledge of its potentials, limitations and dangers
Thank you for your attention