Optimising your Doppler settings for an accurate PI

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Applications

• Both maternal uterine and fetal circulations can be studied with doppler sonography
  – Uterine arteries
  – Umbilical artery
  – Fetal Middle cerebral artery
  – Fetal internal carotid artery
  – Fetal thoracic aorta
  – Fetal renal arteries
  – Ductus venosus
Umbilical artery Doppler
• Umbilical artery doppler is a marker of utero-placental insufficiency and consequent intrauterine growth restriction (IUGR) or suspected pre-eclampsia.
• It has been shown in multiple studies to identifying patients with abnormal UA reduces perinatal mortality and morbidity.
• Not useful in the low risk population.
• Used in 3rd trimester where there is increased risk of fetal growth restriction or poor perinatal outcome.
Parameters

• Commonly used parameters are:
  – Umbilical arterial S/D ratio (SDR) systolic velocity/diastolic velocity
  – Pulsatility index (PI) PSV - EDV/temporal average frequency over 1 cardiac cycle
  – Resistance index (RI) PSV - EDV/PSV

• Nationally we have adopted PI and RI but which charts?
• In high risk population, uterine artery doppler at 20 – 24 weeks has a moderate prediction value for a severely SGA baby.

• Women who have a major risk factor should be referred for serial ultrasound measurements of fetal size and assessment of wellbeing with umbilical artery doppler from 26 – 28 weeks.
• When umbilical artery Doppler flow indices are abnormal (pulsatility or resistance index > +2 SDs above mean for gestational age) and delivery is not indicated repeat surveillance twice weekly in fetuses with end–diastolic velocities present and daily in fetuses with absent/reversed end–diastolic frequencies.
Consequences of inaccurate indices

• This means that if the PI or RI are falsely positive sonographer will cause:
  – Parental anxiety
  – Unnecessary scans – safety issues
  – Increased workload – radiology and maternity
  – Increased stress – radiology and maternity

• More importantly if falsely negative we may miss a potential at risk fetus
Optimising the image for an accurate Pi
THE DOPPLER PRINCIPLE

• The Doppler principle is based on doppler shift. When red blood cells move relative to an U/S probe this will cause a frequency shift in the returning U/S signal.

• This frequency shift is proportional to the velocity at which the structure moves.
THE DOPPLER PRINCIPLE

• The Doppler shift is affected by the relative angle between the direction of the U/S beam and the direction of the red blood cell.

• In summary, the frequency shift increases as the structure moves towards the probe and decreases as the structure moves away from the probe.
Colour flow vs Pulsed wave Doppler

Color flow Doppler
• Overall view of flow in a region
• Limited flow information
• Poor temporal resolution/flow dynamics (frame rate can be low when scanning deep)
• Color flow map (different color maps)
• Direction information
• Velocity information (high velocity & low velocity)
• Turbulent flows

Pulsed wave Doppler
• Examines flow at one site
• Detailed analysis of distribution of flow
• Good temporal resolution – can examine flow waveform
• Allows calculations of velocity and indices
Triplex mode

• When these modes are used simultaneously, the performance of each is decreased.

• When transducer elements are employed in three modes (B-mode, color flow and pulsed wave Doppler)
  – the frame rate is decreased
  – the color flow box is reduced in size
  – the available pulse repetition frequency is reduced
  – leading to increased susceptibility to aliasing.

• Top Tip - always freeze B-mode and colour flow before measuring PI
COLOUR DOPPLER KNOBOLOGY

• COLOUR GAIN - used to amplify the overall strength of the echoes displayed in the colour. To correctly set the colour gain, turn the gain up until there is colour bleeding, then reduce the gain until the noise reduces.

• COLOUR MAPS - situated on the touch screen and scrolled through in the same way as Gray maps.

• Top Tip - Personal preference – some colours give better contrast resolution
BMUS
Colour Doppler Knobology

- COLOUR SCAN AREA - The size can be adjusted by reducing the width and maximum depth of the color flow area under investigation will usually improve frame rate and may allow a higher color scan line density with improved spatial resolution.
- COLOUR FOCUS - Always move the focus to the region of interest.
- COLOUR FREQUENCY - Adjusted to improve colour penetration/resolution. Only available on some equipment/transducers.
- Top Tip - High frequencies give better sensitivity to low flow and have better spatial resolution.
Colour Doppler Knobology

- Flow towards the probe is coloured RED
- Flow away from the probe is coloured BLUE.
- Turbulent flow shows a ‘mosaic’ pattern of colours.
- Aliasing is demonstrated as colours ‘wrapped’ into each other.
- **TOP TIP** - eliminate aliasing by increasing colour PRF or lowering the baseline
Top Tips: TO INCREASE COLOUR SENSITIVITY

• Increase colour gain & decrease PRF.
• Decrease wall filter.
• Decrease size of colour box.
• Decrease / increase frequency or change transducer.
B-Flow and Advanced dynamic flow (ADF)

- B-Flow maps the B-mode reflections from the blood components.
- B-Flow is not doppler it will not alias, is not angle dependant and does not bleed over vessel walls.
- ADF uses high resolution doppler techniques to accurately resolve small vessels
- **Top Tip:** Both the above will help distinguish the arteries and vein in the umbilical cord (different names on different manufacturers)
Pulsed wave Doppler
Pulsed doppler display – spectral trace

- Provides a measure of the changing velocity throughout the cardiac cycle and the distribution of velocities in the sample volume (or gate).
- PEAK SYSTOLE-The peak velocity of the cardiac cycle.
- END DIASTOLE-The end point of the cardiac cycle.
If an accurate angle correction is made, then absolute velocities can be measured.

The perfect doppler angle is 0.

In practice the doppler angle should be maintained as close to 60 as possible to achieve reproducible results.
Pulsed wave Doppler Knobology

- BASELINE - changes the spectrum baseline or the colour bar to accommodate higher velocity flow.
- ANGLE CORRECT – can’t change the angle with a curvi-linear probe, must change probe position
- PULSE WAVE GAIN – can be adjusted to increase amplitude of returning echoes. **Top Tip** – too high will affect PI.
Pulsed wave Doppler Knobology

• SAMPLE GATE SIZE - If flow measurements are being attempted, the whole vessel should be insonated. A large gate may include signals from adjacent vessels.
• TRACE DIRECTION - the cursors can be altered to trace above or below the baseline.
• TIMELINE - if selected will display only the doppler and not the B-mode image. Top Tip - not recommended because you can’t see the angle used.
Pulsed wave Doppler Knobology

- DOPPLER FREQUENCY - Altering the transmit doppler frequency can improve penetration/resolution.
- DISPLAY/TIMELINE - will display only the spectral trace and not the B-mode image - **Top Tip** - not recommended because you can’t see the angle used
- SWEEP SPEED - should be fast enough to separate successive waveforms. **Top Tip** Ideal is a display of four to six (but no more than eight to 10) complete cardiac cycles.
Pulsed wave Doppler Knobology

• PULSE REPETITION FREQUENCY - The doppler is pulsed thousands of times a second (Pulse Repetition Frequency (PRF)) through a small sample box.

• If the speed of the blood is faster than half of the PRF rate an artefact called aliasing is produced.
PRF

- Aliasing is displayed by ‘wrapping’ the waveform around the baseline and the peaks are situated below the baseline.
- **Top tip** reduce the PRF or lower the baseline.
- PI cannot be measured if aliasing is present
PRF

• When there is low flow a lower PRF is required, when there is high velocity flow a higher PRF is required.
• PRF is the first factor that needs to be altered if aliasing or low flow is present.
• On most machines – PRF button is usually called SCALE.
• Top Tip - Reduce scale to see end diastolic flow better.
Abnormal spectral trace

PI should not be calculated when there is:

• Fetal breathing movements
• Fetal movements
• Fetal arrhythmia
• Hiccoughs

• Top Tip: wait or walk
PI values

• The end diastolic flow should become thicker with increased gestational age.

• Therefore the ratio of PSV to EDV will reduce therefore PI will decrease with gestational age.

• **TOP TIP** – if the PI is above the 95\(^{th}\) centile but there is thick EDV your technique may be wrong – false positive.
Calculations - Automatic trace

- Manufacturers assure us that auto trace is accurate
- If more than one peak is measured then average is displayed
- However, if one of the peaks has some irregularity the average PI will be lower
- No guidance on how many peaks to choose
- **Top Tip**
  - don’t choose highest or lowest – **CHOOSE THE BEST**
  - choose the best peak
  - 1 peak may be too little – 8 peaks may be too many
PI values – 5 peaks

<table>
<thead>
<tr>
<th>Fetus A</th>
<th>Umb A</th>
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</thead>
<tbody>
<tr>
<td>PI</td>
<td>0.95 (Vmin)</td>
</tr>
<tr>
<td>Vp</td>
<td>37.8 cm/s</td>
</tr>
<tr>
<td>HR</td>
<td>85 bpm</td>
</tr>
</tbody>
</table>

**Ultrasound Image**

- Date: 20171012
- Time: 11:08:58
- Device: TOSHIBA Aplio 900
- Hospital: PONTEFRACT HOSPITAL
- Procedure: OB 1

**Ultrasound Measurements**

- PI: 0.95 (Vmin)
- Vp: 37.8 cm/s
- HR: 85 bpm
PI values – 2 peaks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>PI</td>
<td>0.97 (Vmin)</td>
</tr>
<tr>
<td>Vp</td>
<td>41.2 cm/s</td>
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<tr>
<td>HR</td>
<td>70 bpm</td>
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</table>
Which Chart?

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Which Chart

Umbilical artery PI

Middle Cerebral PI

Parra-Cordero et al. Prenat Diagn 2007; 27: 1251-1257
Raised PI
Artefacts – forward and reverse flow

• If the line of pulse doppler crosses a vessel that is folded or 2 umbilical arteries running in opposite directions forward and reverse flow will be seen on the spectral trace
Artefacts – umbilical vein

- If the pulsed doppler line crosses the artery and the vein the spectral trace of the vein will be seen below the baseline - this can obscure possible reversed flow
- If caught at an angle it can mimic reversed flow
Absent EDV – vein below
Reported as reversed EDV - vein below
NO EDV – reduced scale, reduced sweep speed, correct
PW WALL FILTER

- Wall filters remove the low frequency signal created by wall thump.
- Setting the wall filter too high may erase low velocity flow.
- TOP TIP - reduce the wall filter in low flow situations e.g. No end diastolic flow
- Can’t measure PI if wall filter too high
Fetal middle cerebral artery

- Head in the transverse plane
- Axial section of the brain including the thalami and sphenoid wing bones
- Find vessels on colour/power doppler overlaying the anterior wing near the base of the skull
Fetal middle cerebral artery

• Normal – high resistance flow
• In pathology – low resistance flow as a result of head sparing theory (redistribution)
• Reading obtained close to the internal carotid artery
Fetal middle cerebral artery
Real reversed flow?
Conclusion

• Operator dependent
• Optimise B mode, colour and pulse wave setting before measuring PI – know your equipment
• Use all criteria to decide which PI value to use
• PI value is only part of the story
• Don’t measure if trace irregular