ISUOG Basic Training
The Principles of Doppler Ultrasound
Juriy Wladimiroff
Learning objectives

At the end of this session, you will be able to understand the principles of:

• Doppler effect
• Doppler shift
• pulsed wave Doppler
• colour flow Doppler
• power Doppler
• indices
• clinical applications
• safety
Key questions

• How is the Doppler shift related to flow velocities?

• What is the importance of the insonation angle?

• Why do we use indices (PI)?

• Which ultrasound application has the highest energy?

• Should Doppler be used in the first trimester?
Doppler principle

Christian Johann Doppler
Austrian physicist
(1803 - 1853)
Doppler effect

An effect found in all types of waves, where the source and the receiver are moving relative to each other
Doppler shift
Change in frequency produced by a moving reflector
Doppler principle

Car stationary relative to target
The person is “hit” by a constant number of wave fronts per time unit

Car moving towards target
The person is “hit” by additional wave fronts per time unit

Car moving away from target
The person is “hit” by fewer wave fronts per time unit
What made Christian Doppler famous?

• the change in frequency between emitted and returned sound waves is proportional to the velocity of the moving reflector

• the change in frequency is called the Doppler shift

• high pitched Doppler shift means high velocity
Blood velocity measurement

Transducer

Transmitted beam

Scattered beam

Vessel

Maulik 97
Doppler equation

\[ \Delta f = \frac{2 \times f_0}{v} \cdot V \cos \alpha \]

- \( \Delta f \) : change in frequency
- \( f_0 \) : frequency of transmitted sound (1-3 mHz)
- \( v \) : velocity of sound in the medium (1540 m/s)
- \( V \) : velocity of the reflecting surface (1-250 m/s)
- \( \alpha \) : angle between the sound beam and the direction of motion of the reflecting surface

\( \Delta f \) is proportional with the velocity of the moving reflector

You can hear Doppler ultrasound
Duplex transducer

**Eik-Nes et al. 1980, BMJ 1980**

Insonation of umbilical vein at fixed angle (1979)
Doppler signal processing

- Moving scatterers
  - Produces frequency change
- Transducer
  - Converts sound to energy
- Amplifier
- Demodulator
  - Determines direction of flow
- Spectral processor
  - Sorts frequencies
- Video screen
  - Displays Doppler waveforms
Basic Doppler techniques

- continuous wave Doppler
- pulsed wave Doppler
- colour flow mapping
Continuous wave Doppler

- two transducers
- sending and receiving continuously
- CTG
Pulsed wave Doppler

- one transducer
- sends a pulse
- gate closes
- gate opens after a time
- gates remains open briefly
- gate closes
Insonation angle

The velocity is dependent on the insonation angle (cosine of the angle)
the height of the Doppler spectrum changes according to the *insonation angle* (Doppler beam to vessel) (A,B,C) and the direction of flow (D)
Flow direction and frequency

Small angle = high frequency     Large angle = low frequency
Insonation angle

PI is angle independent
- but all dimensions vary
  with cosine of angle of insonation
Flow volume and velocity
Frequency spectrum

Frequency (Hz)
Velocity (cm/s)

Time (s)
Doppler shift and velocity spectrum

- flow velocity waveform = spectrum of velocities within the vessel
- maximum envelope = fastest red blood cells in the middle of the vessel
Concept of pulsatility

Peak systolic frequency shift

End diastolic frequency shift
Which measurement to use?

Angle independent indices

Angle $< 90$ degrees

pulsatility index (PI) preferred
Pulsatility index = PI

\[ PI = \frac{A - B}{V} \]
What does the PI reflect?

Relationship between pressure and flow in the interrogated vessel, dependant on:

- distance from the heart
- peripheral resistance
- vessel wall elasticity
- blood viscosity
Pulsatility $\rightarrow$ downstream impedance

femoral artery

rest: high peripheral resistance

exercise: low peripheral resistance
Basic principle of colour flow mapping (CFM)

Area with multiple sample volumes

Same area colour coded
Colour coding

- velocities away from transducer *shades of blue*
- velocities towards transducer *shades of red*
- aliasing *shades of green*
Colour Doppler

Principle:
• translation of PW information into pixels of different colours, which are superimposed onto the 2D image
• flow towards the transducer – red
• flow away from the transducer – blue
Colour Doppler

Basic training
Power Doppler

• power Doppler does not display velocity information

• it simply displays the amplitude of the returning Doppler shifted echoes

• less dependent on angle of insonation
Doppler controls

- sample gate width
- pulse repetition frequency (PRF)
- baseline
- sweep speed
- high-pass filter (min)
Doppler controls

- adjust sample gate to cover the vessel, to avoid interferences from nearby vessels
- increase PRF to correct for aliasing (2 x max velocity)
- or modify the baseline
Doppler controls

- use appropriate screen speed
Screen speed and PRF incorrect
Screen speed and PRF correct for UA
High/low pass filter

High pass

Low pass
Importance of a clear Doppler spectrum

- prevents erroneous interpretation of PI by automatic measurement modality
- automatic measurements can be accepted only if Doppler spectrum is clear and trace follows the envelope
Safety

- Heating potential
- Colour Doppler
- Pulsed Doppler
- M-mode
- Harmonic imaging
- B-mode 2D,3D
- Power
ISUOG Statement
The safe use of Doppler in the 11+0 to 13+6 week fetal ultrasound examination

• Pulsed Doppler (spectral, power and colour flow imaging) ultrasound should not be used routinely

• Pulsed Doppler ultrasound may be used for clinical indications such as to refine risks for trisomies

• When performing Doppler ultrasound, the displayed thermal index (TI) should be ≤ 1.0 and exposure time should be kept as short as possible
Examination of the embryo?

Do not use Doppler
Key Points

• the Doppler effect is found in waves where the source and receiver are moving relative to each other

• pulsed wave Doppler and colour flow Doppler are the most frequently used techniques

• Doppler techniques make the non-invasive assessment of fetal hemodynamics possible

• do not use Doppler in the 1st trimester unless clinically indicated