

Applications of Doppler Ultrasound in Fetal Growth Assessment



David Cole



BIRMINGHAM
City University

Aims

- The aim of this presentation is to consider the use of Doppler ultrasound to investigate and monitor those pregnancies at risk of perinatal morbidity and mortality due to uteroplacental insufficiency



BIRMINGHAM
City University

Learning outcomes

- Describe the main applications of Doppler Ultrasound in Obstetrics
- Explain the principles underlying the Doppler Technique
- Describe the uteroplacental anatomy
- Describe the feto-placental anatomy
- Describe the Doppler ultrasound techniques for examining the uteroplacental, feto-placental and fetal circulations
- Describe how spectral Doppler waveforms are interpreted



BIRMINGHAM
City University

Introduction

- The main use of Doppler Ultrasound in Obstetrics is to identify and monitor those fetuses at risk of perinatal mortality or morbidity due to uteroplacental insufficiency
- This is achieved by investigating blood volume flow to the placenta; in the umbilical arteries and in the fetus.



BIRMINGHAM
City University

Topics

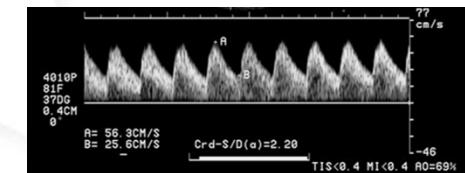
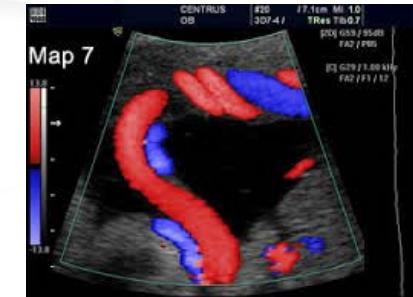
- Colour flow imaging and Spectral Doppler
- Interpretation of the spectral Doppler waveform
- Doppler indices
- Uterine artery Doppler
- Umbilical artery Doppler
- Middle cerebral artery Doppler
- Fetal venous Doppler



BIRMINGHAM
City University

Colourflow imaging and Spectral Doppler

- Colour Doppler gives a map of blood flow superimposed on the normal 2D image and is used to identify a particular blood vessel and sample the blood velocity within that vessel.
- Spectral Doppler gives a graph of blood velocity versus time – the Doppler waveform. This waveform is analysed to detect changes in resistance to blood flow



BIRMINGHAM
City University

Colour flow imaging

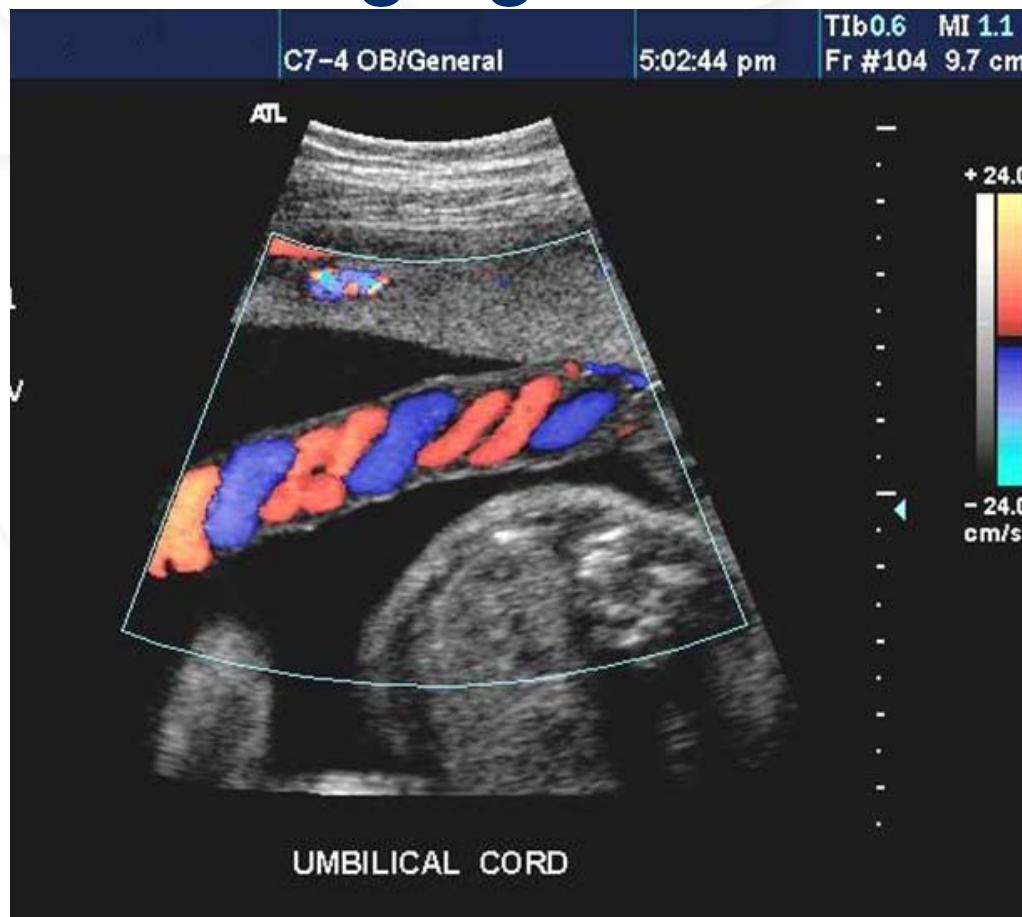


Image courtesy of UNIVERSAL DIAGNOSTIC SOLUTIONS



BIRMINGHAM
City University

Colour flow imaging - sampling

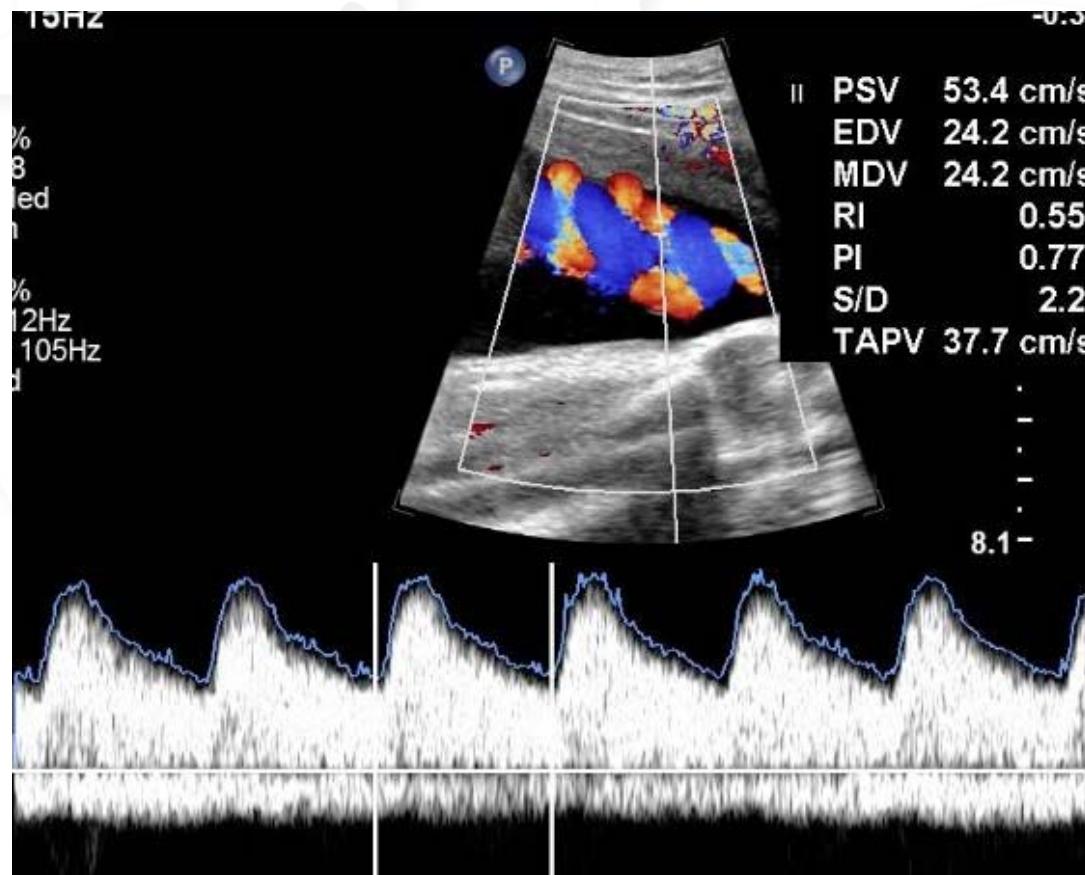
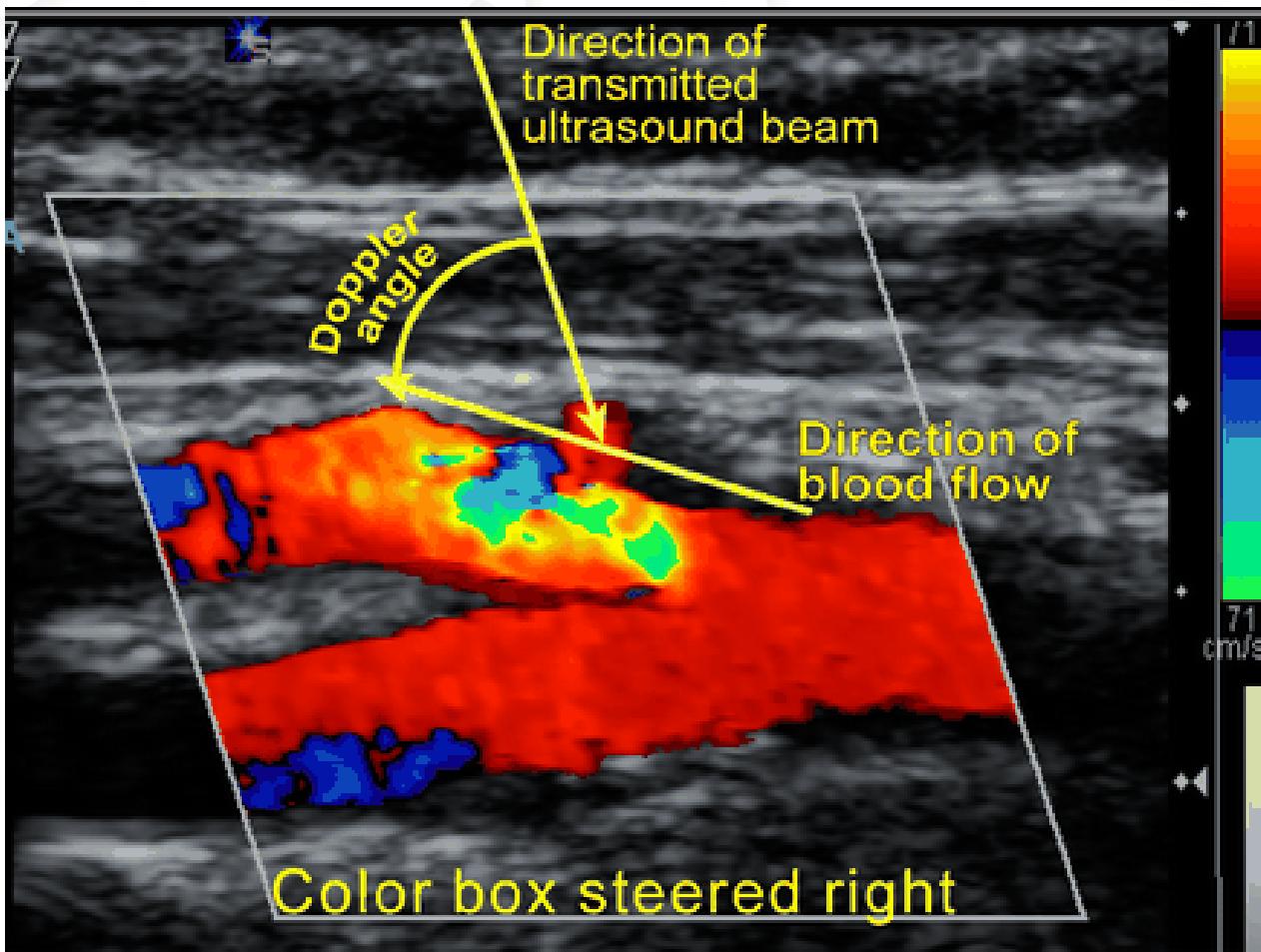


Image: Courtesy of IAME



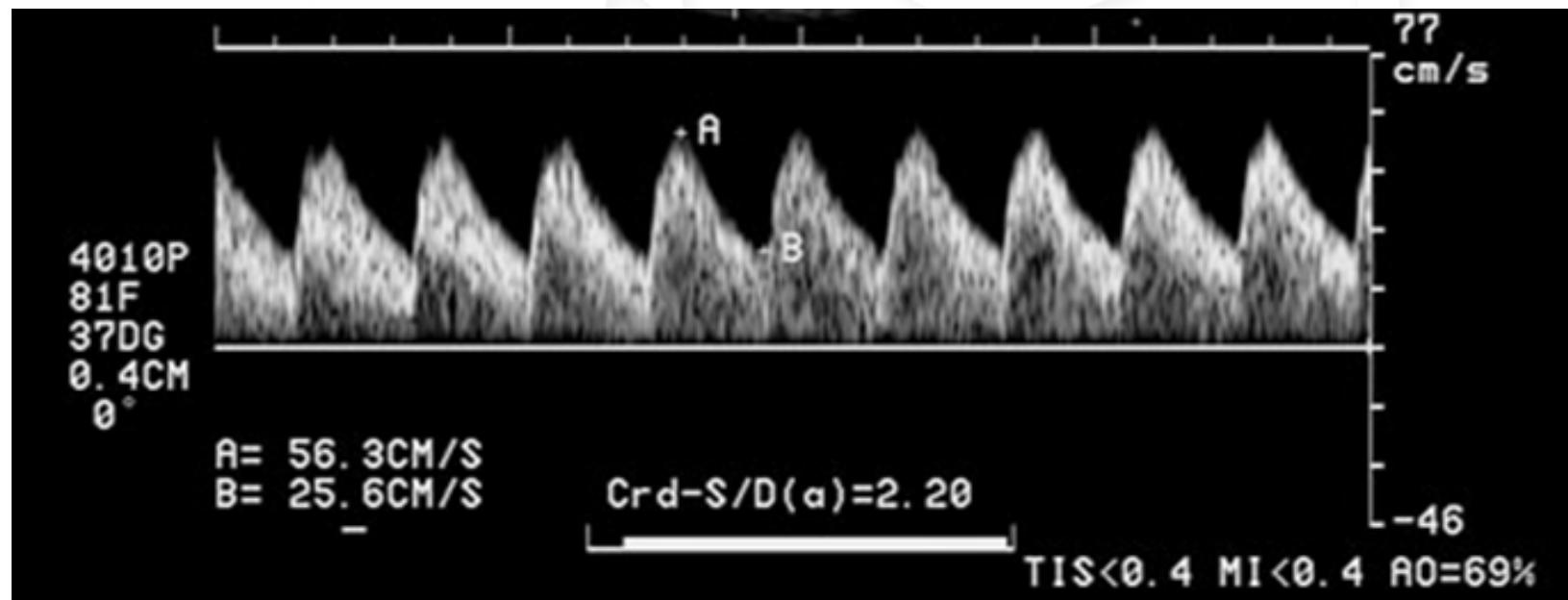
BIRMINGHAM
City University

Aliasing in colour flow imaging



BIRMINGHAM
City University

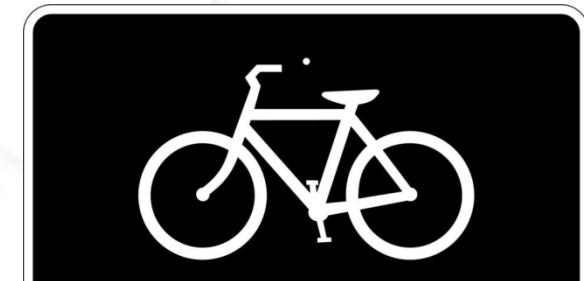
The spectral Doppler waveform



BIRMINGHAM
City University

Interpretation of the spectral Doppler waveform

- The Doppler waveform represents the velocities of blood cells within the sample volume plotted against time.



Interpretation of the spectral Doppler waveform

- The Doppler waveform represents the velocities of blood cells within the sample volume plotted against time.
- The waveform can be analysed by:
 - Waveform pattern recognition.
 - Waveform shape analysis



Waveform pattern recognition.

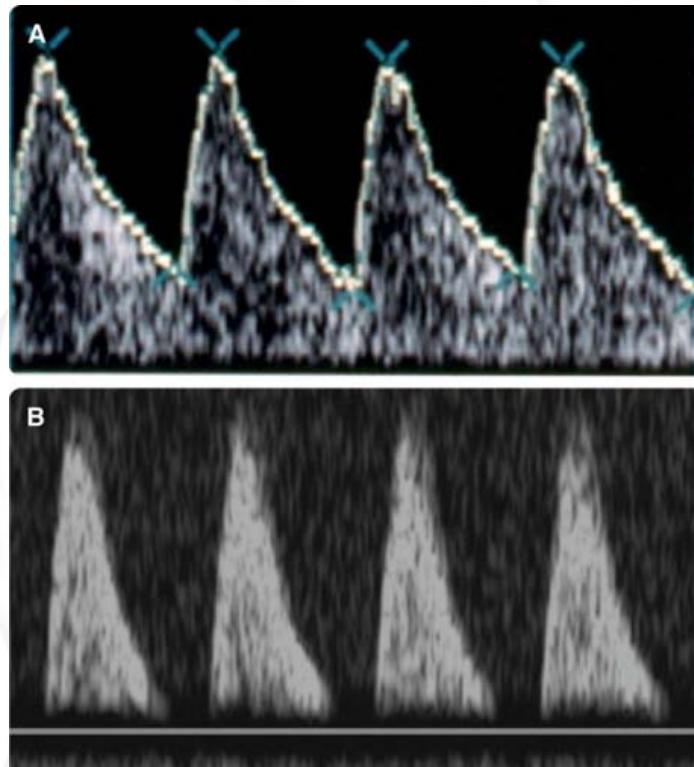


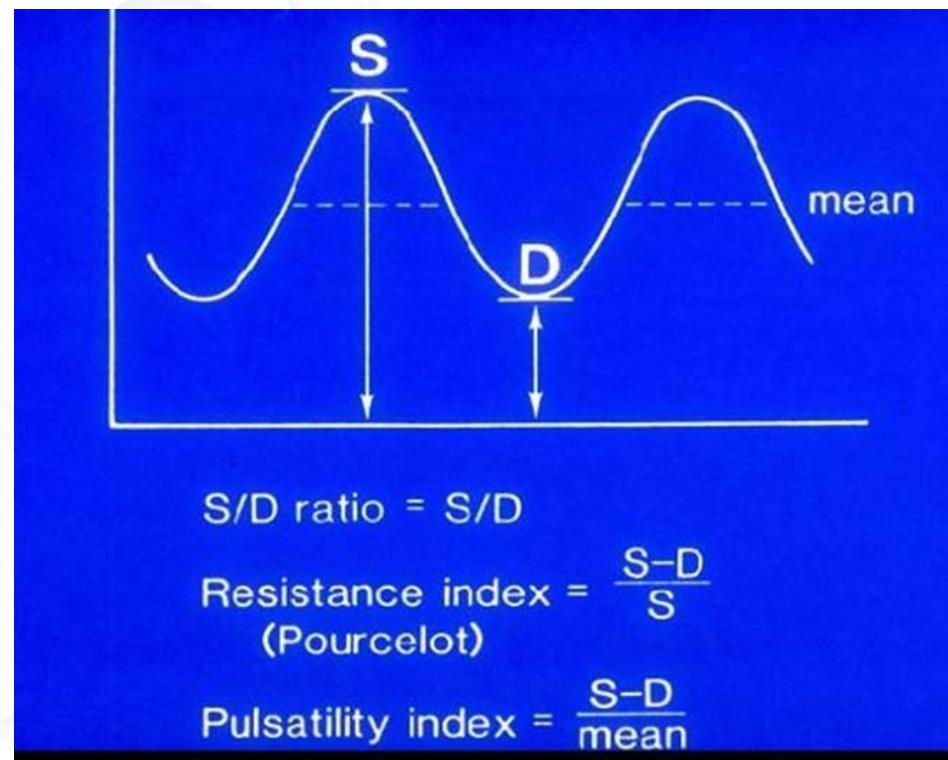
Image courtesy of Science Direct



BIRMINGHAM
City University

Waveform shape analysis

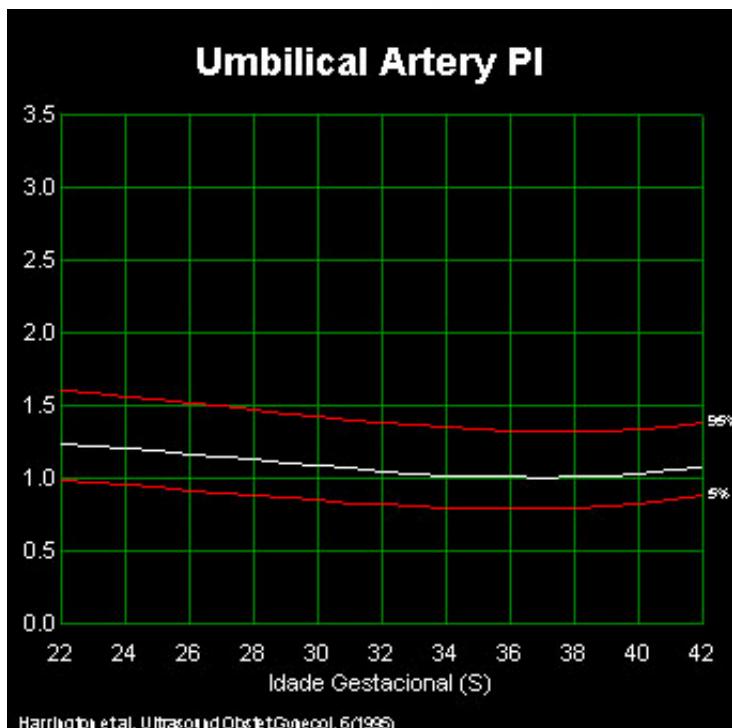
- A semi- quantitative method of analysing the waveform



BIRMINGHAM
City University

Doppler indices

PULSATILITY INDEX



$$\frac{\text{SYSTOLIC} - \text{DIASTOLIC}}{\text{MEAN}}$$

RESISTIVE INDEX

Kurmanavicius et al.

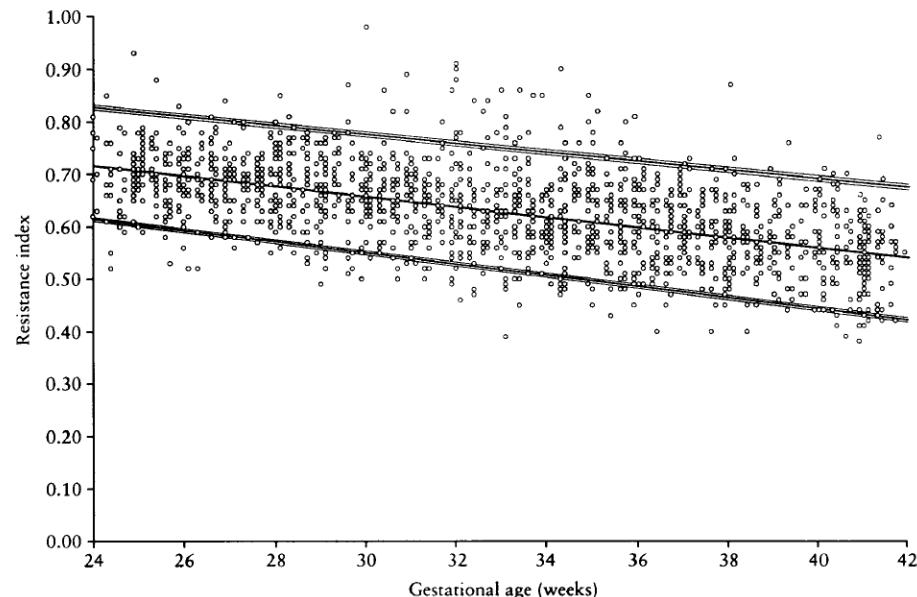


Fig. 2 Raw data for umbilical artery resistance index with fitted 5th, 50th and 95th centiles together with 95% confidence intervals
■ 5th and 95th centiles

$$\frac{\text{SYSTOLIC} - \text{DIASTOLIC}}{\text{SYSTOLIC}}$$

Reference resistance indices of the umbilical,
fetal middle cerebral and uterine arteries at
24–42 weeks of gestation

J. Kurmanavicius, I. Florio, J. Wisser, G. Hebisch, R. Zimmermann, R. Müller, R. Huck and A. Huck



Doppler Ultrasound in Fetal Growth Assessment

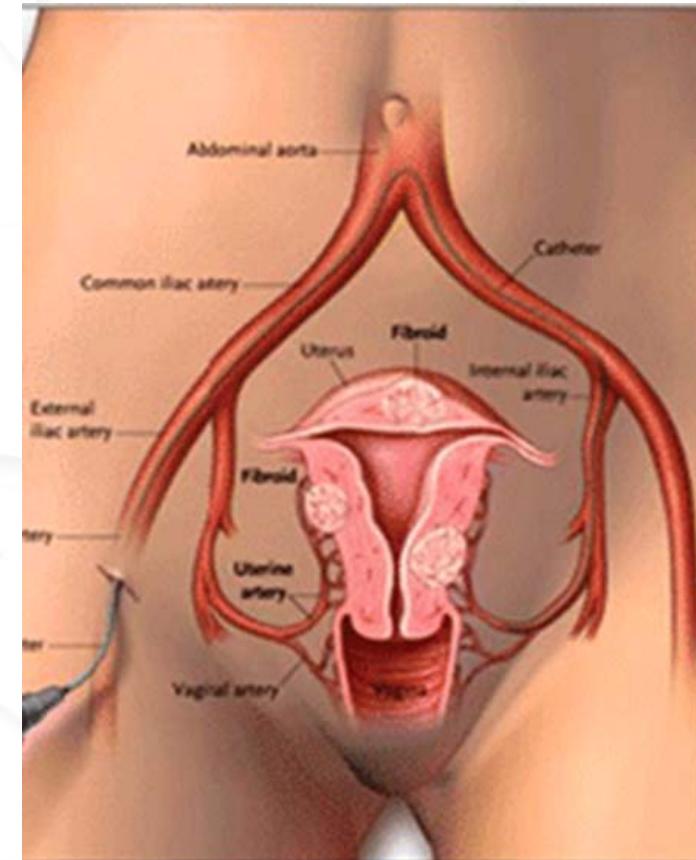
- Uterine artery Doppler
- Umbilical artery Doppler
- Middle cerebral artery Doppler
- Fetal venous Doppler



BIRMINGHAM
City University

Uterine artery Doppler

- Uterine artery Doppler is usually performed as a screening test on a high risk population. Its purpose is detect those pregnancies at risk of preeclampsia or intrauterine growth retardation (IUGR).



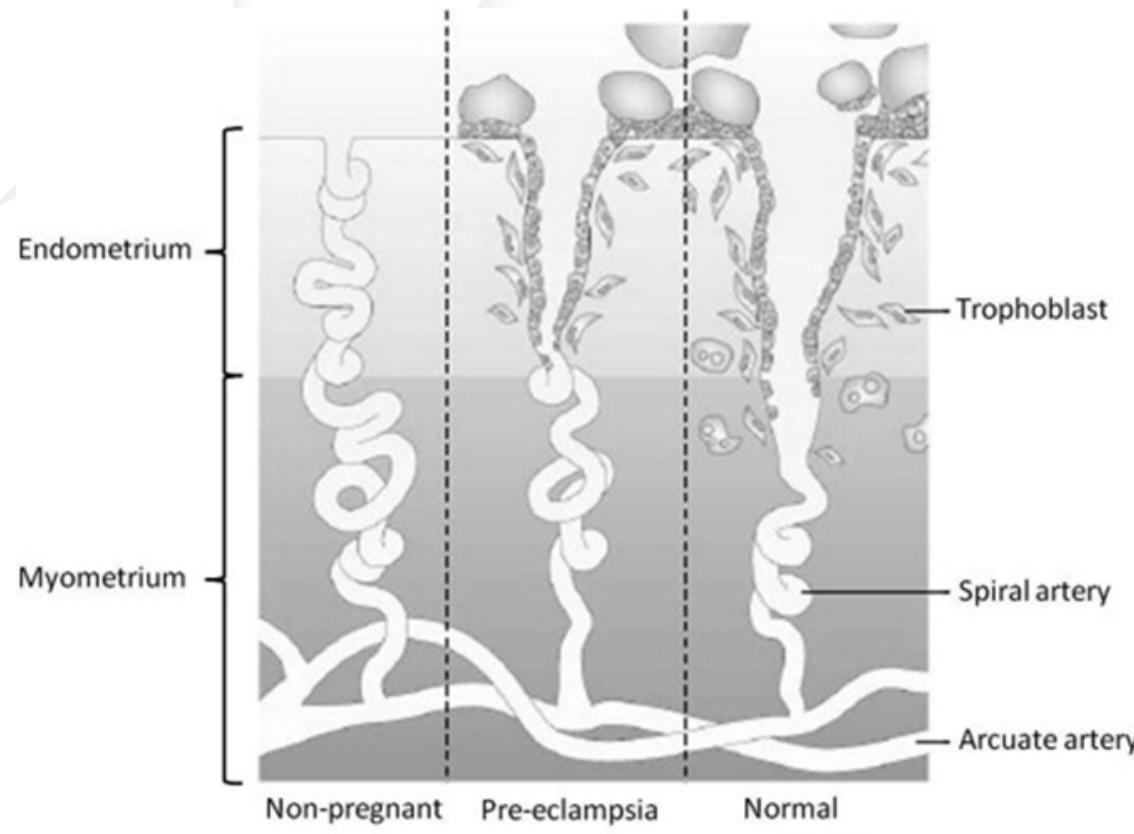
BIRMINGHAM
City University

The Utero Placental Circulation

The spiral arteries within the wall of the uterus supply blood to the endometrium.

During the first trimester of pregnancy these spiral arteries are invaded by trophoblastic cells from the developing placenta.

This invasion of trophoblastic cells produces dilated spiral arteries and results in a low resistance blood flow to the placenta



reproduced from Moffett-King (2002)



BIRMINGHAM
City University

Uterine artery Doppler

- Normally carried out at 20 -24 weeks gestation –The uterine artery is sampled to examine the spectral Doppler waveform.
- Both arteries are examined and reported on.
- In addition the position of the placenta should be recorded, especially if it is lateral.

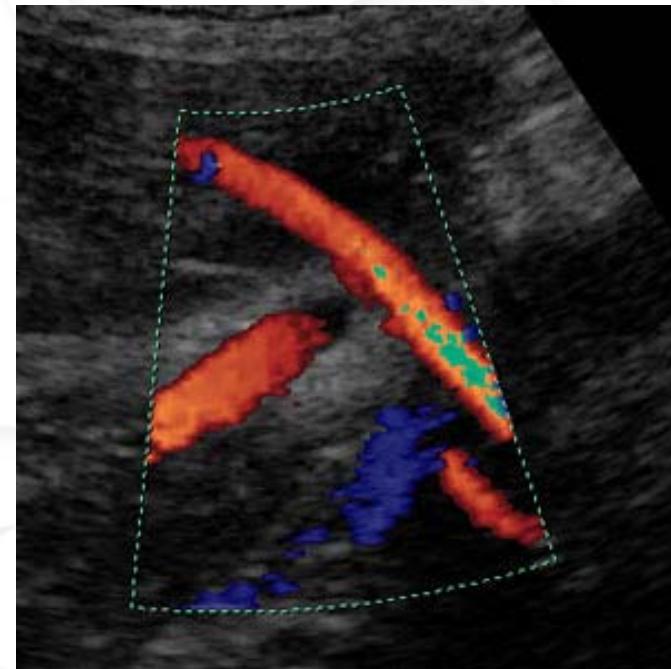


Image courtesy of Kypros Nicolaides et al at:

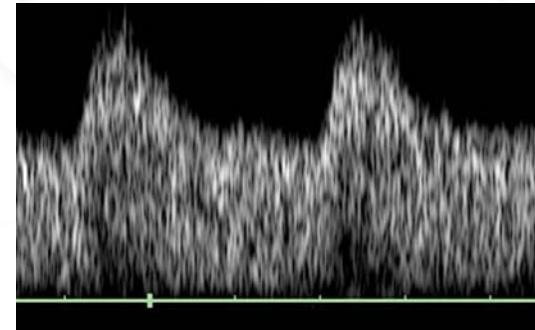


**BIRMINGHAM
City University**

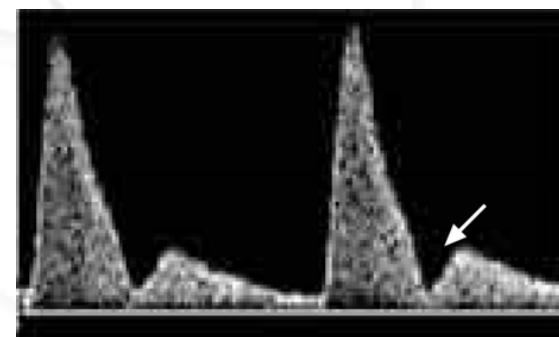
Uterine artery Doppler

- In high risk populations an abnormal trace gives moderate predictive value for severe SGA
- Little value in repeating examination once an abnormal trace is detected
- Green –top no 31

Normal Uterine Waveform



Abnormal Uterine Artery Waveform



Images courtesy of Kypros Nicolaides et al at:

http://www.centrus.com.br/DiplomaFMF/SeriesFMF/doppler/capitulos-html/chapter_05.htm



BIRMINGHAM
City University

Umbilical artery Doppler

- Umbilical artery Doppler is the most widely used Doppler examination in obstetrics and abnormal results have good correlation with adverse perinatal conditions.
- Performed from 24 weeks gestation to term and it's purpose is to detect those fetuses at risk of perinatal morbidity or mortality due to growth retardation.
- **Examination Technique**
- This can normally be carried out from 24 weeks gestation – a colour flow image of the cord is scanned.
- The sample should be taken from either free-floating cord or cord close to the placenta.

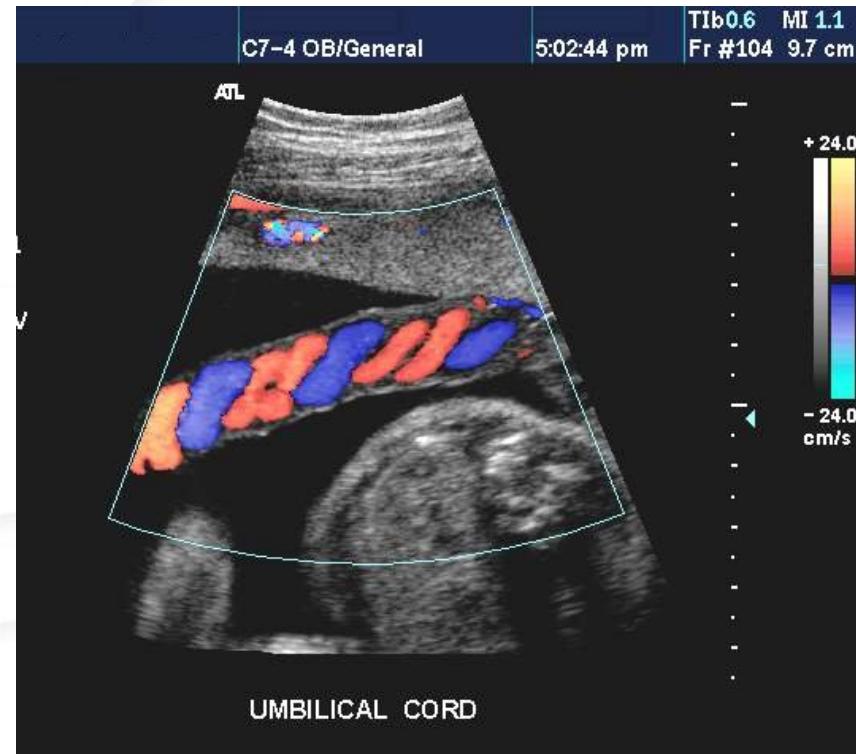


Image courtesy of UNIVERSAL DIAGNOSTIC SOLUTIONS



BIRMINGHAM
City University

Umbilical artery normal anatomy

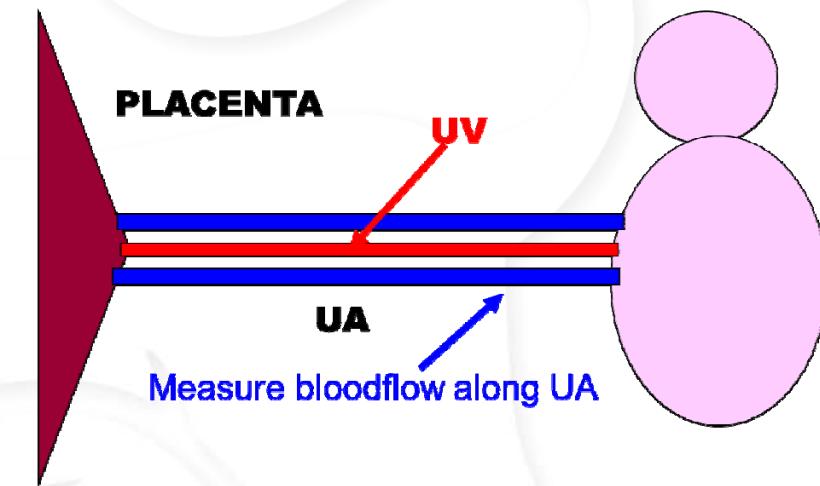
The Umbilical Cord

The umbilical cord normally contains two arteries and one vein. The arteries carry de-oxygenated blood from the fetus to the placenta, where it is mixed with maternal blood for oxygenation, nutrient uptake and elimination of waste products. The umbilical vein carries oxygenated blood rich in nutrients from the placenta to the fetus.

Blood Flow in the Umbilical Artery

The blood flow in the umbilical artery is pulsatile and is governed by the fetal heart rate. In the normal pregnancy the resistance to flow is low with forward flow in systole and diastole.

The Feto-placental Circulation



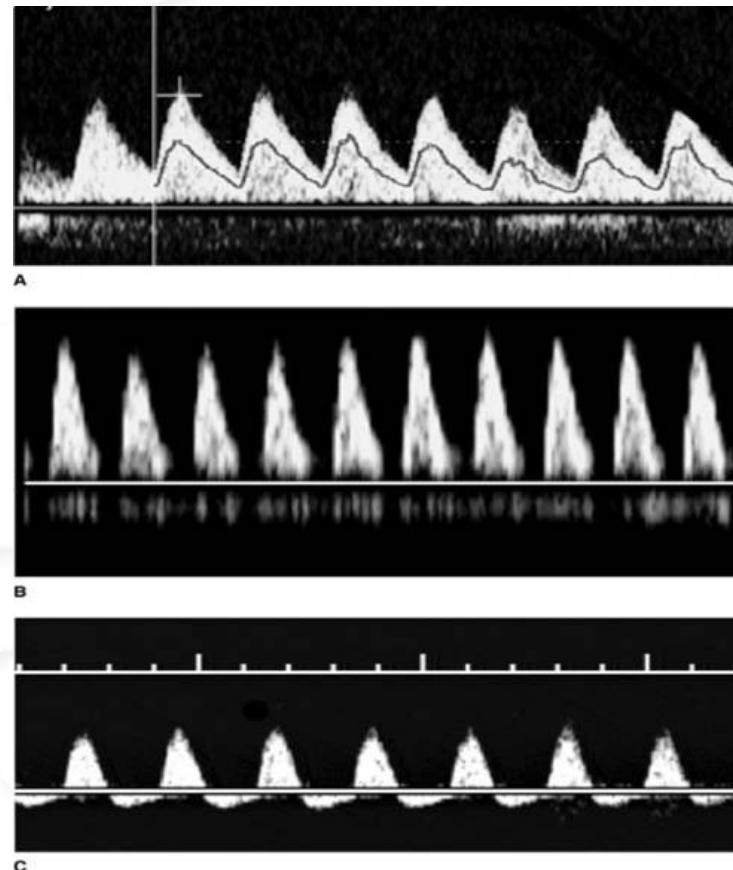
Schematic representation of the feto-placental circulation showing the fetus, placenta, umbilical arteries and umbilical vein.



BIRMINGHAM
City University

Umbilical artery Doppler

- Primary surveillance tool in the SGA fetus
- When Doppler indices are normal it is reasonable to repeat every 14 days
- More frequent measurements if the fetus is severely SGA
- **Green –top no 31**



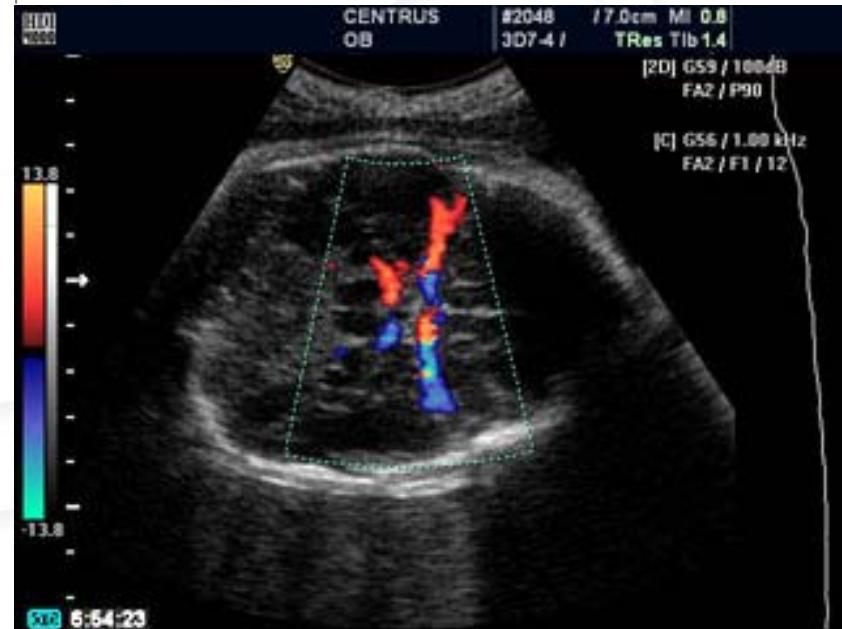
BIRMINGHAM
City University

Middle cerebral artery Doppler

This examination is used to monitor those fetuses at risk of perinatal morbidity or mortality due to growth retardation.

It is used as to gain information about the fetal circulation on those pregnancies with an abnormal umbilical artery Doppler waveform.

Colour Flow Image of Fetal Cerebral Circulation



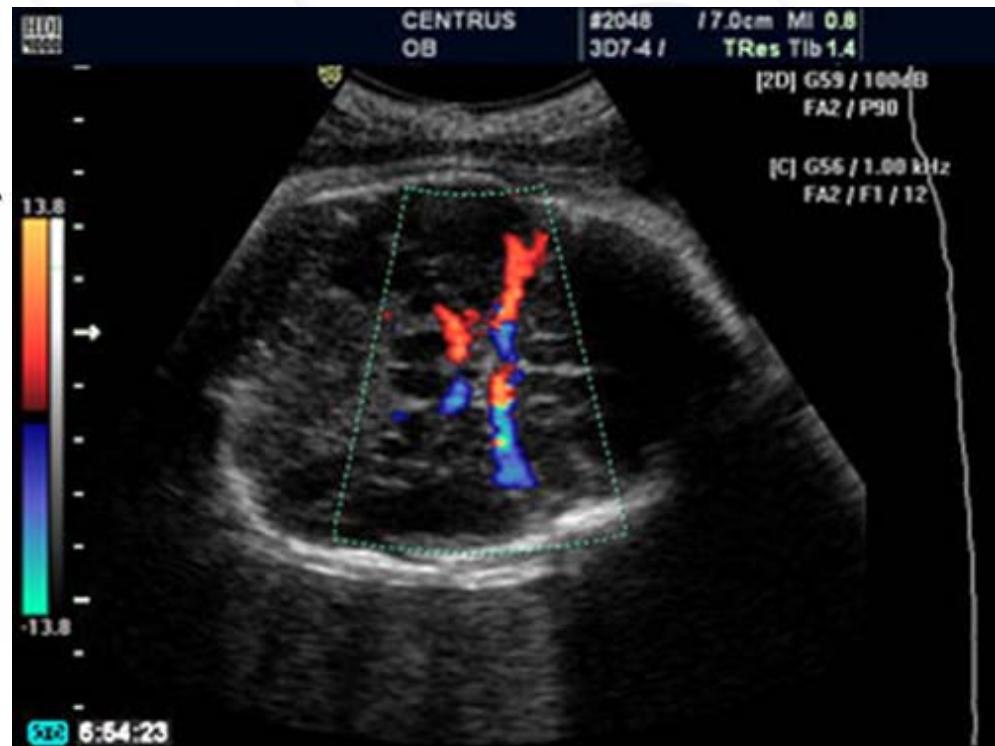
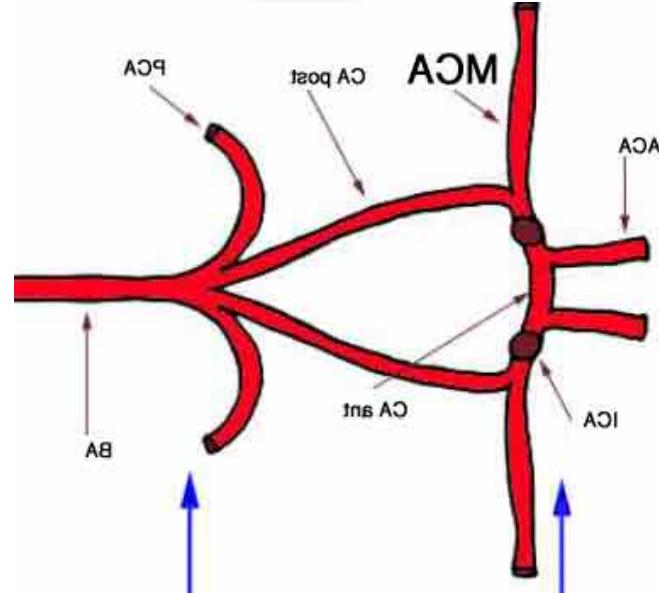
Colour flow image showing Circle of Willis and middle cerebral arteries.

Images courtesy of Kypros Nicolaides et al at:



BIRMINGHAM
City University

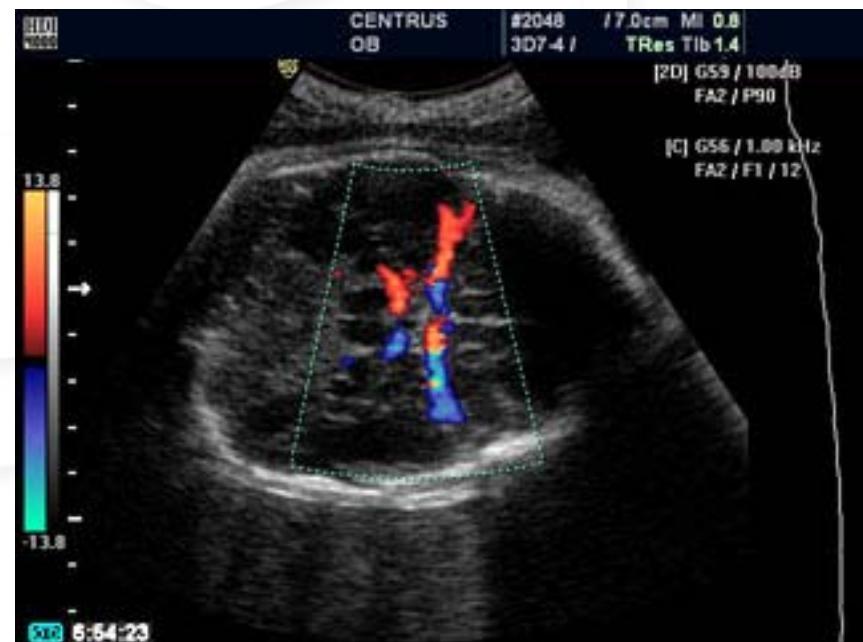
Middle cerebral artery Doppler



BIRMINGHAM
City University

Middle cerebral artery Doppler

- **Examination Technique**
- A transverse section of the fetal head is obtained and the colour box applied to view the Circle of Willis and middle cerebral arteries (MCAs).
- The sampling gate is placed in the proximal MCA to obtain the Doppler waveform.



BIRMINGHAM
City University

Middle cerebral artery Doppler

Normal MCA waveform at 32 weeks

This is a high resistance flow with low end diastolic velocity and a large difference between peak systolic and end diastolic velocities.

Middle Cerebral Artery Doppler Waveform

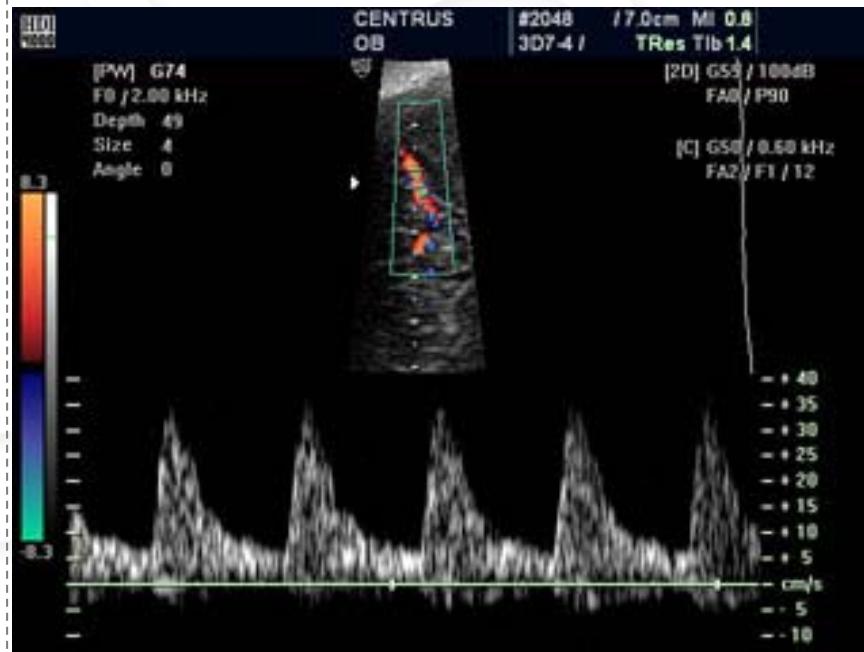


Image showing normal High resistance flow in the middle cerebral artery.

Image courtesy of Kypros Nicolaides et al



BIRMINGHAM
City University

Middle cerebral artery Doppler

Abnormal MCA waveform at 32 weeks

This is a low resistance flow with good forward flow in diastole.

This is due to “brain sparing” in the growth retarded fetus. Blood is preferentially shunted to the life support centres in the brain heart and adrenals rather than to the abdominal organs and skeletal muscles

Middle Cerebral Artery Doppler Waveform

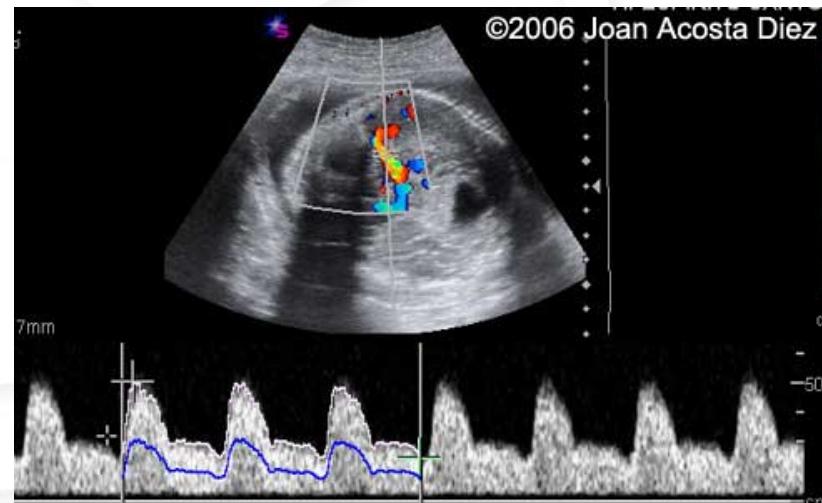


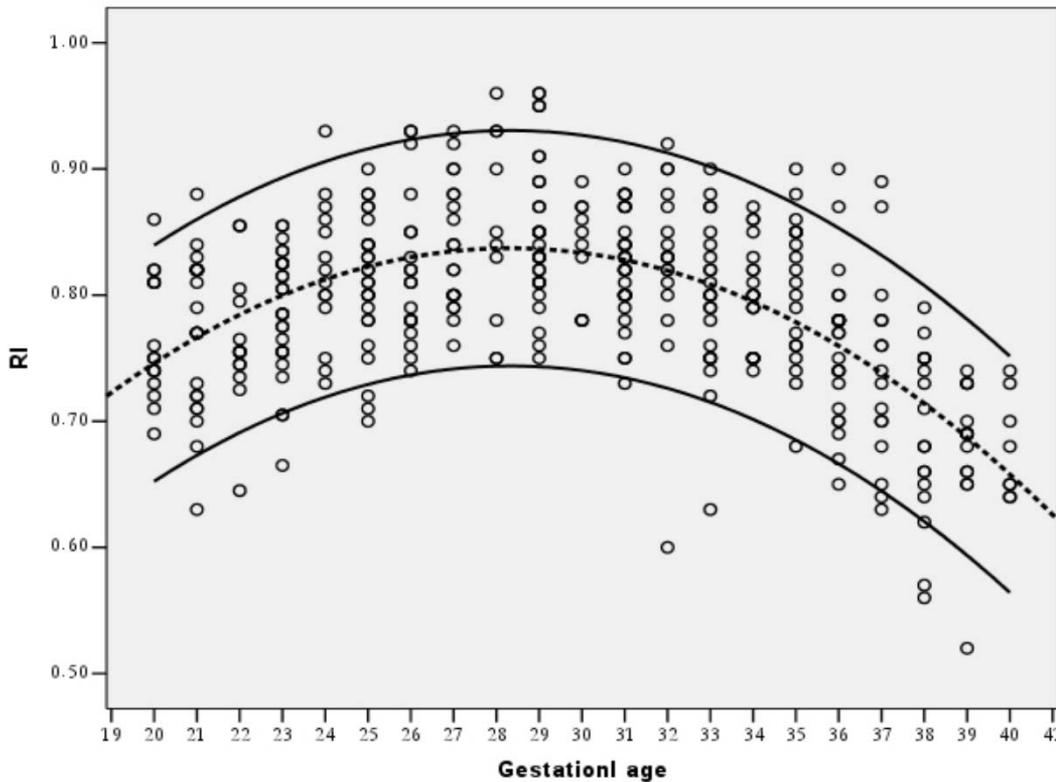
Image showing low resistance flow in the middle cerebral artery.

Image: Courtesy of Phillip Jeanty



**BIRMINGHAM
City University**

Middle cerebral artery Doppler



Doppler Waveform Indices of Fetal Middle Cerebral Artery
in Normal 20 to 40 Weeks Pregnancies

Mohammad-Kazem Tarzamni MD*, Nariman Nezami MD•**, ***, Fatemeh Gatreh-Samani MD*,
Sakine Vahedinia MD*, Mariam Tarzamni MD†



BIRMINGHAM
City University

Middle cerebral artery Doppler

- In the preterm SGA fetus, middle cerebral artery (MCA) Doppler has limited accuracy to predict acidaemia and adverse outcome and should not be used to time delivery.
- In the term SGA fetus with normal umbilical artery Doppler, an abnormal middle cerebral artery Doppler (PI < 5th centile) has moderate predictive value for acidosis at birth and should be used to time delivery.

Green top guide 31



BIRMINGHAM
City University

Arterial Doppler

- The waveforms from arterial Doppler examinations depend on both cardiac output and vascular resistance.
- Arterial Doppler alone is inadequate for examination of impaired fetal cardiac function.



BIRMINGHAM
City University

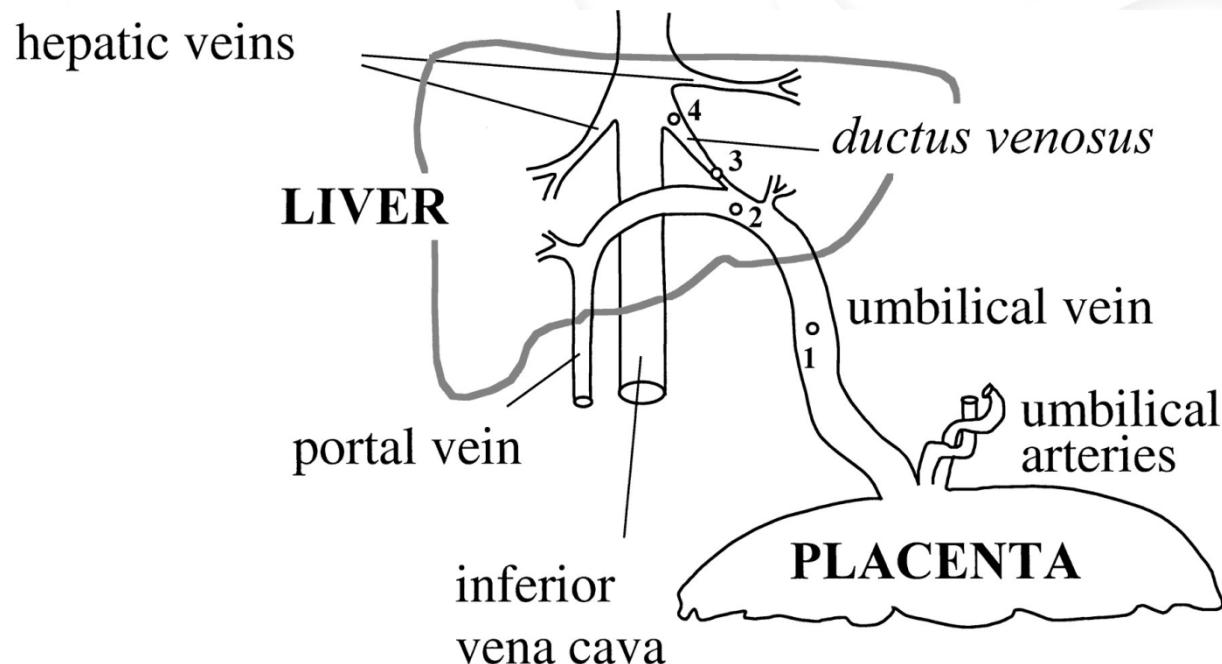
Fetal venous Doppler

- Fetal venous Doppler is used to complement umbilical artery and middle cerebral artery Doppler in identifying those fetuses with IUGR at risk of death in utero.
- Includes umbilical vein, ductus venosus and IVC
- Ductus venosus waveforms have been found to be the most useful in terms of reproducibility and identifying the “at risk” fetus
- Application late second and early third trimester fetuses with IUGR.



BIRMINGHAM
City University

Fetal venous Doppler anatomy



Role of ductus venosus in distribution of umbilical blood flow in human fetuses during second half of pregnancy

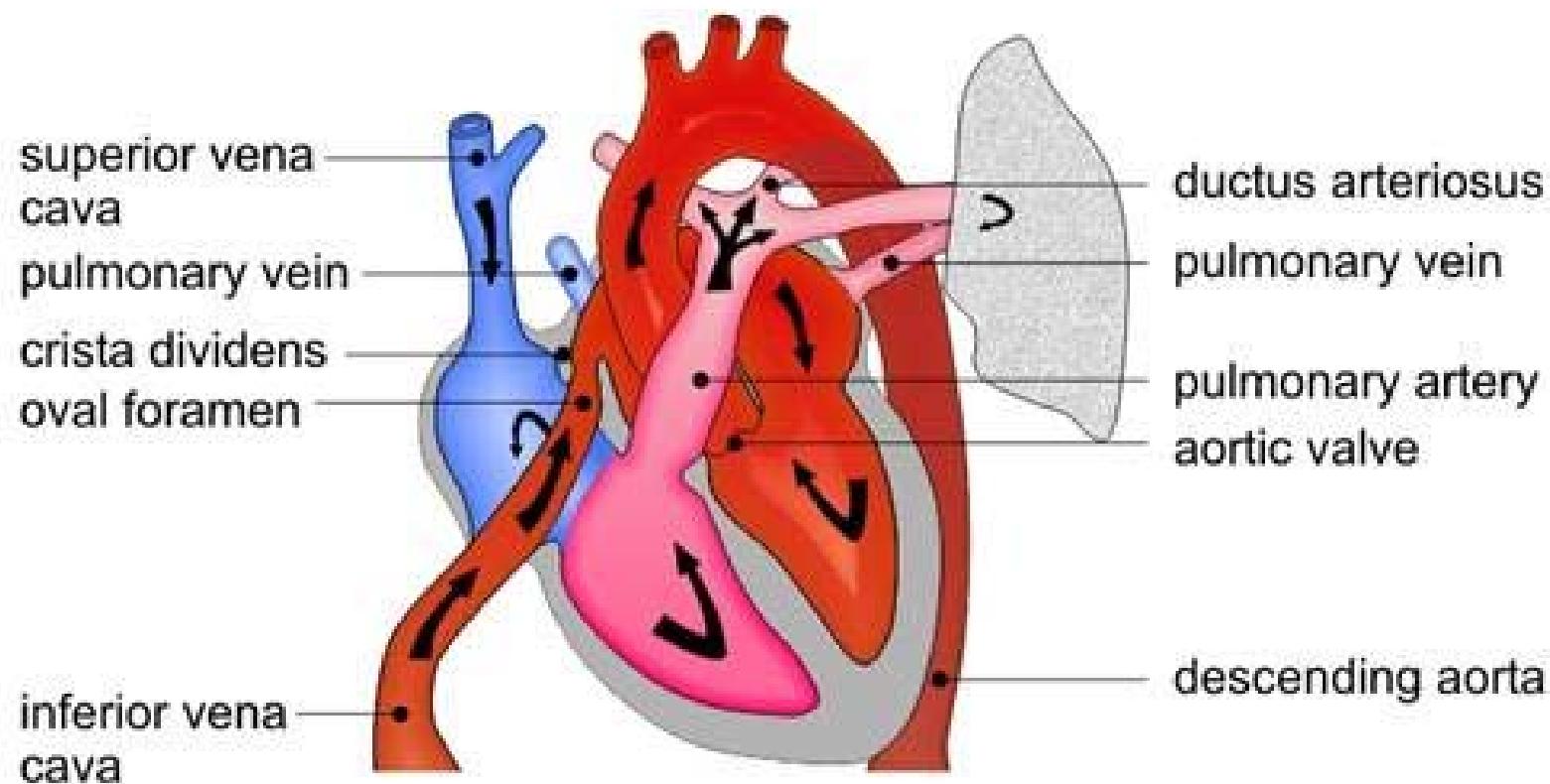
Maria Bellotti , Giancarlo Pennati , Camilla De Gasperi , Frederick C. Battaglia , Enrico Ferrazzi

American Journal of Physiology - Heart and Circulatory Physiology Published 1 September 2000 Vol. 279 no. H1256-H1263



BIRMINGHAM
City University

Fetal heart



BIRMINGHAM
City University

Ductus Venosus Doppler

“The deterioration of fetal condition due to severe FGR is usually accompanied by signs of cardiovascular changes that can be shown by venous Doppler studies”

“Evidence of impaired cardiac function has been documented using Doppler flow studies of the precordial veins”

Aberry and Soothill 2007

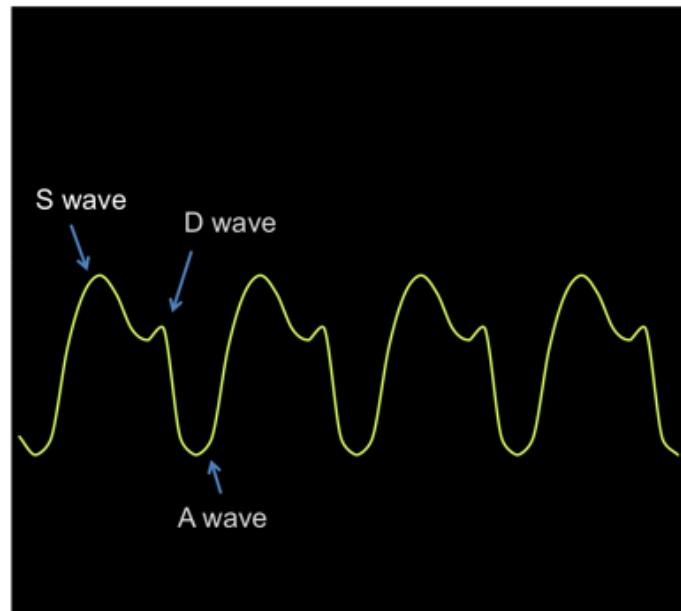
Arch Dis Child Fetal Neonatal Ed 2007;92:F62–F67. doi: 10.1136/adc.20



BIRMINGHAM
City University

Ductus venosus waveforms

Normal ductus venosus waveform



- **S wave** : corresponds to fetal ventricular systolic contraction
- **D wave** : corresponds to fetal early ventricular diastole
- **A wave** : corresponds to fetal atrial contraction

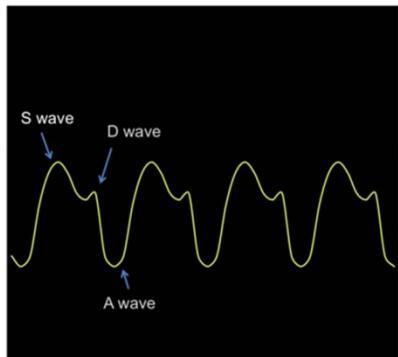
Weer



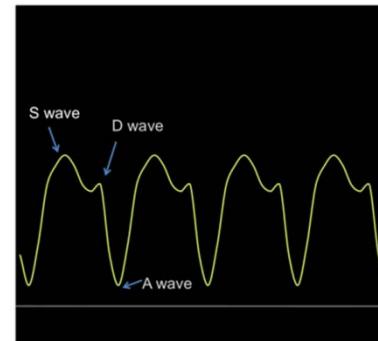
BIRMINGHAM
City University

Ductus venosus waveforms

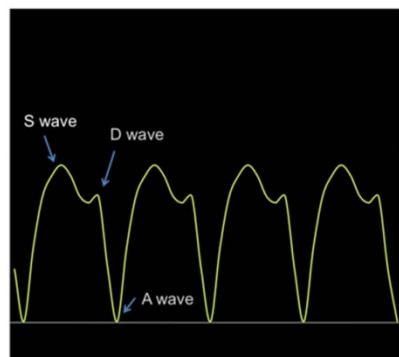
Normal ductus venosus waveform



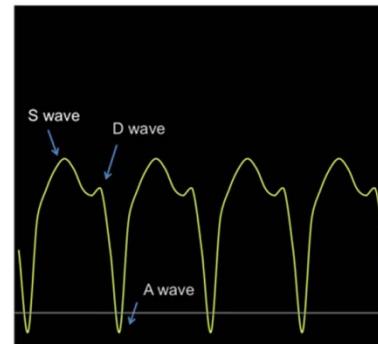
Reduction of flow in A wave



Absent flow in A wave



Reversal of A wave



Weerakkody ®

Weerakkody ®

Ductus Venosus Doppler

Technique

- the probe is ideally focused so sampling is done where the umbilical vein joins the ductus venosus
- the probe is ideally angled to allow a mid sagittal plane or a transverse oblique plane through the fetal abdomen
- do not contaminate the ductus venosus from flow from the fetal inferior vena cava
- the fetus should be as still as possible

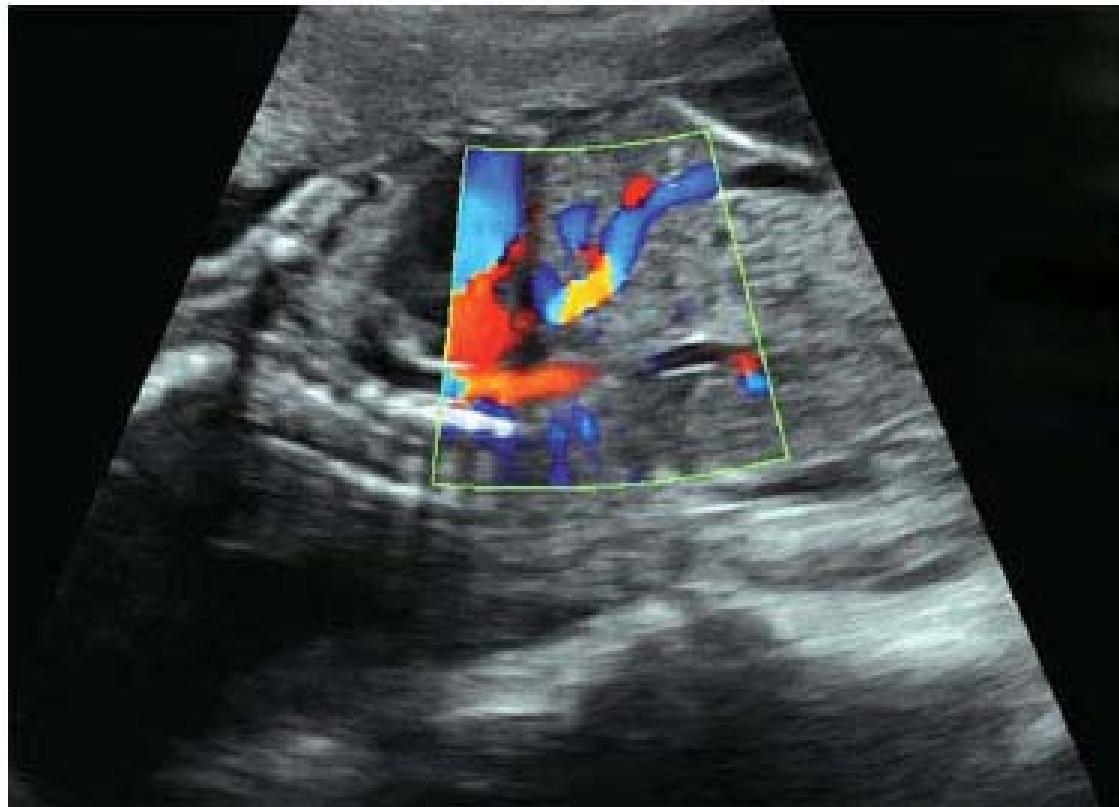


Three-dimensional Sonography in the Assessment
of Normal Fetal Anatomy in Late Pregnancy
Honeymayer and Kurjak et al 2010



BIRMINGHAM
City University

Aliasing in ductus venosus colour flow imaging



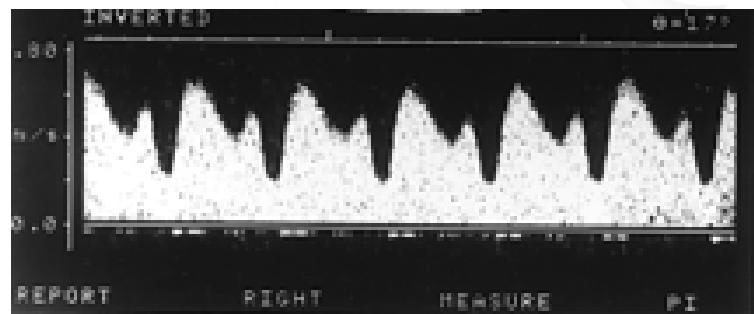
Three-dimensional Sonography in the Assessment
of Normal Fetal Anatomy in Late Pregnancy
Honeymayer and Kurjak et al 2010



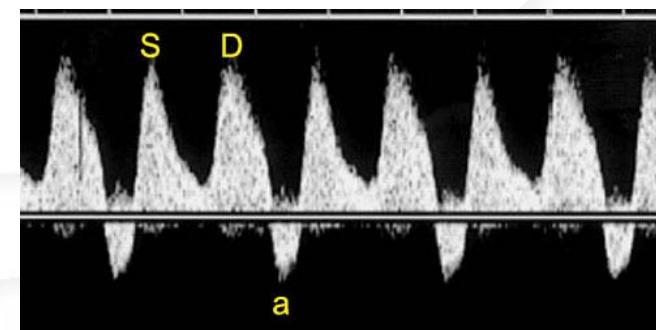
BIRMINGHAM
City University

Ductus venosus waveforms

Normal



Reversed A wave



**Assessment of Fetal Compromise by Doppler
Ultrasound Investigation of the Fetal
Circulation**
Hecher & Campbell et al 1995



BIRMINGHAM
City University

Ductus Venosus Doppler

- Ductus venosus Doppler has moderate predictive value for acidaemia and adverse outcome.
- Ductus venosus Doppler should be used for surveillance in the preterm SGA fetus with abnormal umbilical artery Doppler and used to time delivery.

Green top guide 31



BIRMINGHAM
City University

Applications of Doppler Ultrasound in Fetal Growth Assessment

Summary

- Uterine artery Doppler – screening examination
- Umbilical artery Doppler – assessment of SGA fetuses
- MCA Doppler – to detect brain sparing on fetuses with abnormal UA Dopplers
- Ductus venosus Dopplers – to detect impaired cardiac function on SGA fetuses and to time delivery



BIRMINGHAM
City University

THE END