ISUOG Basic Training

Umbilical and Uterine Artery Doppler

Learning objectives

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

- Describe how to perform, assess & report an umbilical artery Doppler examination correctly

- Describe how to perform, assess & 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?

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RECOMMENDATIONS

ISUOG Education Committee recommendations for basic training in obstetric and gynecological ultrasound

- Umbilical and uterine artery 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

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 & when not to use Doppler

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Fetal circulation

- High heart rate

- Low blood pressure (BP)

- Low peripheral resistance (placenta)

- Placental circulation constant
  (does not respond to vasoactive substances)

- With advancing gestation fetal BP & arteriola
  placental bed flow increase, peripheral
  resistance decreases
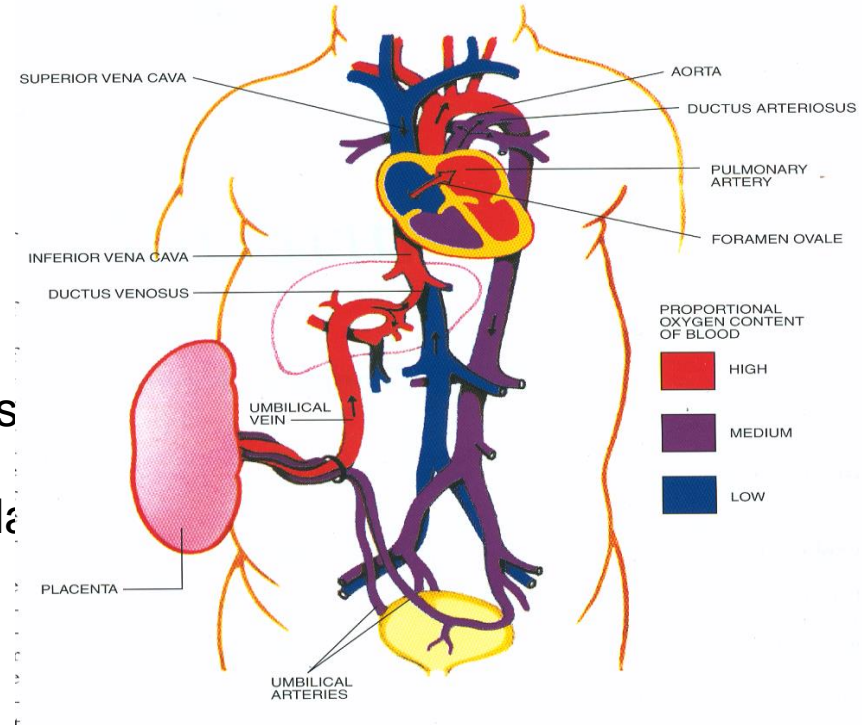
Fetal and maternal vessels

Fetal side

- Umbilical artery (UA)
- Middle cerebral artery (MCA)
- Ductus venosus (DV)
- Umbilical vein (UV)

Maternal side

- Uterine arteries (UtA)

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Indications for Doppler in pregnancy

Placentation

- Trophoblast invasion of spiral arteries

Fetal well-being

- Hypoxaemia
- Anaemia
- Chromosomal anomalies (1st trimester)
- Heart anomalies (heart function)
- MC twins
- Placental abruption
- Post-term pregnancies
- Diabetes

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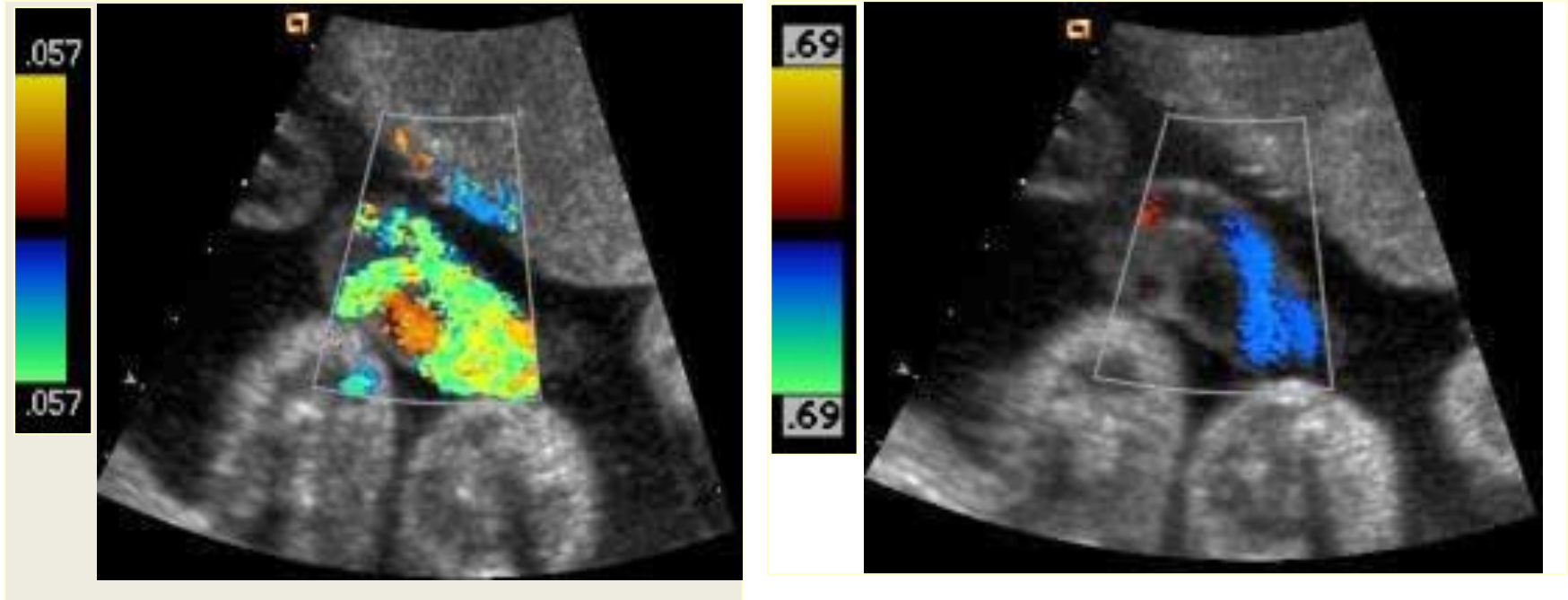# Umbilical artery Doppler
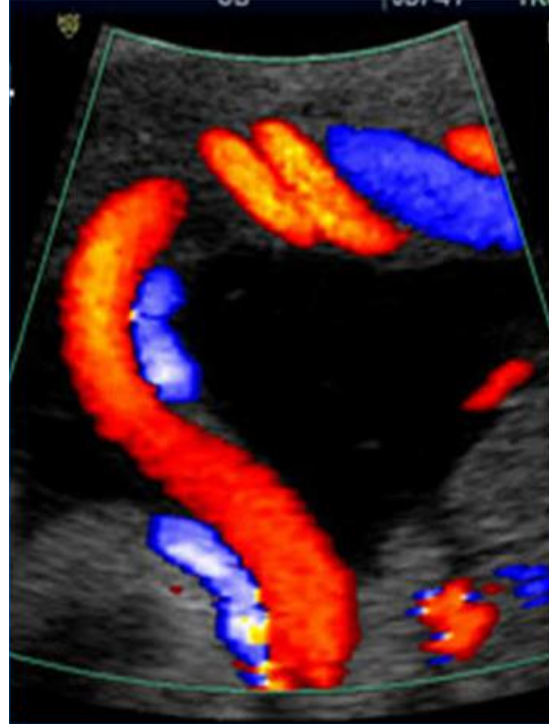
Umbilical artery Doppler
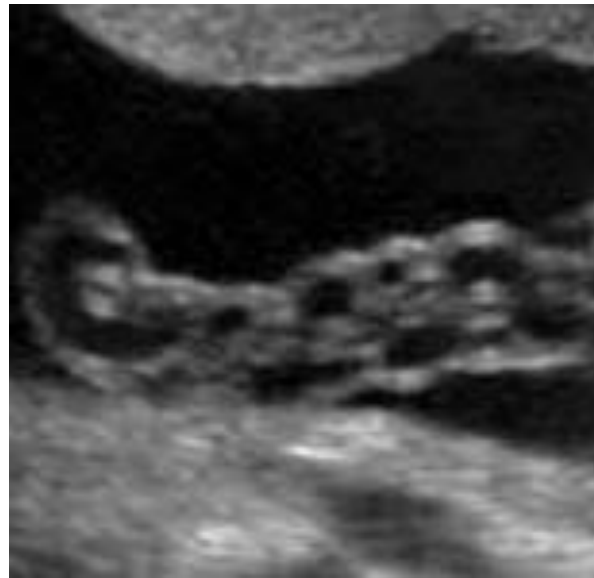
1. Visualise the cord, select a free loop, not too close to the fetal cord insertion or the placental insertion
2. Zoom up/magnify the area of cord
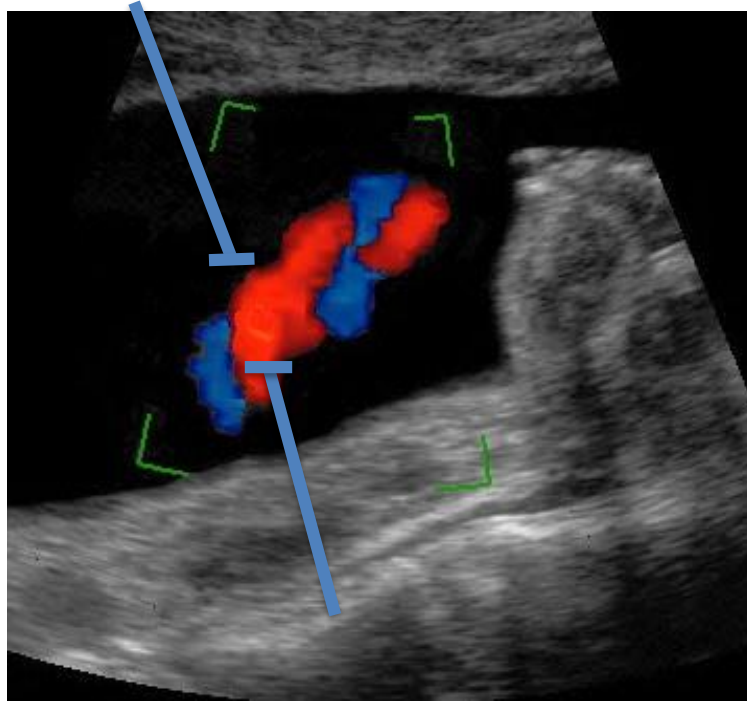
Umbilical artery Doppler
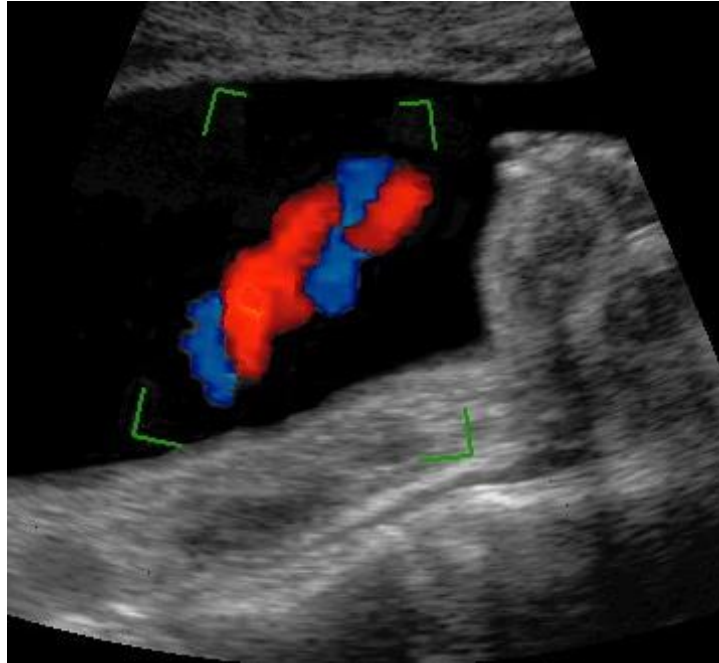
3. Switch on the colour Doppler modality (not compulsory)
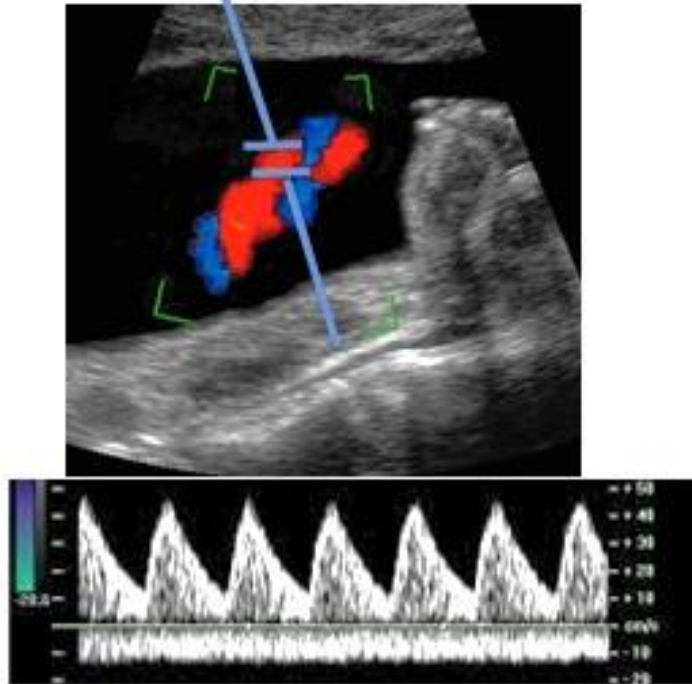
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Umbilical artery Doppler

3a. Optimise the colour flow mapping (CFM) scale
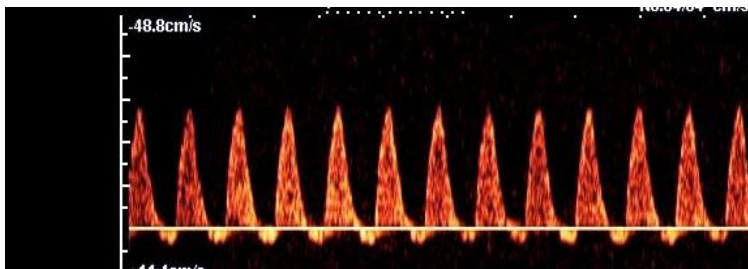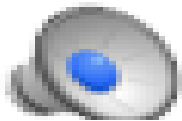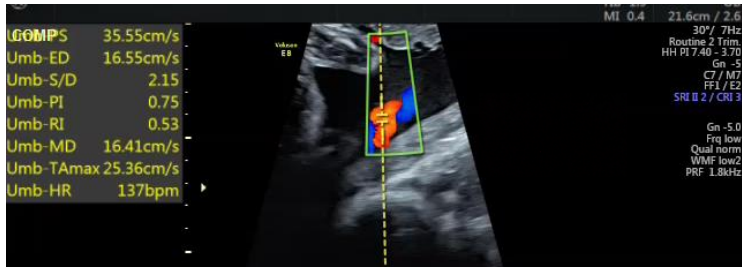
Umbilical artery Doppler

4. Place the sample gate on the umbilical artery

Umbilical artery Doppler

5. Start the pulsed Doppler function

Umbilical artery Doppler
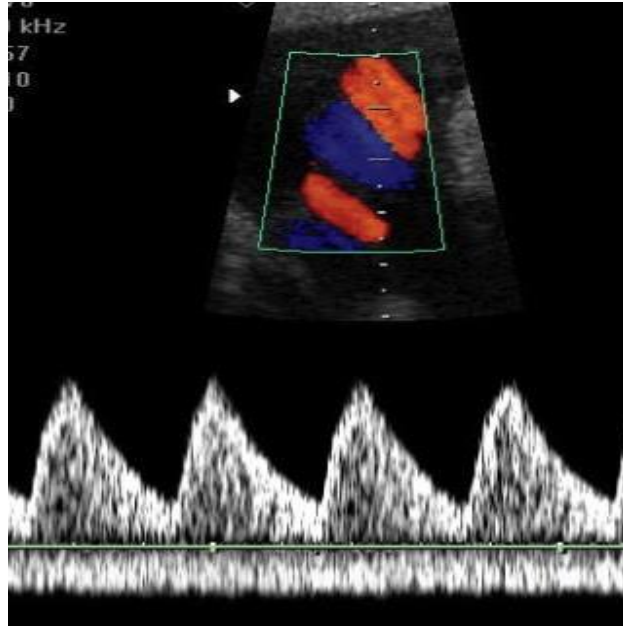

Laurin et al. Ultrasound measurement of fetal blood flow in predicting fetal outcome, BJOG, 1987, 94(10): 940-948
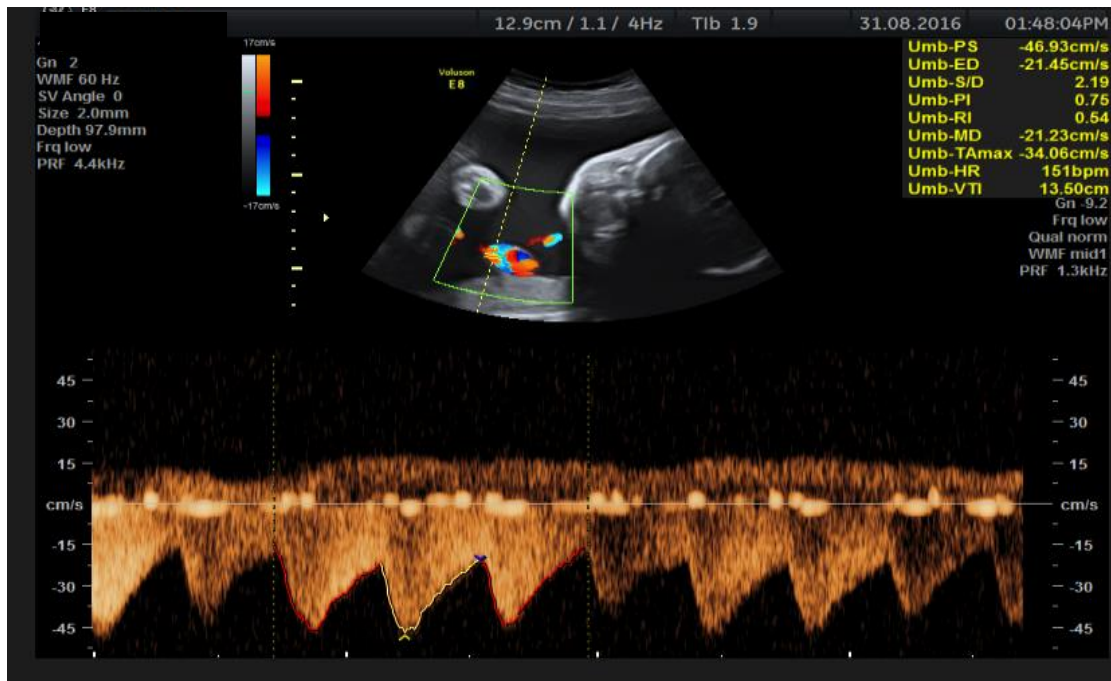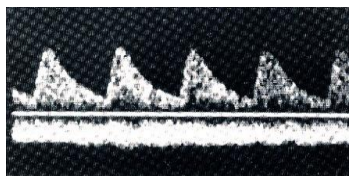
2D/pulsed Doppler

- 2D image in freeze mode provides better Doppler signals

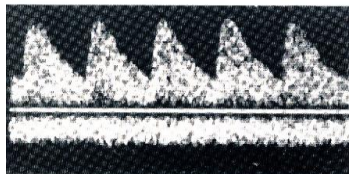# Irregular umbilical artery flow velocity pattern due to fetal breathing
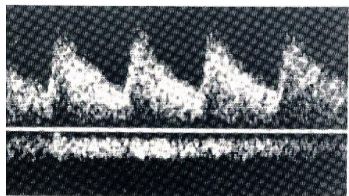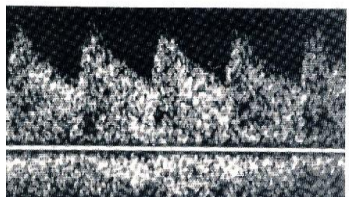
Umbilical cord Doppler

16 weeks

24 weeks

32 weeks

40 weeks

A. umbilicalis PI

95%

5%

Resistance in the placenta falls progressively with advancing gestation

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Umbilical artery in pathological pregnancies

High PI

Absent end diastolic flow (AEDF)

Reversed end diastolic flow (REDF)

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Abnormal UA findings

Elevated UA index

$$y = -0.0246x + 1.7791$$
$$r^2 = 0.4025$$

Pulsatility index

Gestational age (weeks)
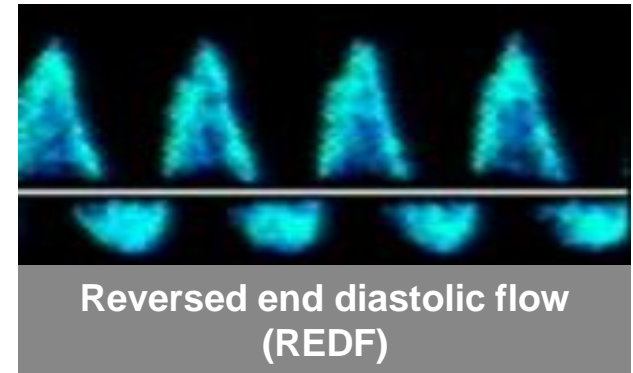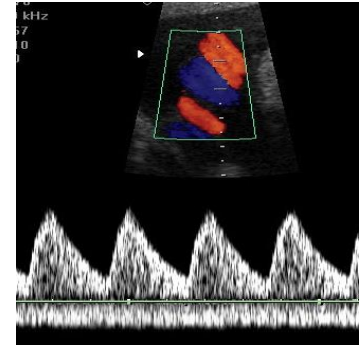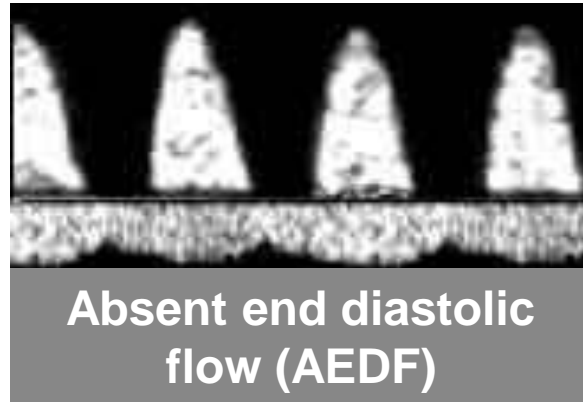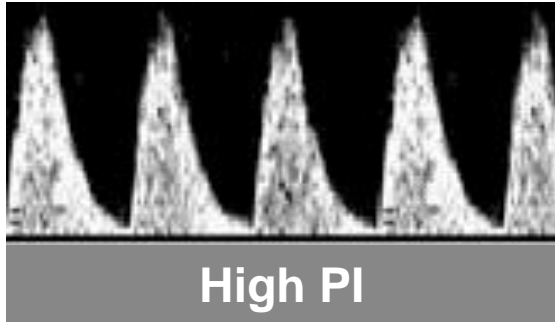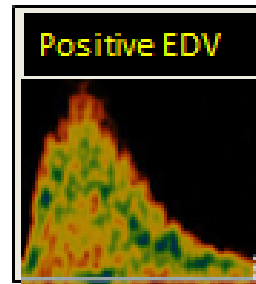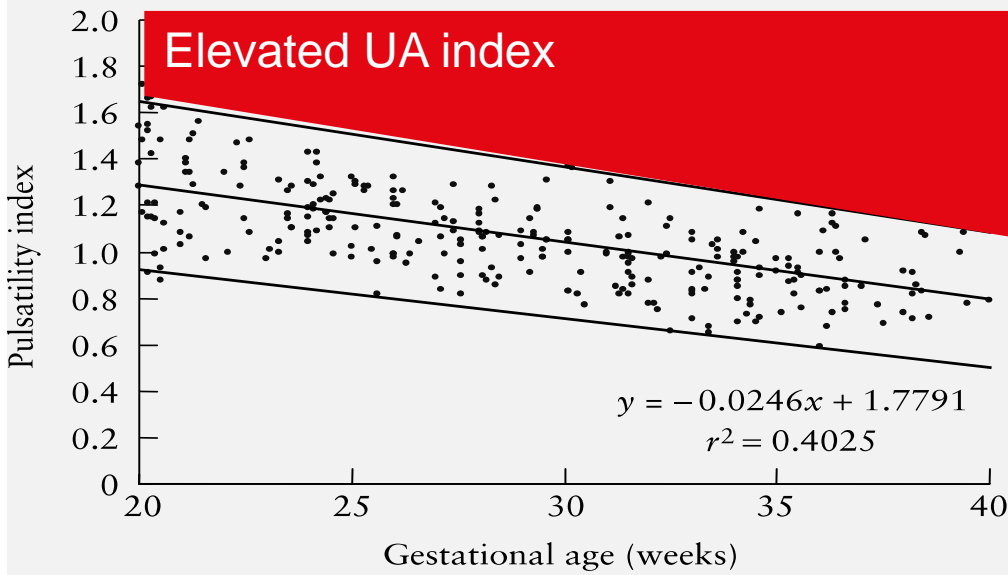
Positive EDV — 30% of villous vessels are underperfused
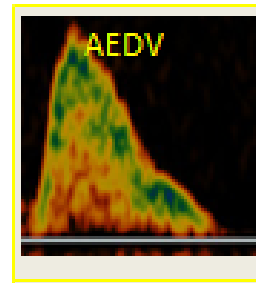
AEDV — 50% of villous vessels are underperfused
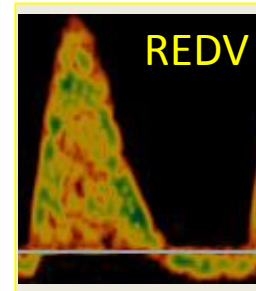
REDV — 70% of villous vessels are underperfused

Baschat A, Gembruch U, UOG 2003, 21: 124-7

Trudinger BJ, Giles WB, Br J Obstet Gynaecol, 1996, 105: 487-9

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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 & consistency, measurements should be made in a free cord loop

- In multiple pregnancies, &/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)

- Monochorionic twins

- Fetal hydrops

- EDF (+ve, absent or reversed) more sensitive than PI

Uterine artery Doppler
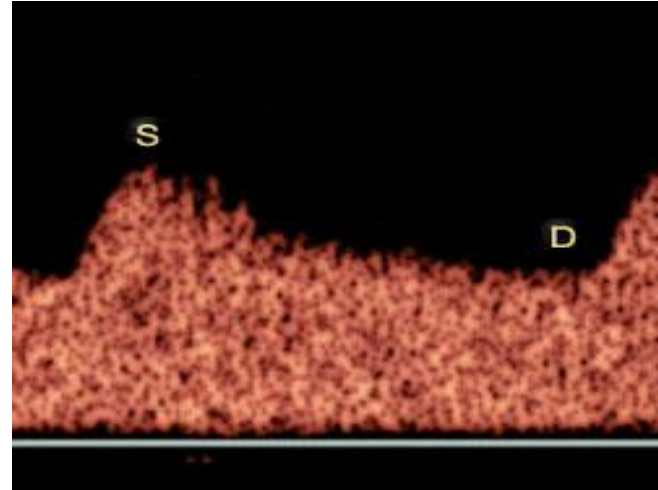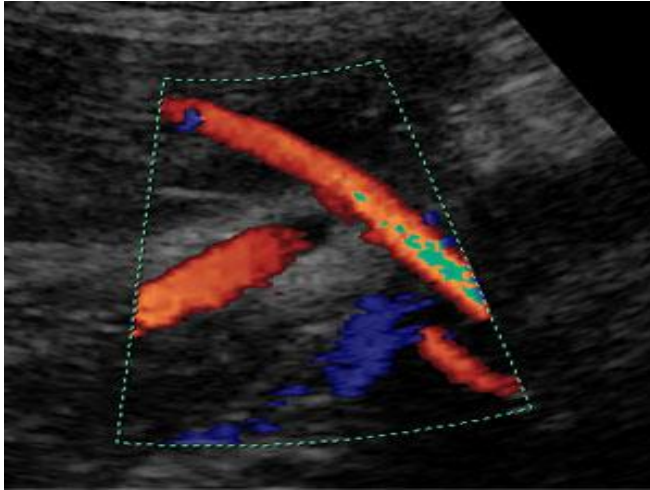
Uterine artery Doppler - technique

- Trans-abdominally, the probe is placed longitudinally in the lower lateral quadrant of the abdomen, & 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

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Trophoblast invasion
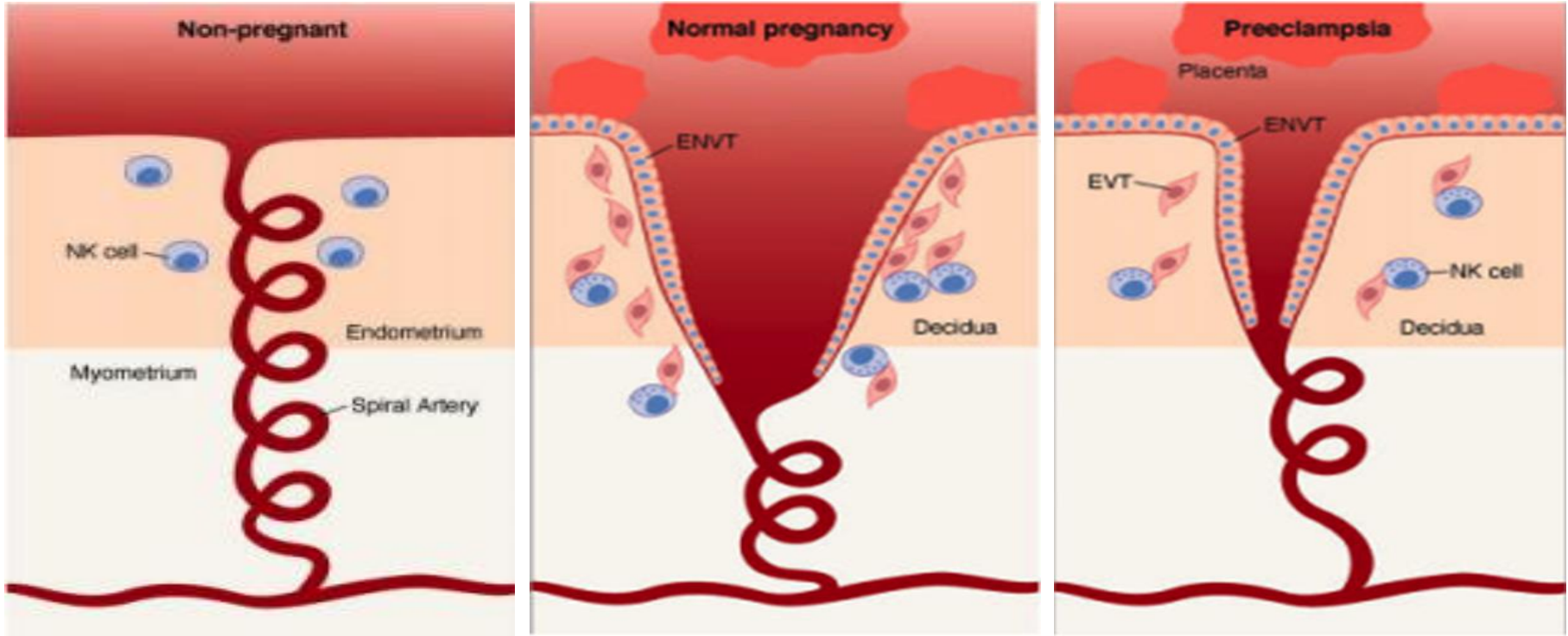
Uterine artery

THE LANCET

Figure 1. (a) and (b) arcuate artery flow velocity waveforms from two study patients; (c) diagrammatic representation of the resistance index.

New doppler technique for assessing uteroplacental blood flow.

Campbell S, Diaz-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.

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Normal uterine artery waveform

Abnormal uterine artery waveform
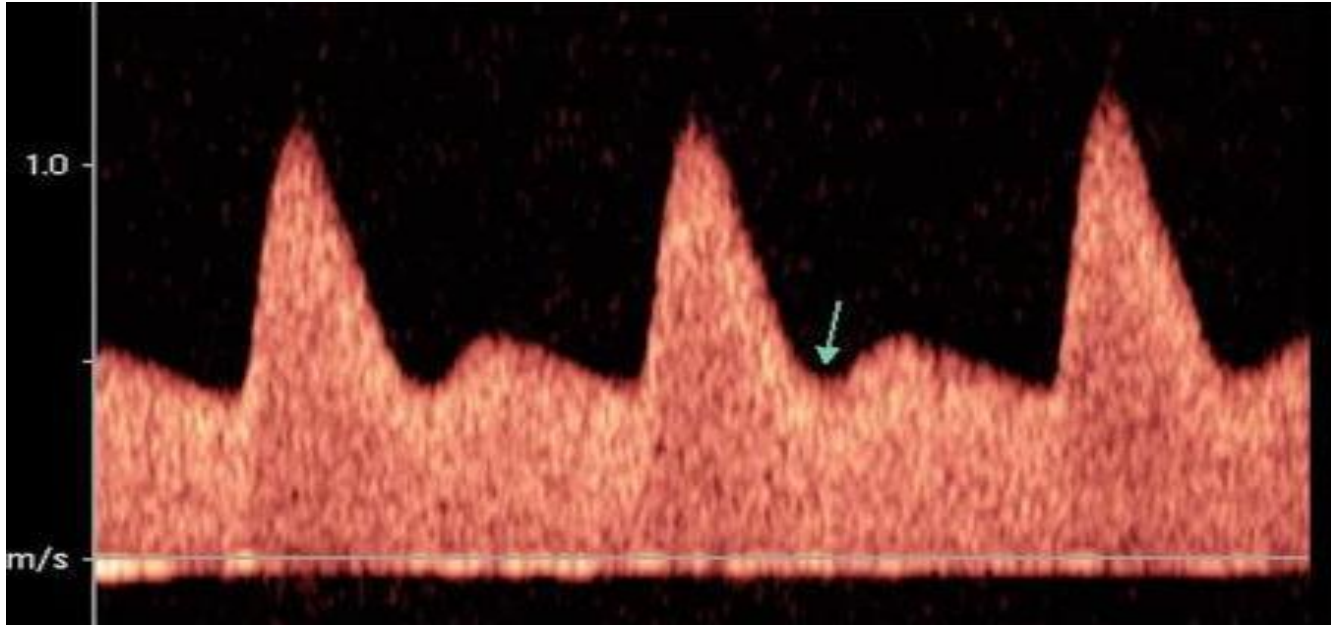
Note notch (arrow) implying increased resistance in the uterine artery

Normal range uterine artery PI
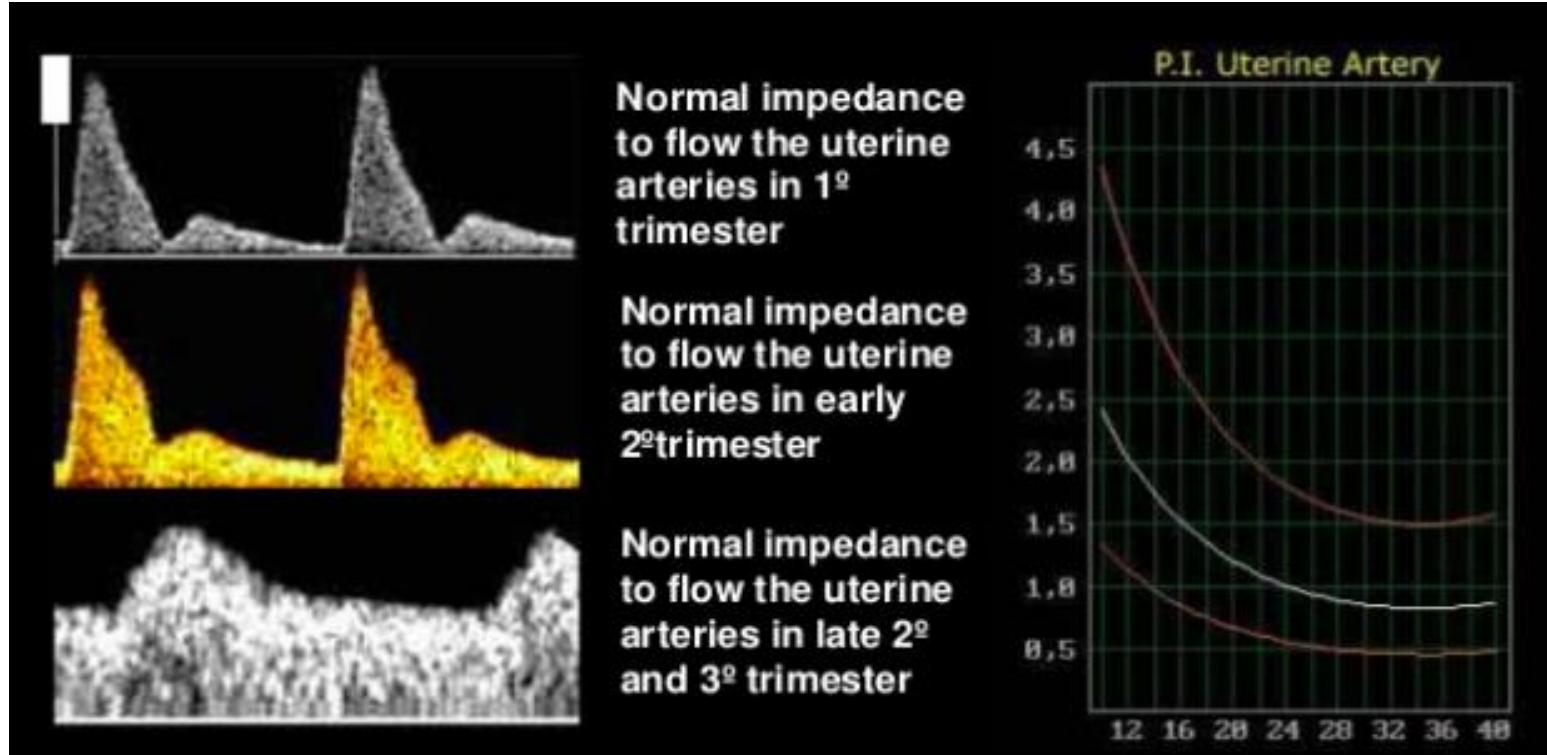
Uterine artery screening at 22-24 weeks
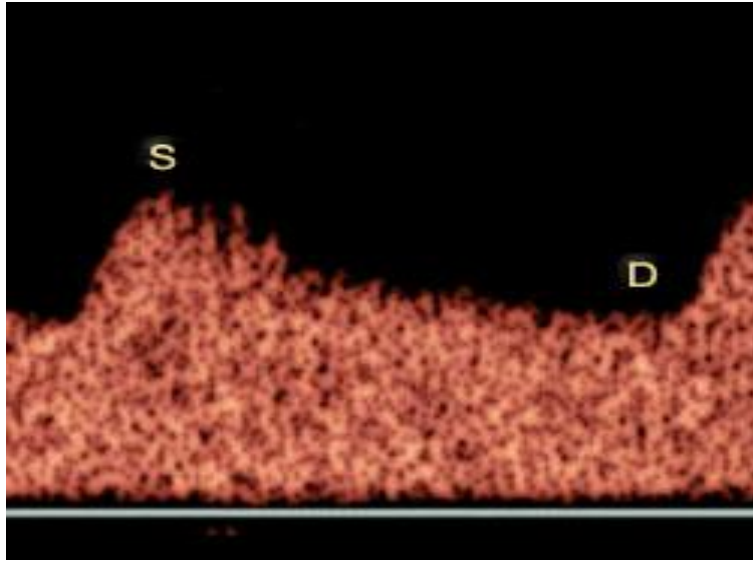
Low risk for preeclampsia (PE) & intrauterine growth restriction (IUGR)
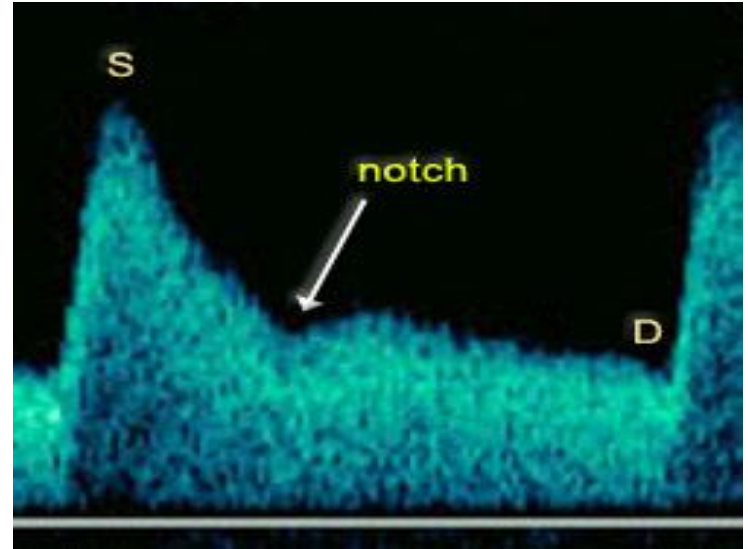
High risk for PE & IUGR

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Abnormal uterine artery waveforms after 20-24 weeks
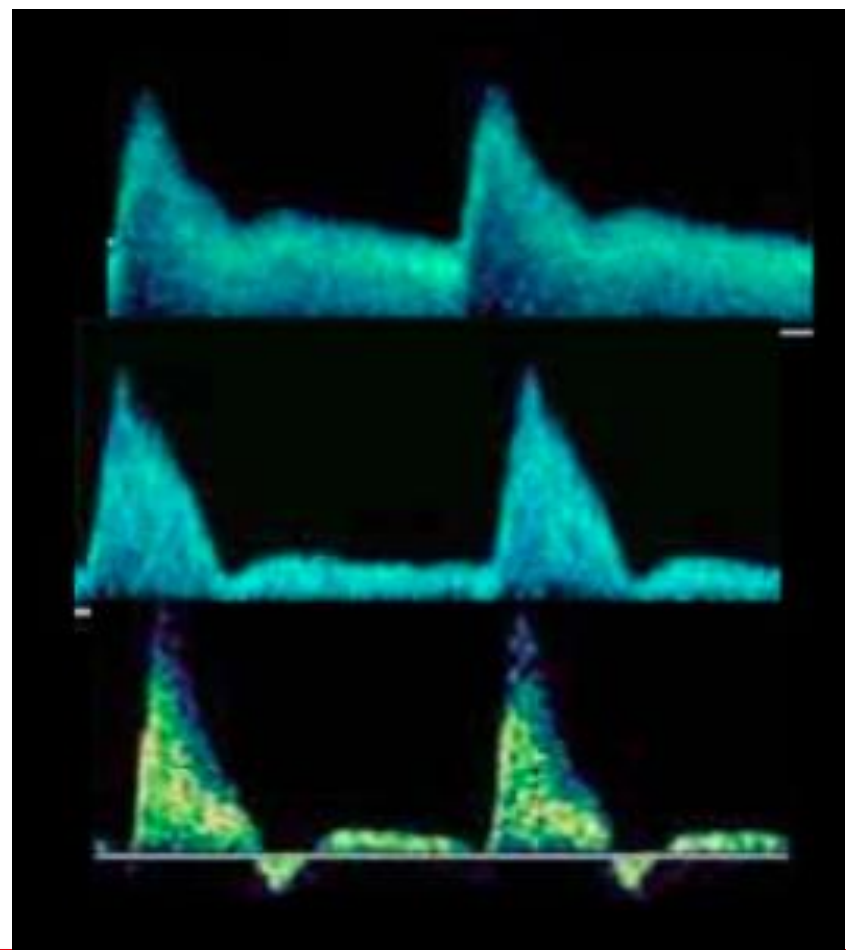
Uterine artery
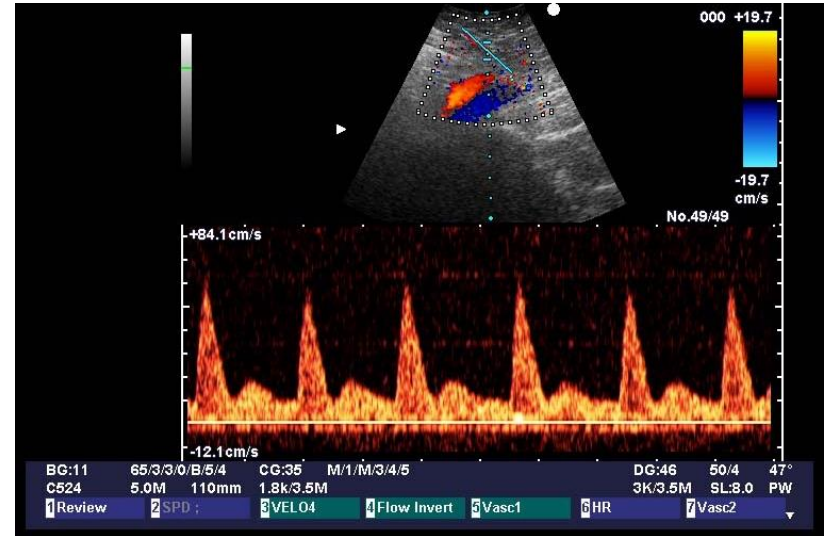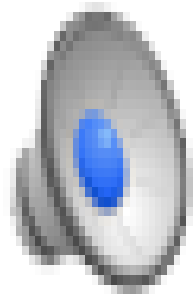
Clinical applications

Constitutionally Small

no increased perinatal death or morbidity

AC < 10th centile

Doppler

FGR

uteroplacental insufficency
hypoxemia, acidosis

Soothill, 1999

Doppler associated with 38% reduction perinatal death

Study	Treatment n/N	Control n/N	Peto Odds Ratio 95% CI	Weight (%)	Peto Odds Ratio 95% CI
Chester 1992	1/338	4/336		4.0	0.30 [0.05. 1.72]
Dublin 1992	4/241	3/235		5.6	1.30 [0.29. 5.78]
Edinburgh 1993	12/1132	16/1197		22.2	0.79 [0.38. 1.67]
Leeds(I) 1990	3/250	3/250		4.8	1.00 [0.20. 4.99]
London(Guys) 1994	11/236	14/231		19.1	0.76 [0.34. 1.70]
Maastricht	2/74	3/76		3.9	0.68 [0.12. 4.03]
Oxford 1991	4/438	8/459		9.5	0.53 [0.17. 1.67]
Perth(I) 1991	9/275	9/270		14.0	0.98 [0.38. 2.51]
Sweden	0/214	3/212		2.4	0.13 [0.01. 1.28]
Sydney 1987	1/127	5/162		4.7	0.32 [0.06. 1.65]
Tygerberg	6/108	7/104		9.9	0.82 [0.27. 2.50]
Total (95% CI)	3433	3532		100.0	0.71 [0.50. 1.01]

Total events: 53 (Treatment), 75 (Control)

Test for heterogeneity chi-square=5.61 df=10 p=0.85 I^2=0.09%

Test for overall effect z=1.88 p=0.06

0.1 0.2 0.5 1 2 5 10

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When are uterine artery measurements indicated?

- Suspicion of placental insufficiency / FGR

- FGR in previous pregnancy

- Mothers with systemic lupus erythematosus (SLE), 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

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

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.

Papageorghiou et al, UOG, 2001, 18(5): 456-459

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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)

Reference	Screen-positive rate (%)	Prevalence (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Albaiges et al., 2000	7.5	3.1	45	94	23	98
Aquilina et al., 2001[30]	9.8	5.5†	60	93	33	98
Papageorghiou et al., 2001[31]	5.1	1.4†	41	95	12	99

*Blood pressure ≥ 140/90 and proteinuria > 150 mg/24 h
†Blood pressure ≥ 140/90 and proteinuria > 300 mg/24 h
‡Blood pressure rise (systolic > 30 mmHg and diastolic > 25 mmHg) with proteinuria > 500 mg/24 h

Increased impedance to flow in the uterine arteries in pregnancies attending for routine antenatal care identifies approximately 40% (L.R. 6.0) of those who subsequently develop PE & approximately 20%(L.R. 3.5) of those who develop fetal growth restriction
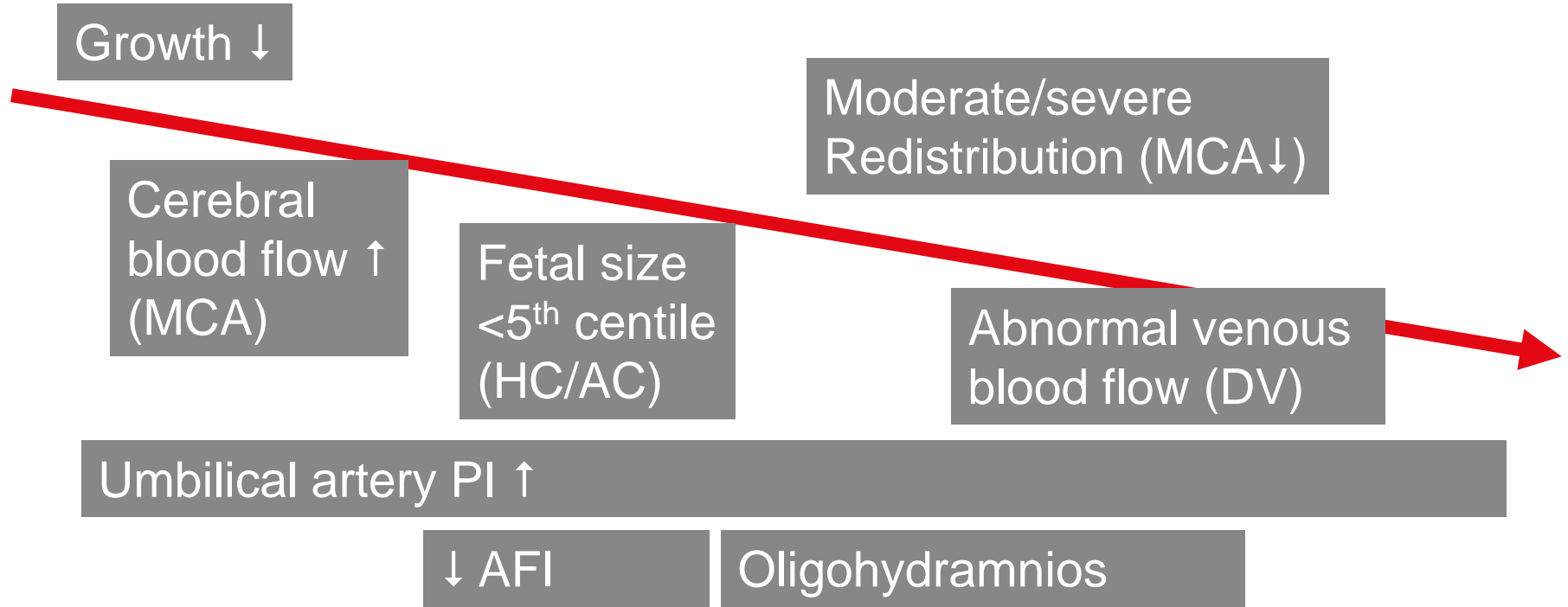
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PI in clinical practice

- The decrease in uterine artery PI between 11w to 13w6d and 21w to 24w6d is steeper in pregnancies with a normal outcome than those developing pre-eclampsia (PE)

- Effective screening for PE can be achieved by uterine artery PI measurement at 11w to 13w6d & the change between these two periods

Plasencia, Maiz, Poon, Yu, Nicolaides, UOG, 2008, 32:138-146.

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Uteroplacental failure
- sequential well being changes

Growth ↓

Moderate/severe Redistribution (MCA↓)

Cerebral blood flow ↑ (MCA)

Fetal size <5th centile (HC/AC)

Abnormal venous blood flow (DV)

Umbilical artery PI ↑

↓ AFI

Oligohydramnios

Key points

1. Doppler investigations give insight into fetal & pregnancy patho-physiology

2. Doppler is one of the major breakthroughs in Fetal Medicine

3. Doppler can be used in all trimesters for different indications

4. Doppler can be used as a screening or a diagnostic tool, according to the circumstances

5. In the 2nd & 3rd trimesters Doppler studies can indicate abnormal placentation, fetal hypoxemia, fetal anemia & impending heart failure

6. Operators should use Doppler skillfully & with knowledge of its potentials, limitations & dangers

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