The use of uterine artery Doppler in pregnancy induced hypertensive disorders

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Doppler ultrasound: basic principles

Ultrasound images of flow (color or spectral Doppler), are essentially obtained from measurements of movement.

The ultrasound scanner transmits a series of pulses to detect movement of blood.
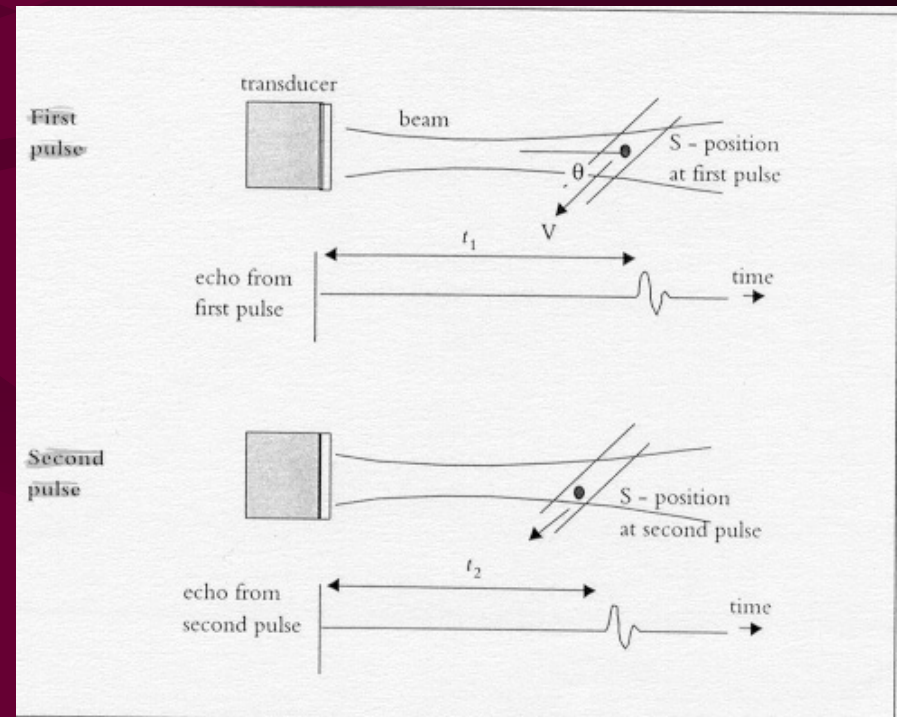
Doppler velocity measurements

Echoes from stationary tissues are the same from pulse to pulse. Echoes from moving objects exhibit slight differences in the time for the signal to be returned to the receiver.

- *These differences can be*
- *measured as a direct time difference or, more*
- *usually, in terms of phase shift from which the*
- *Doppler frequency is*
- *obtained. As blood velocity*
- *increases, so does the Doppler frequency.*

The effect of the Doppler angle in the sonogram
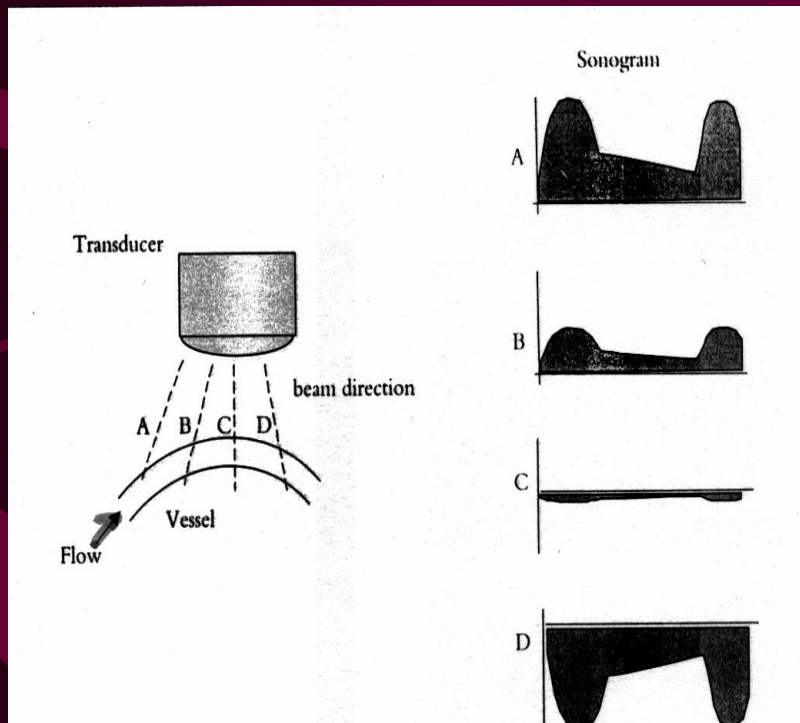
- *A higher-frequency Doppler signal is obtained if the beam is aligned more to the direction of flow.*

- *In the diagram, the beam A is more aligned than beam B and produces higher-frequency Doppler signals.*

- *The beam/flow angle C is almost 90º and there is a very poor Doppler signal.*

- *The flow D is away from the beam and there is negative signal.*

Doppler ultrasound: basic principles

The time difference or phase shift are then proceeded to produce either color flow display or a Doppler sonogram

The possible Doppler velocimetry sites

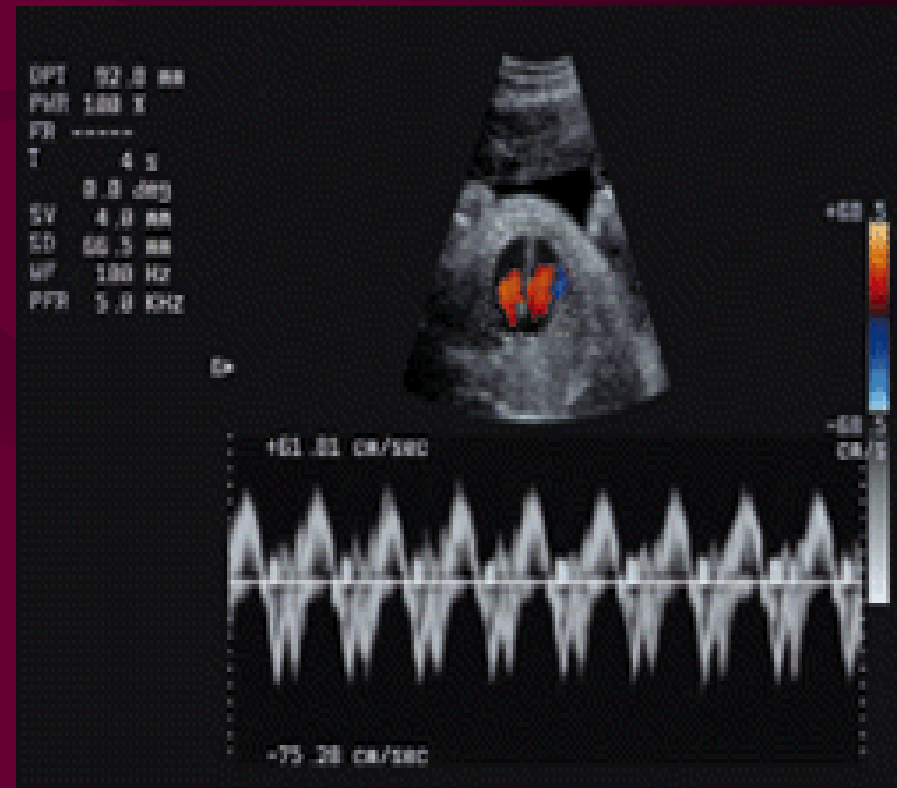- Umbilical artery in cases of fetal growth restriction and other cases with non-reassuring fetal heart rate.

The possible Doppler velocimetry sites

Middle cerebral artery in cases of fetal growth restriction or for anaemia detection.

The possible Doppler velocimetry sites

The detection of congenital fetal heart anomalies

The possible Doppler velocimetry sites

- There is also a possibility to evaluate blood flow in fetal *renal artery* in cases of intrauterine fetal growth restriction(IUGR), *lienal artery* (in cases of Rh alloimmunisation for Hb level evaluation), in the *fetal veins* (V. cava, umbilical V., venous ductus) in cases of IUGR, and in pulmonary veins (for pulmonary status evaluation)

The flow velocimetry waveforms of the uterine artery (normal waveform)

- *For prediction of pre-eclampsia and fetal intrauterine growth restriction in the first and second trimester of pregnancy;*

- *For the differential diagnosis of the causes of fetal intrauterine growth retardation.*

The technique of uterine artery Doppler

The Doppler velocimetry measurements of the uterine artery are taken at the point just distally to the crossover with the iliac artery, before uterine artery division into arcuate arteries.
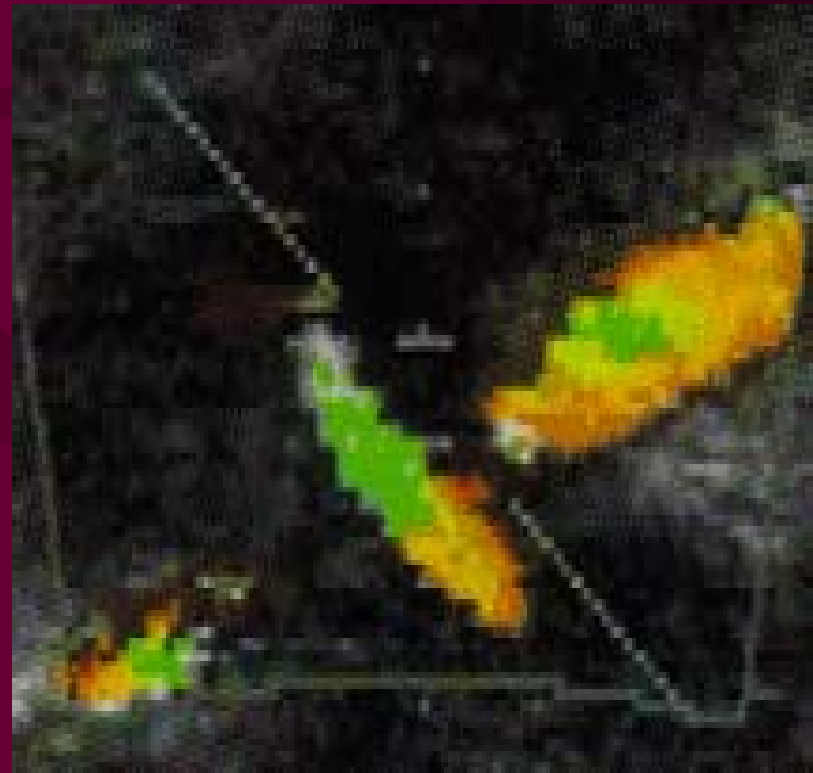
Changes in uterine blood flow in normal pregnancy (1)

- *Placental trophoblastic invasion into the myometrium has profound effect on the uterine circulation.*

- *It happens by means of changing of the lay-muscular tissue by endovascular throphoblast in spiral arteries wall.*

- *As a result these arteries loose the possibility to react to endogenous vasoconstrictive agents.*

Changes in uterine blood flow in normal pregnancy (2)

- *The blood flow in it changes from one of low flow and high resistance to one of high flow and low resistance latest until 24 weeks of pregnancy.*

- *The uterine artery represents the whole uteroplacental blood flow.*

Abnormal uterine artery Doppler waveforms(low diastolic flow and protodiastolic notch)
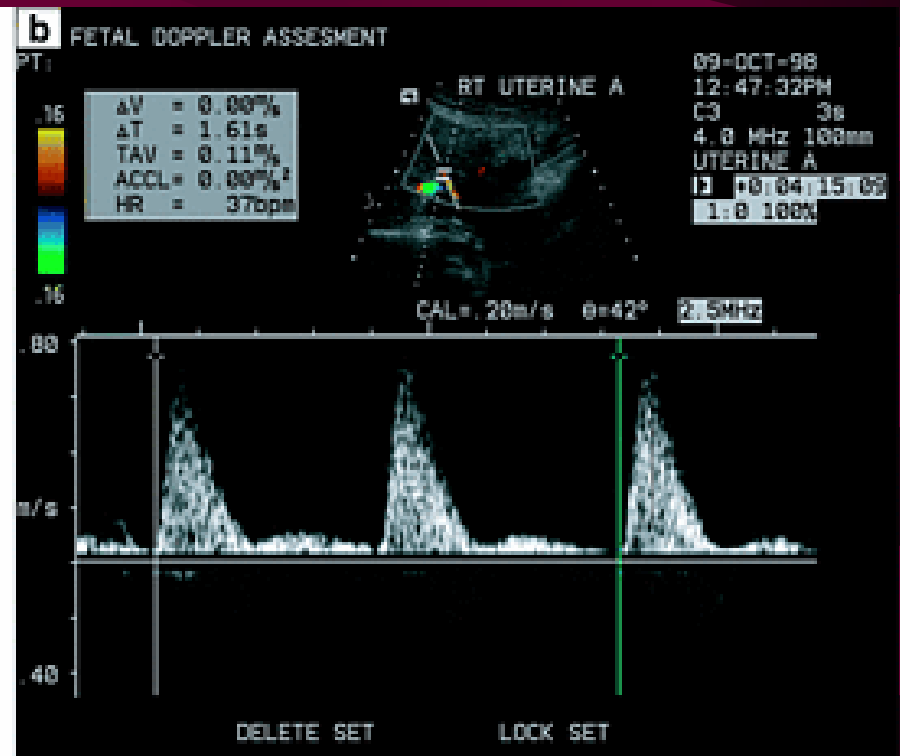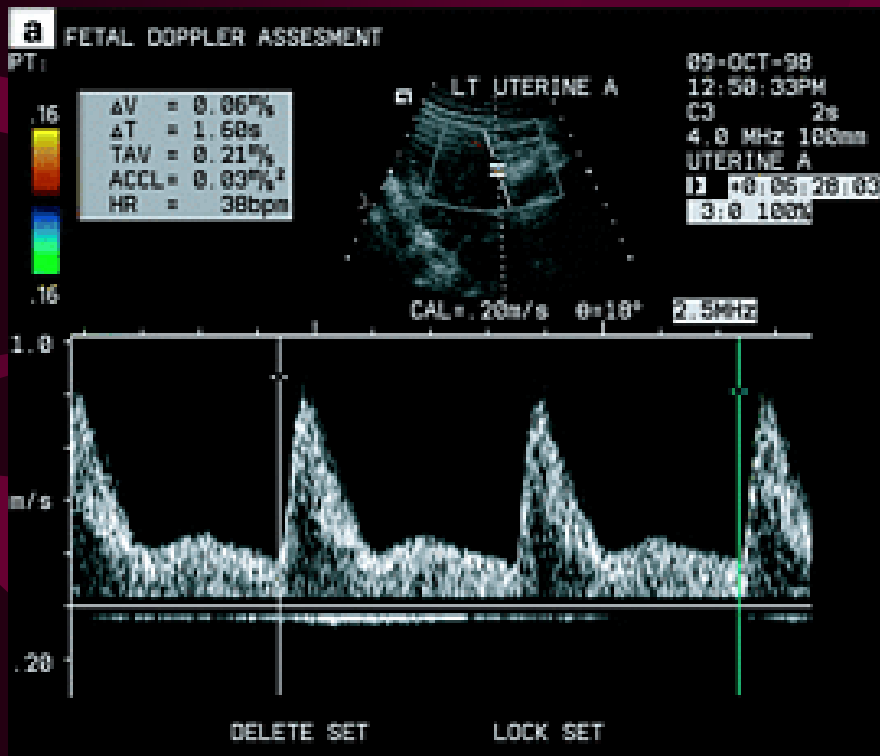
Doppler velocimetry indices

- **A/B=**   (the systolic/diastolic ratio) is calculated by measuring the systolic peak and the end-diastolic flow.

- **A/C=**   (systolic proto-diastolic ratio) is used to evaluate the depth of the proto-diastolic notch.

- **RI=** $$\frac{\text{Peak systolic flow (A)-least diastolic flow (B)}}{\text{Peak systolic flow (A)}}$$

- **PI=** $$\frac{\text{Peak systolic flow (A)-least diastolic flow (B)}}{\text{Mean blood flow velocity}}$$

The reason for early pre-eclampsia screening

- The possibility to distinguish the high risk pregnancies (with abnormal uterine artery Doppler velocimetry results and history of impaired placentation) would let to modify the follow-up

- and to try preventive treatment regimens (low-dose aspirin, low-molecular weight heparin or antioxidants).

Pre-eclampsia screening in the first trimester of pregnancy

The combined use of transvaginal ultrasonography with the pulse-color Doppler technique allows the study of the uterine and umbilical circulation during the first trimester.

Color Doppler imaging helps to identify the changes in uterine artery blood flow at 6-9 weeks of gestation.

Doppler velocimetry use for pre-eclampsia screening in the early pregnancy

- **Arduini D.** et al. (1991) examined *330* low-risk pregnancies recruited from the outpatient division at 7-16 weeks of gestation

- **Elzen** et al. (1995) measured pulsatility index (PI) values at 12-13 weeks in a prospective cohort study of *352* women aged 35 years or older.

- **Harrington K.** et al. (1997) carried out a follow-up study in *652* women with singleton pregnancies who had transvaginal uterine and umbilical artery Doppler examinations performed at 12-16 weeks' gestation.

- **Uzan M.** (6th annual meeting in fetal medicine, that was held 29 March - 1 April, 2001) presented the data of the two years study of uterine artery Doppler performed at 12 weeks of gestation

The Results of the studies

- **Arduini D. et al. (1991)** *no evident differences* were found in arteries (uterine, arcuate or trophoblastic) between patients with later complications and those with normal pregnancy.

- **Uzan M. et al.(2001)** concluded that normal uterine artery Doppler FVWs in early pregnancy allowed to *distinguish the group of pregnancies with very low risk* to develop pregnancy vascular complications.

- **Elzen et al. (1995)** found a *significant association* between uterine artery PI values (comparing lowest and highest quartile) at 12-13 weeks and hypertensive disorders (RR=4)

- **Harrington K. et al. (1997)** values from women with a normal pregnancy outcome, *differ significantly* from women who subsequently developed PPIH (mean RI = 0.80 vs.. 0.695, $p < 0.001$).

Pre-eclampsia screening in the second trimester of pregnancy

- **More than 30 publications reported on the pre-eclampsia screening in the second trimester of pregnancy**

- **in high risk pregnancies**
- **and in unselected population**

Comprehensive comparison of all previously published methods

- **Aquilina J. et al.** (2000) examined 614 primiparous women by color flow/pulse Doppler imaging of both uterine arteries at 20 weeks gestation. Receiver operator characteristic (ROC) curves were created for the **A/B** ratio, **RI** and **A/C** ratio for **placental and non-placental** uterine arteries, individually or in combination with the presence of **unilateral or bilateral notches**.

- **The highest sensitivity (88%)** and **specificity** of **(83%)** was obtained using bilateral notches/mean **RI > 0.55** (50th centile) and unilateral notches/mean **RI > 0.65** (80th centile), when the false-positive rate was set at 17%.

- Placental velocimetric indices performed better than mean indices but the differences in sensitivity at the set false-positive rates were not statistically significant.

The best sensitivity and PPV by the apex of the ROC curves

	Sens. (%)	Spec. (%)	PPV (%)	OR (95% CI)
Any notch plus mean A/B ratio >/=2,64	8	83	26	14,6(6,9-30,9)
Billateral notches A/C ratio >/=2,1	86	83	28	31,0(11 6-82,3)
Billateral notches plus mean RI>/=0,55	88	83	28	33,1(12,6-86,9)

Receiver operator characteristic curves for methods using RI
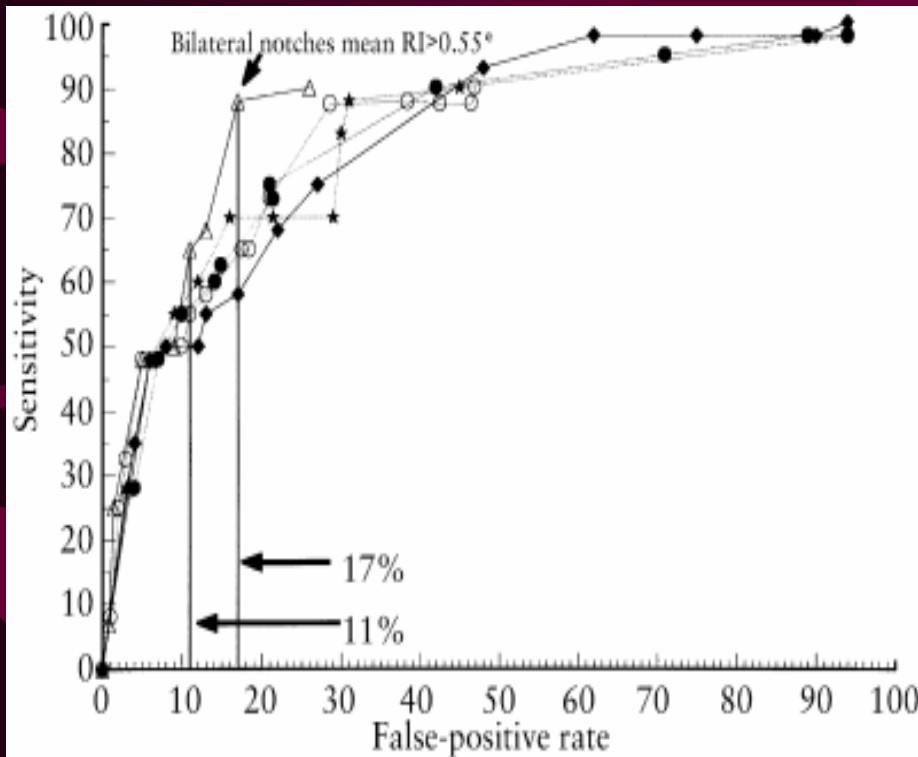
- mean RI (diamonds)

- mean RI plus any notch (open circles)

-

- placental RI (closed circles)

- placental RI ratio plus any notch (stars)

-

- bilateral notches plus mean RI (triangles).

Pre-eclampsia probability changes using Doppler velocimetry (Chien F. et al. systematic review 2000)

	Abnormal test results	Normal test results
Low risk pregnancies	3,5 (95%CI 3,1-3,9) to 18,8 (95%CI 16,4-21,5)	3,5(95%CI 3,1-3,9) to 2,5 (95%CI2,1-2,9)
High risk pregnancies	9,8 (95%CI7,9-11,8) to 23,5 (95%CI18,6-29,2)	9,8 (95%CI7,9-11,8) to 7,8(95%CI 6,1-10,0)

Conclusions

- **Increased impedance to flow in the uterine arteries in both high-risk and low-risk pregnancies is associated with increased risk of development of pre-eclampsia and intrauterine growth restriction.**

- **Women with normal impedance to flow in the uterine arteries constitute a group that have a low risk of developing obstetric complications related to uteroplacental insufficiency.**

Conclusions

- Increased impedance to flow in the uterine arteries in pregnancy attending for routine antenatal care identifies about 50% of those that subsequently develop pre-eclampsia.

- Abnormal Doppler is better in predicting severe rather than mild pre-eclampsia. The sensitivity for severe pre-eclampsia is about 75%.

What questions remain to be answered?

- Very early screening ??

- For what ??

- Aspirin or other preventive treatment ??

- What kind of studies to be done??