Introduction

Pre-eclampsia and to a lesser extent hypertension in pregnancy is a vascular disease affecting both maternal and fetal circulations. On the maternal side, one of the very early characteristics of the disease is the deficient infiltration of the spiral arteries by the trophoblast, failing to convert it to uteroplacental arteries [12]. Subsequently, the 10- to 12-fold increase in uterine perfusion, as is seen in normal pregnancy, does not occur. This affects blood flow in the uterine artery [16]. On the fetal side there is poor vascularization of the terminal villi, villous stromal hemorrhage and hemorrhagic endovasculitis [50, 51] or even obliteration of stem villi [26, 27]. As Doppler techniques enable one to study flow velocity waveforms in a non-invasive way, it became one of the most ideal methods to analyze the maternal and fetal circulations and in particular that of the uterine and umbilical arteries. Although Satomura [86] described the feasibility of Doppler ultrasound to determine flow velocity in a peripheral artery, it took almost 20 years until the next important development in this field, when Fitzgerald and Drumm [34] used Doppler ultrasonography to investigate the human fetal circulation. Six years later Campbell et al. [16] reported, for the first time, the importance of uterine artery Doppler in obstetrics. Subsequently, developments have been summarized in very good recent reviews to which the interested reader is referred [13, 24, 26, 27, 36, 50, 51, 64, 65]. Although the research on the umbilical artery preceded that on the uterine artery and the use of its flow velocity waveforms is more established in clinical medicine, the uterine artery is discussed first to follow chronological events in pregnancy.

Uterine Artery

As a result of the trophoblast invasion of the spiral arteries, and increase in uterine perfusion, end-diastolic flow in the uterine artery increases as the pregnancy advances. This gives the flow velocity waveform of the uterine artery a unique shape, characterized by high end-diastolic velocities with continuous forward blood flow throughout diastole [27]; however, in abnormal pregnancy there is poor trophoblast invasion of the spiral arteries. Subsequently, the end-diastolic flow does not increase or the diastolic notch does not disappear (Fig. 19.1).

To be able to apply the use of uterine artery flow velocity in clinical practice the following questions need to be answered:
1. How accurate is the screening?
2. When should the screening start?
3. What is the best method of screening?
4. Should any high-risk women be screened?
5. Which risks should be identified?
6. Can intervention in the identified women improve the outcome of pregnancy?

Screening in the First Trimester

Schuchter et al. [87] examined both uterine arteries in 380 singleton pregnancies during the 11–14 weeks of screening for nuchal translucency. They used a pulsatility index at and above the 90th percentile to identify fetal growth restriction, pregnancy-induced hypertension, pre-eclampsia and placental abruption. Their screening was positive in 10% of women. The sensitivity was 25%, and 8.4% of tests were false positive. They also assessed the placental volume at the same examination and found that a combination of the two examinations reduced the sensitivity but increased the number of false-positive tests.

Screening in the Second Trimester

Coleman et al. [21] studied 116 pregnancies in 114 women at high risk of pre-eclampsia. They screened the women between 22 and 24 weeks’ gestation using a resistance index (RI) >0.58 as abnormal. Outcome measures were pre-eclampsia, small for gestational age (SGA), placental abruption, intrauterine death and “all” and “severe” outcomes. The sensitivity of any RI >0.58 for pre-eclampsia, SGA, “all” outcomes and “severe” outcomes was 91, 84, 83 and 90%, respectively. Specificity for these outcomes was 42, 39, 47 and 38%, respectively. The positive predictive val-
ue for these outcomes was 37, 33, 58 and 24%, respectively. Using both values and a RI of ≥0.7 the positive predictive value improved to 58, 67, 85 and 58%. In the cases of bilateral notches the positive predictive value was 47, 53, 76 and 65%, respectively. They concluded that uterine artery Doppler waveform analysis was better than the clinical risk assessment in the prediction of pre-eclampsia and SGA babies.

Ohkuchi et al. [77] examined 288 normal women attending the antenatal clinic between 16 and 23.9 weeks of gestation, using the notch depth index (NDI) to identify the patient at risk. End points were pre-eclampsia, which developed in 3.1% of women and SGA which occurred in 6.3% of newborns. The sensitivity, specificity and positive predictive values were 67, 92 and 22%, respectively. Using receiver-operating characteristics curves, they found that the NDI was better than the RI or peak systolic to early diastolic velocity ratio in predicting pre-eclampsia or the SGA infant.

Recently, a one-stage screening for pregnancy complications by color Doppler assessment at 23 weeks’ gestation was introduced [4]. A mean PI of more than 1.45 was considered increased. Bilateral uterine artery notches were also noted. Increased PI was noted in 5.1% of the 1757 pregnancies. Bilateral notches were noted in 4.4%. Examining how bilateral notches or the mean pulsatility index above 1.45 could predict pre-eclampsia, they found that the sensitivity, specificity and positive predictive value was 45, 94 and 23%, respectively. For pre-eclampsia delivered before 34 weeks these values were 90, 93 and 7%, respectively. They then looked at the PI and bilateral notches individually and in combination and concluded that the screening results were similar for increased PI or bilateral notches. Women with bilateral notches and a high mean PI had a 40% chance of developing pre-eclampsia.

McCowan et al. [66] concentrated on high-risk pregnancies. First of all they selected 224 women with suspected SGA babies (<10th percentile by abdominal circumference on ultrasound) and who were normotensive when the uterine artery Doppler studies were performed. Of the 50 women who developed subsequent hypertension, 42 had gestational hypertension and 8 had eclampsia. When the first uterine artery Doppler examinations were done, both RIs were >0.58 in 7% of pregnancies which remained normotensive, in 17% of pregnancies where gestational hypertension developed and in 50% of pregnancies where pre-eclampsia developed. For bilateral abnormal uterine artery Doppler, in the prediction of gestational hypertension or pre-eclampsia, the sensitivity, specificity and positive predictive value were 22, 93 and 45%, respectively. They also found that more severe uterine artery Doppler abnormalities were associated with more severe fetal disease.

In a different approach, Valensise et al. [100] studied 36 normotensive women with a uterine artery RI >0.58 and bilateral notching at 24 weeks’ gestation. Twelve of them developed gestational hypertension and 3 had SGA newborns. When compared with the pregnancies with a normal outcome, these 15 patients (at 24 weeks) had smaller left ventricular outflow

**Fig. 19.1.** Different flow velocity waveforms of the uterine artery. **a** Good velocity, no notch. **b** Slightly reduced velocity with visible notch. **c** Reduced diastolic velocity with visible notch. **d** Poor diastolic velocity with visible notch.