Fetal Diagn Ther 1991;6:58–64

1015–3837/91/0062–0058$2.75/0

Doppler Study of Uterine Artery Blood Flow: Comparison of Findings in the First and Second Trimesters of Pregnancy

P. Kaminopetros, M.T. Higueras, K.H. Nicolaides

Harris Brithright Research Centre for Fetal Medicine, King's College Hospital Medical School, London, UK

Key Words. Uterine artery · Doppler ultrasound · Uteroplacental circulation

Abstract. In 55 women with singleton pregnancies, colour flow mapping and pulsed wave velocimetry were used to measure impedance to flow in the uterine arteries at 10–13 weeks gestation and again at 19–22 weeks. In the first trimester, examinations were performed both transabdominally and transvaginally and in the second trimester transabdominally only. There were significant associations between the first- and second-trimester measurements obtained with both Doppler techniques. These associations were higher when transvaginal than transabdominal Doppler was used and when the measurement of impedance was the pulsatility index (PI) rather than the resistance index. These data suggest that impedance to flow in the uteroplacental circulation in the second trimester is dependent on impedance in the first trimester. In any prospective, first-trimester, uterine artery Doppler screening study for pregnancy complications, it may be preferable to use transvaginal Doppler and measure PI.

Introduction

Doppler studies of the uteroplacental circulation have documented increased impedance to flow in pregnancies complicated by fetal growth retardation and/or pregnancy-induced hypertension. Furthermore, several screening studies at 18–24 weeks gestation have suggested that abnormal Doppler results may precede these pregnancy complications by several weeks [1–6]. The commonly cited pathophysiologic basis for this observation is the histologic demonstration of impaired trophoblastic invasion of the maternal spiral arteries [7–9].

Since the onset of trophoblastic migration into the spiral arteries normally starts in the first trimester [10, 11], it is hypothesized that establishment of the uteroplacental circulation in the second trimester is not a random phenomenon, but rather a consequence of events in the first trimester. If this was the case, screening for pregnancy complications by Doppler studies of the uteroplacental circulation could be extended to the first trimester. In this study, two different Doppler

techniques for measurement of impedance to flow in the uterine arteries in the first trimester are applied for the investigation of the mode of development of the uteroplacental circulation and compared.

Patients and Methods

In 55 women with singleton pregnancies, impedance to flow in the uterine arteries was measured by Doppler ultrasound at 10–13 weeks gestation and again at 19–22 weeks. Examinations were performed by colour flow mapping and pulsed wave velocimetry; in the first trimester both transabdominally and transvaginally and in the second trimester transabdominally only.

All women were healthy, and they were referred to our unit for fetal karyotyping by early amniocentesis or chorionic villus sampling [12]. The Doppler investigations were performed before the invasive test. In all cases included in this study, the fetal karyotype was normal. Subsequently, the patients were reviewed for detailed ultrasound examination at 19–22 weeks, and no fetal abnormalities were detected. Gestational age was calculated by the maternal menstrual history and confirmed by ultrasound measurement of the fetal crown-rump length. The study was approved by the hospital ethics committee, and informed consent was obtained in each case.

Transabdominal Doppler examinations were performed with the patient in the supine position with left lateral tilt. For transvaginal examinations, the patients were lying on the examination couch with their knees bent. In each case, flow velocity waveforms (FVWs) were obtained from the left and right uterine arteries. In all Doppler examinations, the high pass filter was set at 100 Hz.

For both transvaginal and transabdominal studies, colour flow mapping was used to visualize each uterine artery and FVWs were obtained by pulsed wave Doppler (Aloka color Doppler SSD-680; Aloka, Japan, with 3.5-MHz transabdominal and 5-MHz transvaginal curvilinear transducers). In the first-trimester studies, each uterine artery was visualized at the level of the internal os and in the second trimester at the level of its crossing with the corresponding external iliac artery [13–15]. The resistance index (RI) and pulsatility index (PI) were calculated using the built-in spectrum analyzer [16, 17]. For each uterine artery, a minimum of four FVWs were measured, and the values were averaged.

Inta-observed variation was determined from the study of 10 measurements from each artery, in 3 patients, in each group (transvaginal and transabdominal at 10–13 weeks and transabdominal at 19–22 weeks). For the transabdominal and transvaginal first-trimester studies, the mean intra-observer variations for RI and PI were 5.95 and 9.23, and 3.1 and 6.16%, respectively; for the second-trimester transabdominal studies, the mean intra-observer variations for RI and PI were 4.13 and 7.07%, respectively.

Regression analysis was used to examine the significance of inter-correlations of the Doppler indices between the left and right uterine arteries and between measurements in the first and second trimesters with the different Doppler techniques.

Results

With colour flow mapping and pulsed wave Doppler, both uterine arteries were seen and FVWs were obtained in all cases with transvaginal sonography in the first trimester and in all with transabdominal sonography in the second trimester. However, with transabdominal sonography in the first trimester, the uterine artery could not be seen in 4 cases on the right and in 1 case on the left.

Impedance to flow decreased with gestation (table 1; fig. 1). There were significant associations for RI and PI between left and right uterine arteries and between first- and second-trimester measurements for each vessel; these associations were higher when transvaginal than transabdominal Doppler was used and when the index of impedance was the PI rather than the RI (table 2; fig. 2, 3).

The difference in PI between the left and right uterine arteries at 10–13 weeks gestation was significantly higher than at 19–22

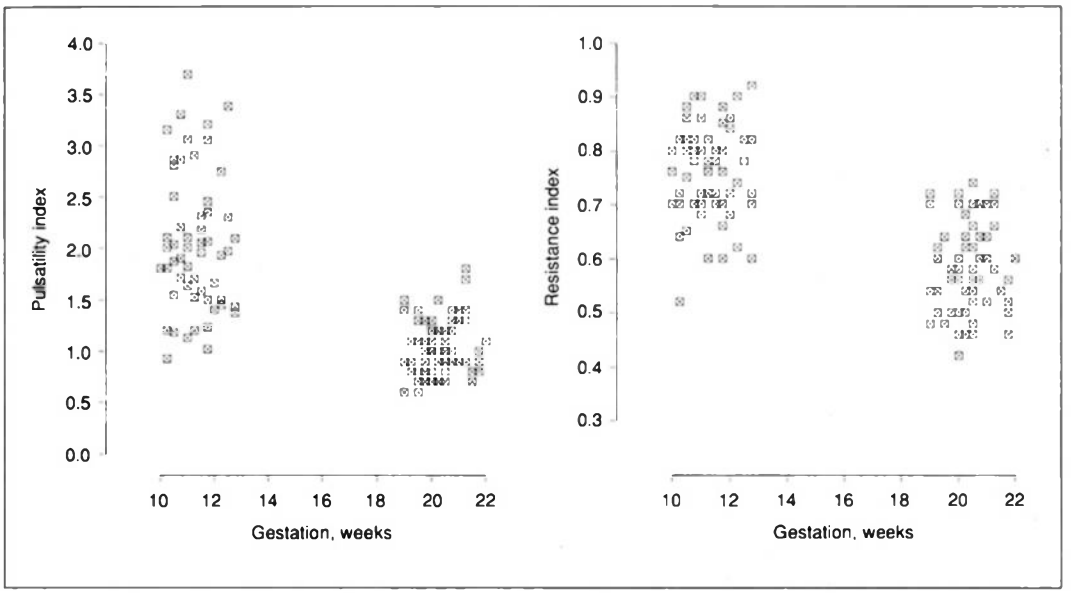

Fig. 1. PI and RI in the left uterine artery measured transvaginally at 10–13 weeks gestation and transabdominally at 19–22 weeks.

Table 1. Mean (± SD) RI and PI from the left and right uterine arteries in 55 patients at 10–13 weeks and at 19–22 weeks gestation by transvaginal and transabdominal ultrasonography

	10–13 weeks		19–22 weeks abdominal
	abdominal	vaginal	
Uterine RI			
Left	0.75 ± 0.10	0.78 ± 0.09	0.59 ± 0.08
Right	0.73 ± 0.07	0.76 ± 0.09	0.59 ± 0.09
Uterine PI			
Left	1.78 ± 0.57	2.05 ± 0.67	1.05 ± 0.27
Right	1.71 ± 0.45	1.86 ± 0.53	1.05 ± 0.29

Student's paired t test demonstrated that in all cases the measurements at 19–22 weeks were significantly lower than those at 10–13 weeks.

Table 2. Inter-correlations for RI and PI between the left (L) and right (R) uterine arteries and between measurements in the first (1st) and second (2nd) trimesters with the different Doppler techniques

	RI		PI	
	n	r	n	r
TA 1st L vs. TA 1st R	50	0.29*	50	0.29*
TV 1st L vs. TV 1st R	55	0.35**	55	0.37**
TA 1st L vs. TA 2nd L	54	0.56***	54	0.60***
TV 1st L vs. TA 2nd L	55	0.62***	55	0.69***
TA 1st R vs. TA 2nd R	51	0.45**	51	0.54***
TV 1st R vs. TA 2nd R	55	0.55***	55	0.58***
TA 1st L vs. TV 1st L	54	0.55***	54	0.68***
TA 1st R vs. TV 1st R	51	0.54***	51	0.61***
TA 2nd L vs. TA 2nd R	55	0.53***	55	0.58***

TA = Transabdominal; TV = transvaginal.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

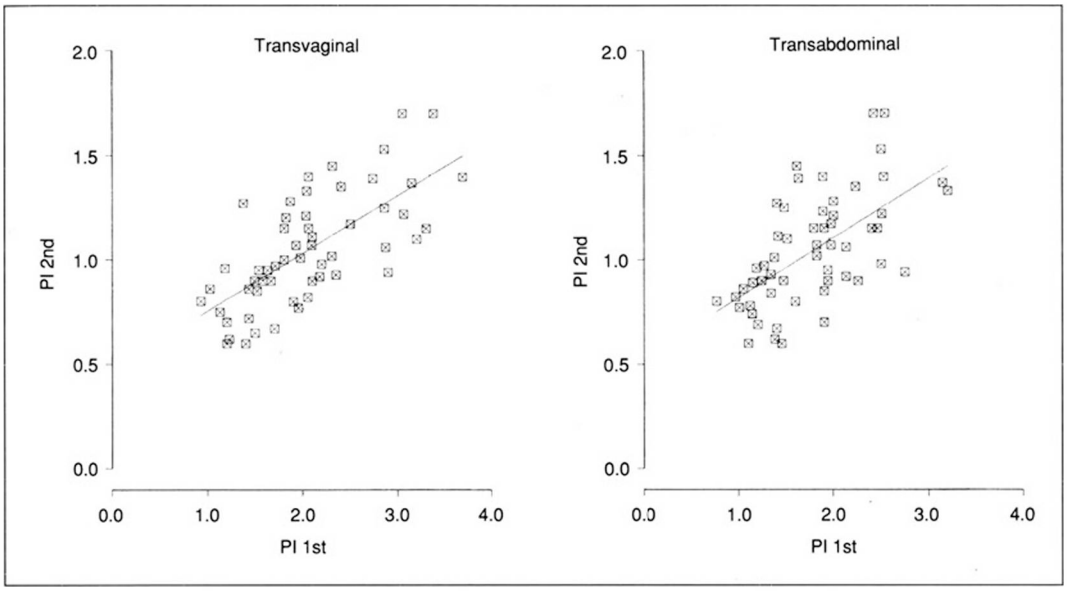

Fig. 2. Relationship of PI in the left uterine artery measured transvaginally and transabdominally at 10–13 weeks gestation (1st) and transabdominally at 19–22 weeks (2nd).

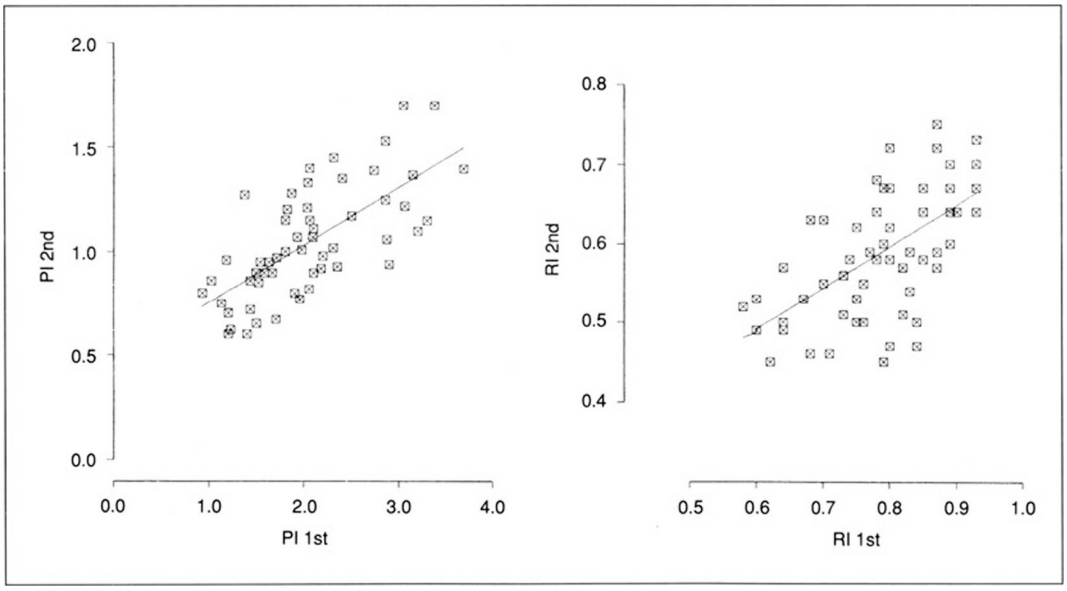

Fig. 3. Relationship of PI and RI in the left uterine artery measured transvaginally at 10–13 weeks gestation (1st) and transabdominally at 19–22 weeks (2nd).

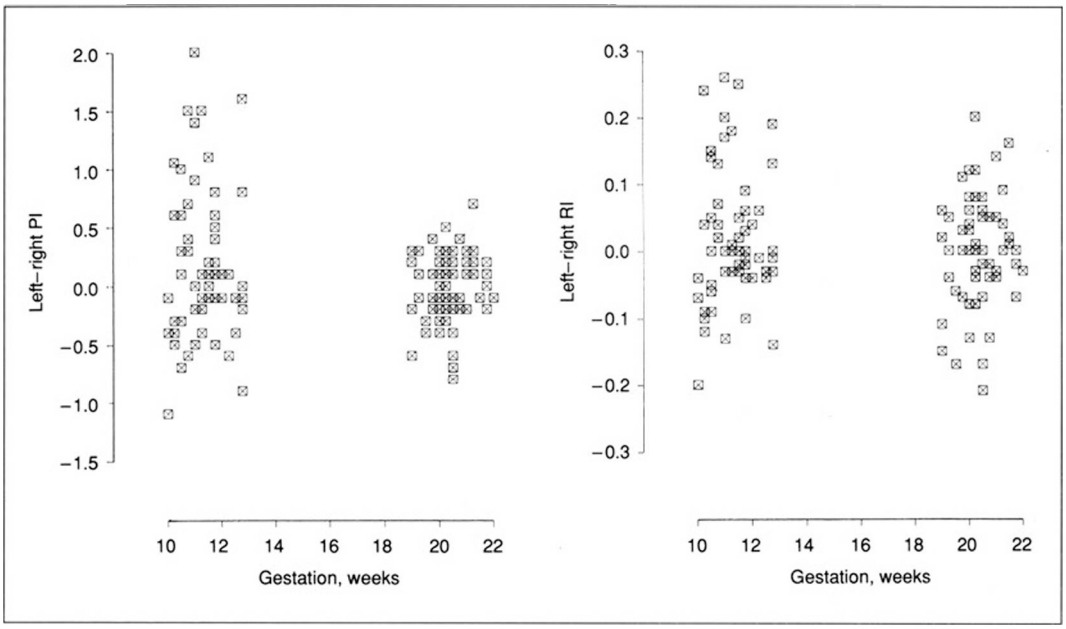

Fig. 4. Difference in PI and RI between the left and right uterine arteries measured transvaginally at 10–13 weeks gestation and transabdominally at 19–22 weeks.

weeks (fig. 4; transvaginal mean difference = 0.225, SEM = 0.049, t = 4.62, $p < 0.0001$; transabdominal mean difference = 0.279, SEM = 0.061, t = 4.57, $p < 0.0001$). The difference in RI between the left and right uterine arteries at 10–13 weeks gestation was not significantly compared to that at 19–22 weeks (fig. 4; transvaginal mean difference = 0.021, SEM = 0.015, t = 1.40, p = 0.17; transabdominal mean difference = 0.010, SEM = 0.012, t = 0.84, p = 0.40).

Discussion

The findings of this study demonstrate that impedance to flow in the uterine arteries decreases with gestation between 10 and 22 weeks. Furthermore, these results indicate that impedance to flow in the uteroplacental circulation in the second trimester is dependant on impedance in the first trimester.

Histological studies suggest that second-trimester endovascular trophoblast migration into the myometrial segment of the spiral arteries is preceded and influenced by changes in the decidual spiral arteries induced by the trophoblast during the first trimester [10, 11, 18]. The decrease in impedance to flow in the uterine arteries with gestation is compatible with these histological findings and has also been reported in previous Doppler studies which used either conventional real-time ultrasonography or colour flow mapping to visualize the arteries [13, 14, 19, 20].

With the application of transvaginal colour flow mapping, the uterine arteries can

be positively identified in the first trimester at the level of the internal os as they approach the uterus laterally and curve upwards alongside the uterine body. The low intra-observer variation in measurements demonstrates the high accuracy of this technique. With transabdominal scanning in the first trimester, visualization of the uterine arteries at the level of the internal os is more difficult. This may explain the higher intra-observer variation and the poorer association between first and second trimester measurements with transabdominal compared to transvaginal Doppler. With second-trimester transabdominal scanning, the uterine arteries can be visualized reliably at the level of their crossing with the corresponding external iliac artery, and the intra-observer error is not different from that of first trimester transvaginal scanning.

In the first trimester, the mean difference in impedance between left and right uterine arteries is greater, and the significance of the association in values between the two vessels is poorer than in the second trimester. A likely explanation for these findings is that the anastomotic network between the two uterine arteries improves with advancing gestation.

In the calculation of PI, in addition to the peak systolic and end-diastolic velocities which are used for calculation of RI, the area under the waveform is taken into account, and therefore PI may provide a better measure of the actual impedance to flow [16, 17]. Although the intra-observer errors for PI were higher than for RI, more significant associations between first- and second-trimester measurements were achieved with PI, and therefore this may be the preferred index in any subsequent screening study.

Doppler studies of the uteroplacental circulation at 18–24 weeks gestation can predict the subsequent development of fetal growth retardation and/or pregnancy-induced hypertension [1–6]. The findings of the present study indicate that impedance to flow in the second trimester is significantly associated with impedance in the first trimester. A large prospective study of first-trimester transvaginal Doppler will determine the degree to which pregnancies destined to develop pre-eclampsia and intra-uterine growth retardation will demonstrate pathological FVWs and whether screening in the first trimester is more or less predictive than in the second trimester.

References

1 Campbell S, Pearce JMF, Hackett G, Cohen-Overbeek T, Hernandez C: Qualitative assessment of uteroplacental blood flow: Early screening test for high-risk pregnancies. Obstet Gynecol 1986;68:649–653.

2 Arduini D, Rizzo G, Romanini C, Mancuso S: Utero-placental blood flow velocity waveforms as predictors of pregnancy-induced hypertension. Eur J Obstet Gynecol Reprod Biol 1987;26:335–341.

3 Bewley S, Campbell S, Cooper D: Uteroplacental Doppler flow velocity waveforms in the second trimester of pregnancy. A complex circulation. Br J Obstet Gynaecol 1989;96:1040–1046.

4 Schulman H, Winter D, Farmakides G, Ducey J, Guzman E, Coury A, Penny B: Pregnancy surveillance with Doppler velocimetry of uterine and umbilical arteries. Am J Obstet Gynecol 1989; 160:192–196.

5 Steel SA, Pearce JM, Mcparland P, Chamberlain CV: Early Doppler ultrasound screening in prediction of hypertensive disorders of pregnancy. Lancet 1990;i:1548–1551.

6 Newnham JP, Patterson LL, James IR, Diepeveen DA, Reid SE: An evaluation of the efficacy of Doppler flow velocity waveform analysis as a

screening test in pregnancy. Am J Obstet Gynecol 1990;162:403–410.
7 Brosens IA, Dixon HG, Robertson WB: Fetal growth retardation and the arteries of the placental bed. Br J Obstet Gynaecol 1977;84:656–663.
8 Robertson WB, Brosens I, Dixon G: Uteroplacental vascular pathology. Eur J Obstet Gynecol Reprod Biol 1975;5:47–65.
9 Khong TY, De Wolf F, Robertson WB, Brosens IA: Inadequate maternal vascular response to placentation in pregnancies complicated by pre-eclampsia and by small-for-gestational age infants. Br J Obstet Gynaecol 1986;93:1049–1059.
10 Pijnenborg R, Dixon G, Robertson WB, Brosens I: Trophoblastic invasion of human decidua from 8 to 18 weeks of pregnancy. Placenta 1980;1:3–19.
11 Pijnenborg R, Bland JM, Robertson WB, Brosens I: Uteroplacental arterial changes related to interstitial trophoblast migration in early human pregnancy. Placenta 1983;4:397–414.
12 Byrne D, Marks K, Azar G, Nicolaides KH: Early amniocentesis: A viable alternative to chorionic villus sampling. Ultrasound Obstet Gynecol 1991, in press.
13 Deutinger J, Rudelstofer R, Bernaschek G: Vaginosonographic velocimetry of both main uterine arteries by visual vessel recognition and pulsed Doppler method during pregnancy. Am J Obstet Gynecol 1988;159:1072–1076.
14 Jurkovic D, Jauniaux E, Kurjak A, Hustin J, Campbell S, Nicolaides KH: Transvaginal color Doppler assessment of the uteroplacental circulation in early pregnancy. Obstet Gynecol 1991;77:365–369.
15 Pearce JM, Campbell S, Cohen-Overbeek T, Hackett G, Hernandez J, Royston JP: References ranges and sources of variation for indices of pulsed Doppler flow velocity waveforms from the uteroplacental and fetal circulation. Br J Obstet Gynaecol 1988;95:248–256.
16 Pourcelot L: Applications cliniques de l'examen Doppler transcutane; in Peronneu P (ed): Velocimétrie ultrasonore Doppler. Paris, Inserm, 1974, vol 34, pp 213–241.
17 Gosling RG, King DH: Ultrasound angiology; in Marcus AW, Adamson L (eds): Arteries and Veins. Edinburgh, Chruchill Livingstone, 1975, pp 61–98.
18 Pijnenborg R, Bland JM, Robertson WB, Dixon G, Brosens I: The pattern of interstitial trophoblastic invasion of the myometrium in early human pregnancy. Placenta 1981;2:303–316.
19 Schulman H, Fleischer A, Farmakides G, Bracero L, Rochelson B, Grunfeld L: Development of uterine artery compliance in pregnancy as detected by Doppler ultrasound. Am J Obstet Gynecol 1986;155:1031–1036.
20 Thaler I, Manor D, Itskovitz J, Rottem S, Levit N, Timor-Tritsch I, Branders JM: Changes in uterine blood flow during human pregnancy. Am J Obstet Gynecol 1990;162:121–125.

Received: July 30, 1991
Accepted: August 15, 1991

K.H. Nicolaides, MD
Harris Birthright Research Centre for Fetal Medicine
King's College Hospital Medical School
Denmark Hill
London SE5 8RX (UK)