Transabdominal and transvaginal color Doppler in the assessment of fetomaternal circulation during all three trimesters of pregnancy

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Introduction

More than any other available method, diagnostic ultrasound has a unique potential for the non-invasive study of fetal and maternal circulation. Pulsed Doppler combined with real-time ultrasonic imaging, the so-called duplex method, allows the precise localization of deep vessels and the location of the Doppler sample volume within it.

The duplex technique is now widely used to detect blood flow in the human fetus but it also has a potential for the study of normal pelvic blood flow. However, the most exciting recent developments in the field of diagnostic ultrasound in obstetrics and gynecology are, undoubtedly, color Doppler and transvaginal sonography. These two modalities have recently been produced as a single probe, called transvaginal color Doppler.

The ultrasound diagnosis in congenital heart disease must involve the identification of anatomical abnormalities and the characterization of their pathophysiological consequences. For well over a decade, two-dimensional echocardiographic imaging has provided the details of cardiac anatomy in developing fetal heart. Pulsed and continuous-wave Doppler echocardiography have added physiological details unavailable with imaging alone. Synthesis of the two aspects of echocardiographic diagnosis into a single real-time display by showing the Doppler information as a color overlay is the recent promising development.

The purpose of this study was to evaluate the potential contribution of transabdominal and transvaginal color Doppler in the assessment of fetomaternal circulation during all three trimesters of pregnancy.

Patients and Methods

Our study was arranged in two parts. The first-trimester part included 41 volunteer pregnant women whose gestational age ranged between 6 and 10 weeks.

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They were recruited from patients scheduled for termination of pregnancy on request. Furthermore, there were 36 patients examined with pathologic early pregnancy. Six of them had ultrasonically diagnosed blighted ovum, six had missed abortion, and in one case a molar pregnancy was diagnosed. The rest of them (23) had clinically suspected ectopic pregnancy.

All patients were examined with 5 MHz transvaginal color and pulsed-water Doppler probe (Aloka Co, Japan). A Color Doppler signal which displays the mean frequency of the Doppler shift was used to screen the entire region of interest. The red or blue color superimposed on the B-mode image indicated the vascular region that should be interrogated by the pulsed Doppler technique for flow velocity waveform analysis. The peripheral impedance of detected blood flow was quantified by means of the resistance index, which is the ratio of the difference between peak systole and end diastole to peak systole [1]. This angle-independent index is believed to be a good assessor of downstream vascular resistance.

In all patients we have tried to obtain signals from both uterine arteries and trophoblast. In 41 patients with normal pregnancy, additional analyses of signals from umbilical arteries were performed.

In the second part of our study fetal intracardiac flow examinations were attempted in 486 fetuses between 15th and 40th weeks. Prior to color flow mapping, a two-dimensional examination of the fetal heart was made, using standard echocardiographic plains (four-chamber view, long axis of the left ventricle, short axis through the heart at the level of the great vessels, and aortic arch plain). When the proper angle between the ultrasound beam and pressumed flow was achieved (tending the flow to be as much as parallel to ultrasound beam), color Doppler was superimposed on cross-sectional and/or M-mode to study blood-flow patterns. In the second and the third trimester examinations, transabdominal semiconvex 3.5 and electronic sector 5 MHz probes were used.

Principles of color Doppler are described in our previous papers published elsewhere [2,3].

Results

First trimester examinations

Uterine arteries. Color Doppler signal from both the uterine arteries could be easily seen in all patients just lateral to the cervix at the level of cervicocorporeal junction of the uterus. The calculated resistance indices (RI) for all three groups of patients (normal, pathologic, suspected ectopic) are given in Tables I and II. The RI values ranged from 0.52 to 0.95, but statistical comparison of mean RI values for all

TABLE I

Resistance index in the first trimester of normal pregnancy (n = 41)

Uterine artery	0.81 (SD = 0.06)
Umbilical artery	1 (SD = 0)
Trophoblast	0.48 (SD = 0.08)

TABLE II

Comparison between mean resistance indices from normal and pathologic pregnancy

Uterine artery				
Normal	(n = 41)	0.81(0.06)		
Blighted ovum	(n = 6)	0.77(0.11)	t = 0.03	p > 0.01
Normal	(n = 41)	0.81(0.06)		
Missed abortion	(n = 6)	0.69(0.13)	t = 2.4	p > 0.01
Trophoblast				
Normal	(n = 41)	0.47(0.08)		
Blighted ovum	(n = 4)	0.42(0.15)	t = 1.0	p > 0.01

included groups (normal pregnancy; mean RI 0.81 (0.31); blighted ovum: mean RI 0.77 (0.11); missed abortion: mean RI 0.69 (0.13); ectopic pregnancy: mean RI 0.78 (0.11) could not reveal any significant difference between obtained values. RI in both uterine arteries of molar pregnancy was 0.80.

Trophoblast. A Color signal seen within hyperechoic area in close proximity to the gestational sac was considered as trophoblastic intra-uterine flow (Fig. 1). Always, when a consistent color signal was obtained in that region, a clear flow velocity waveform of low pulsatility was easily obtained (Fig. 2). A Color flow signal was visualized in 33% of cases at 6 week gestation and in 100% of cases from the 7th week of gestation onward.

The mean RI value in normal pregnancy is 0.47 (0.08) and 0.42 (0.15) in blighted ovum pregnancy. It should be stressed that in four cases of missed abortion, two cases of blighted ovum and one molar pregnancy, it was impossible to detect any trophoblast flow.

Umbilical artery. A Doppler color signal from the umbilical artery can be seen only occasionally at 6 gestational weeks (33%) and can be consistently obtained from the 7th gestational week onward (Table III) (Fig. 3). During the investigated period, neither the diastolic flow nor the umbilical vein signal could be revealed in the umbilical arteries. This finding can be explained with slow, low volume umbilical cord flow at that gestational age which is below detectability with the present color Doppler sensitivity and 100 Hz high-pass-filter-pulse-wave-Doppler.

TABLE III

Visualization rate of color Doppler signal of uterine artery, trophoblast and umbilical artery in the first trimester of normal pregnancy (n = 41)

Weeks	Visualization rate		
	uterine artery (%)	trophoblast (%)	umbilical artery (%)
6 (n = 8)	100	33	33
7–10 (n = 33)	100	100	100

TABLE IV

Diagnostic accuracy of transvaginal color and pulse wave Doppler in the detection of ectopic pregnancy

	Ectopic	Not ectopic
Color flow present and RI < 0.56	11 TP	1 FP
Color flow not present	3 FN	8 TN
Sensitivity = 0.79		
Specificity = 0.89		

TP, true positive. FP, false positive.
TN, true negative. FN, false negative.

Ectopic pregnancy. The Doppler signals from the uterine arteries could not differentiate between normal adnexa and adnexa with ectopic pregnancy. When the color flow was obtained in the adnexal region and the RI was less than 0.50, the specificity and sensitivity of this diagnostic test for ectopic pregnancy rise up to 0.89 and 0.79, respectively (Table IV) (Fig. 4).

Intracardiac flow patterns in the second and the third trimester

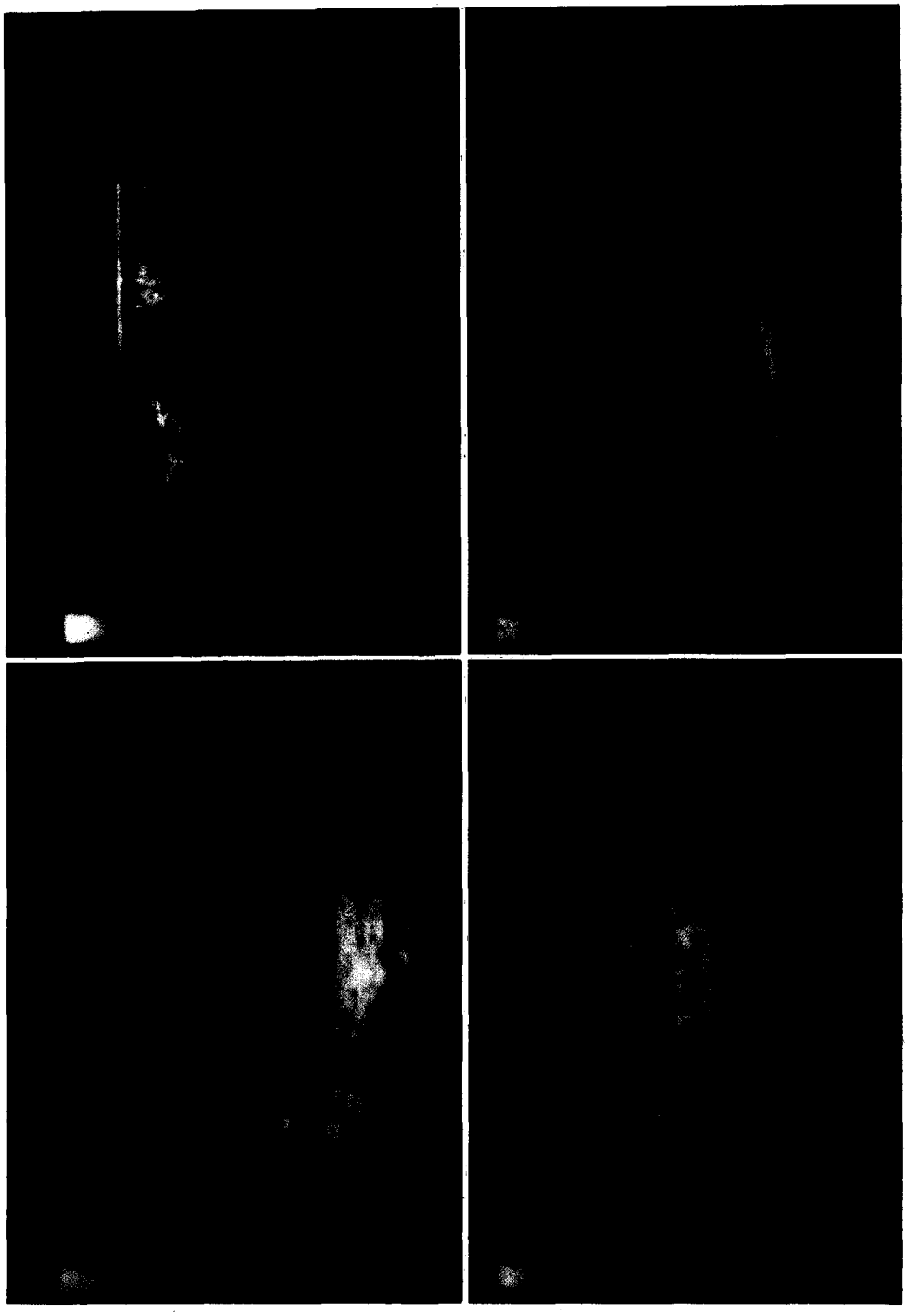
The intracardiac flow through all cardiac valves, as well as through the foramen ovale could be observed even from the 15th week of pregnancy, but the success rate increases and later decreases with gestational age. The success rate of intracardiac color flow visualisation according to gestational age is presented in Table V.

TABLE V

Intracardiac and great vessel color Doppler success rate

Gest. age	No examined fetuses	AVf	%	LOFT--Aof	%	Pf	%	AoAf	%
15–16	22	19	86	16	73	14	63	10	45
17–18	30	26	87	26	87	20	67	15	50
19–20	37	37	100	36	97	35	95	35	95
21–22	49	49	100	49	100	49	100	49	100
23–24	40	40	100	40	100	40	100	40	100
25–26	48	48	100	48	100	48	100	48	100
27–28	44	44	100	44	100	44	100	44	100
29–30	47	47	100	47	100	47	100	46	98
31–32	40	40	100	40	100	39	98	39	98
33–34	41	41	100	41	100	38	93	38	93
35–36	41	40	98	40	98	31	76	33	80
37–38	27	26	96	26	96	16	60	24	89
39–40	20	18	90	18	90	9	54	13	65

avf, atrioventricular flow; LOFT, left outflow tract; Aof, aortic flow; Pf, pulmonary flow; AoAf, aortic arch flow.



Discussion

While investigators have focused mainly on late-second and third-trimester pregnancy, Doppler studies have recently expanded to the first trimester as well. Its overall value in early pregnancy has yet to be discerned. It has been found that Doppler waveform patterns in the first trimester differ significantly from those found later in pregnancy. For example, the umbilical artery waveform has absolutely no diastolic component early in the first trimester. This contrasts with the third trimester where an absent diastolic flow is associated with poor fetal outcome. The diastolic flow begins to increase around the 12th to 17th week, indicating the decrease in placental resistance. The same pattern holds true for the maternal circulation. It seems that color Doppler could increase the reproducibility of measurements, especially in maternal circulation. With this modality it is possible to clearly visualize even small vessels thus enabling accurate placing of pulsed-Doppler sample volume. Furthermore, visualization of the flow direction yields information on the flow profile. We have shown that the flow profile in the umbilical vein changes during pregnancy. It could be speculated that in some high-risk pregnancies (Rh-immunization, IUGR, anemis) with changes in fetal hematocrit and blood viscosity, the fetal flow profile may be altered as well.

It seems also that color Doppler could reaffirm the value of volume flow measurement. Since there is no difference between the vessel diameter measured on B-mode and flow width, the vessel diameter can be accurately measured even in situations when the investigated vessel lies parallel to the ultrasound beam. Such cases are optimal for the flow measurement. With good quality of Doppler signal and accurate diameter measurement the accuracy of volume flow measurement could be significantly improved [2].

Study of the flow may have a more immediate application in the diagnosis of ectopic pregnancy. Sonographic findings of an ectopic pregnancy include an empty uterus and an adnexal mass. But these are nonspecific features, which can occur in abortions and early normotopic pregnancies as well as in nongravid women. Pulsed and Color Doppler, however, can help to characterize the nature of the adnexal mass, thus enabling preoperative diagnosis when the ectopic fetus and its characteristic heart beat cannot be visualized. Transvaginal sonography permits identification of the ectopic trophoblast and enables differentiation from flow in the corpus luteum. Fetuses invade the maternal tissues, and it is possible to get a very high blood flow from the maternal arteries into spaces around them. So, basically, it is worth using this vascular signature (of trophoblastic flow) as a way of tissue-characterization of the adnexal mass.

Fig. 1 (upper left panel). Color flow mapping of trophoblast in normal intra-uterine pregnancy (6 weeks).

Fig. 2 (upper right panel). Waveform analysis of blood flow in the trophoblast.

Fig. 3 (lower left panel). Blood flow in umbilical cord detected by transvaginal color Doppler (7 weeks).

Fig. 4 (lower right panel). Extra-uterine pregnancy detected by transvaginal sonography. Color flow mapping of ectopic trophoblasts are visualized in adnexal region.

In tumors it is possible to obtain these large vascular spaces, which are lacking in muscular support [4]. The result is low-resistance spaces, with blood shunting across large pressure gradients. The same phenomenon appears to happen in an ectopic pregnancy. Arterial flow produced by trophoblastic invasion of the maternal tissue, would account for the high-velocity low-impedance signals [5,6].

We have combined color and pulsed-wave Doppler transvaginal sonography. The combination has given us the possibility to screen quickly the vascularisation of the entire pelvis. Only in cases when the color signal is detected away from major pelvic vessels, time consuming off-line pulsed-wave Doppler measurement has been undertaken.

In this study the signals from trophoblast, umbilical artery and uterine arteries were easily obtained, but we were unable to detect any statistically significant difference between normal and pathologic intra-uterine pregnancy. This finding does not corroborate with the observations of Schaaps and Soyeur [7]. The scanning technique in the cited paper is obviously different (they were unable to detect flow in normal trophoblast), and therefore much more uniform; probably multicentric work is required before final conclusions can be drawn.

We are in agreement that our results in the transvaginal Doppler diagnosis of ectopic pregnancy have been good enough to justify its clinical application. The current policy in our Department is to wait with management if there is no trophoblast flow outside the empty uterus in the amenorrhoic patients. On the contrary, where there is color flow in the adnexal region with a RI < 0.50, the patients are scheduled for laparoscopy regardless of clinical signs. One false-positive finding was due to a detected flow in a corpus luteum cyst, whereas the three false-negative findings were tubal abortions with apparently low trophoblast activity (β-subunit of HCG < 500 IU).

We hope that with the increased number of patients the sensitivity (0.79) and specificity (0.89) of color and pulsed-wave Doppler transvaginal diagnosis of ectopic pregnancy will be even higher.

Following successful use in adult and pediatric echocardiography, color Doppler was also introduced in fetal echocardiography [2,3,8–12]. Color-coded blood flow through the fetal heart and great vessels may be obtained even from the 15th week of pregnancy. Earlier visualisation of intracardiac blood flow compared to our previously published results [5] are due to the use of a 5 MHz probe which enabled clearer visualisation of the cardiac structures as well as better detection of the smaller flow velocities. Unfortunately, the success rate of color Doppler flow visualisation is age-dependent, because a completely noise-free signal has to be obtained if one wants to get clear flow visualisation. Any kind of disturbance, such as shadows produced by fetal bones, may thwart the examination and a bad signal quality will be obtained. Despite these limiting factors, color Doppler offers a new possibility for visualizing the blood flow of the intracardiac and great vessels and a rapid examination of the cardiac valve function. Besides, any disturbance of the intracardiac blood flow, which can be easily and rapidly detected by color Doppler, may point at some morphological change in fetal heart structures [2,3,5,9–12].

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