

Doppler Ultrasound Hemodynamic Assessment in Preeclampsia

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Abstract

Background: Preeclampsia (PE) is the main factor in maternal mortality across the world, affecting 5%–8% of pregnant women. The impairment in placental perfusion due to vascular abnormalities leads to clinical presentations and is detectable by Doppler ultrasound. **Objective:** The aim of the study is to assess the hemodynamic changes in pregnant women with and without PE, using Doppler ultrasound of the uterine, the umbilical, and the middle cerebral arteries. **Materials and Methods:** Forty pregnant women aged 19–40 years old, diagnosed with PE, were recruited from the outpatient gynecology clinic into a case–control study. Their Doppler ultrasound hemodynamic assessment of the uterine artery and its early diastolic notching, the middle cerebral artery, and the umbilical artery was compared to that of 60 matched control non-preeclampsia (non-PE) pregnant women aged 19–40 years old. **Results:** The proportions of patients with uterine artery, umbilical artery, and middle cerebral artery Doppler ultrasound abnormalities were 77.5%, 62.5%, and 37.5% in the PE group, compared to nil, 8.3%, and 11.7% in the non-PE women, respectively. Similarly, mean resistance index of each artery and proportions of notch parameters of the uterine artery showed significant differences between PE and non-PE patients ($P < 0.001$). **Conclusions:** Doppler ultrasound assessment in pregnant women of the uterine, the umbilical, and the middle cerebral arteries can be used to determine hemodynamic dysfunction associated with PE.

Keywords: Assessment, Doppler ultrasound, hemodynamics, preeclampsia

INTRODUCTION

Preeclampsia (PE) is the main factor of maternal mortality across the world, affecting 5%–8% of pregnant women, and is characterized by rise in blood pressure and proteinuria.^[1] It increases the risk of poor outcome for both mother and baby; if untreated, it leads to eclampsia.^[2]

One of the noninvasive methods of evaluation of fetal intrauterine health before delivery is Doppler flow velocity waveform analysis. Most high-risk pregnancies can be predicted by this method. The following can be assessed by Doppler ultrasound: umbilical arteries, middle cerebral arteries, maternal pelvic artery waveform, fetal aorta, fetal venous velocities, and fetal ductus venosus.^[3] Hemodynamic alterations in uteroplacental and fetoplacental circulation can be detected before manifestation of obstetric complications.^[4] Pregnancies associated with an abnormal uterine Doppler after 24 weeks of gestation are associated with a more than six-fold increase in the rate of PE.^[5] Therefore, it is possible to use Doppler ultrasound in parental and fetal surveillance to prevent perinatal mortality and morbidity and to schedule delivery.

The aim of this study was to use Doppler ultrasound to assess the hemodynamic changes in the uterine, umbilical, and middle cerebral arteries, among pregnant women with and without PE.

MATERIALS AND METHODS

Ethical approval of the study was obtained from the local Health Ethics Committee in Duhok, and written informed consent was obtained from each woman before enrollment in the study.

Forty pregnant women aged 19–40 years, with gynecologist's confirmed diagnosis of PE according to the guidelines of the International Society for the Study of Hypertension in Pregnancy^[6] and with gestational age between 28 and 36 weeks, were recruited into a case–control study, from the Outpatient Gynecology Clinic of Maternity Hospital in Duhok city, Iraq. The Doppler ultrasound indices in the cases were compared to that of 60 matched non-preeclampsia (non-PE)

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pregnant women aged 19–40 years old with gestational age between 28 and 37 weeks, selected from the same outpatient clinic.

Pregnant women with kidney dysfunction, twin pregnancies, structural abnormalities, intrauterine mortality, or inability to tolerate the Doppler ultrasound examination were excluded from the study.

The patients' recruitment and Doppler ultrasound examination were conducted between January 2016 and October 2016.

A questionnaire was used to collect general, clinical, and laboratory findings, ultrasound outcomes, and consultant diagnosis. The gestational age was calculated according to the last menstrual period and confirmed by ultrasound measurements.

The researchers performed the Doppler ultrasound examinations, supported by an expert in Doppler ultrasonography. Each patient underwent one transabdominal Doppler ultrasound examination using Siemens machine (ACUSON X300) with 3.5 MHS convex transducer with high-resolution monitor and a thermal page printer. One uterine artery of the placental side, the umbilical artery, and one middle cerebral artery were examined for each patient.^[7,8] The measures of umbilical artery were conducted in a free umbilical cord loop. Following confirmation of regular maternal and fetal cardiac frequency, without breathing and/or interference of fetal movement, and away from chest, the waves were registered. The angle of Doppler insonation was located below 60°.

Doppler ultrasound indices were calculated as follows:^[9]

1. Pulsatility index (PI) is defined as:

$$PI = \frac{\text{Peak systolic velocity} - \text{diastolic velocity}}{\text{Mean flow velocity}}$$

2. Resistance index is defined as:

$$RI = \frac{\text{Peak systolic velocity} - \text{diastolic velocity}}{\text{Peak systolic velocity}}$$

The normal values of Doppler velocimetry (26th–42th week of gestation) are as follows:^[10]

Umbilical artery: PI: 0.6–1.4 and RI: 0.5–0.7

Middle cerebral artery: PI: >1.3 and RI: >0.7

Uterine artery: RI: 0.45–0.58

The presence of the early diastolic notch following the 24th gestational week in the uterine artery was considered as a wave abnormality.^[7] Abnormalities for the uterine and umbilical arteries were determined if RI and PI values were above the 95th percentile standardized for gestational age. Abnormality of the middle cerebral artery was determined if below the 10th percentile.^[11] Any changes in the uterine artery parameters were considered as abnormal outcome of that artery, whether they were changes in the individual or combined RI and PI values. In case of the middle cerebral artery, abnormal artery finding was determined as individual decreases in RI

or PI values and their combinations. Abnormalities in the umbilical and the middle cerebral vessels were determined only in combination with another abnormal artery by Doppler ultrasound.

The data were analyzed with SPSS statistics program version 24, (IBM, Armonk, NY, United states of America). Unpaired *t*-test was used to test differences between means. Chi-square test or Fisher's exact test was used to test the association between categorical variables. *P* < 0.05 was considered significant.

RESULTS

One hundred pregnant women were enrolled in the current study, 40 of them diagnosed with PE. The mean age ($\pm$ standard deviation) was 27.8 ± 5.9 years for the PE group and 28.8 ± 6.6 for the non-PE group. Average gestational age was 31.7 weeks for the PE group and 32.1 weeks for non-PE group. Thus, the patients in both groups were comparable with respect to age and gestational age, as shown in Table 1. The principal features of PE diagnosis (arterial blood pressure measurements and prevalence of albuminuria) were significantly different for patients with PE, compared to non-PE women, as displayed in Table 1.

Doppler ultrasound findings are summarized by artery in Table 2 and Figure 1, with comparison between PE and non-PE

Table 1: The general characteristics of the two study groups

Characteristic	PE (n=40)	Non-PE (n=60)	P
Age (years)*	27.8 $\pm$ 5.9 (20-39)	28.8 $\pm$ 6.6 (19-40)	0.437
Gestational age (months)*	31.7 $\pm$ 2.5 (28-36)	32.1 $\pm$ 2.6 (28-37)	0.450
SBP (mmHg)*	145.0 $\pm$ 6.4 (140-160)	118.2 $\pm$ 6.8 (110-130)	<0.001
DBP (mmHg)*	94.0 $\pm$ 5.5 (90-110)	74.25.9 (60-80)	0.001
Albuminuria, n (%)	40 (100)	Nil	

*Mean $\pm$ SD (range). PE: Preeclampsia, SD: Standard deviation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

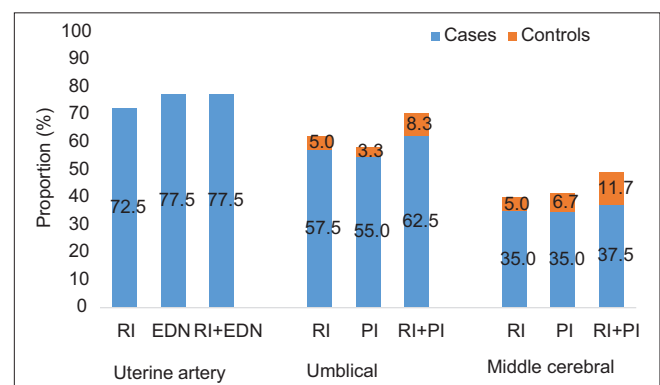


Figure 1: Proportions of abnormal US findings and their combinations for each artery in pregnant women with and without PE

Table 2: Doppler ultrasound findings by artery

	PE (n=40)	Non-PE (n=60)	P
UtA RI*	0.59±0.06 (0.47-0.68)	0.50±0.02 (0.46-0.57)	<0.001
UtA EDN, n (%)	31 (77.5)	Nil	
UtA abnormal, n (%)	31 (77.5)	Nil	
UA RI*	0.68±0.09 (0.55-0.81)	0.57±0.03 (0.52-0.71)	<0.001
UA PI*	1.30±0.22 (0.88-1.52)	0.99±0.11 (0.80-1.43)	<0.001
UA abnormal, n (%)	25 (62.5)	5 (8.3)	
MCA RI*	0.72±0.06 (0.60-0.85)	0.80±0.03 (0.68-0.88)	<0.001
MCA PI*	1.37±0.14 (1.10-1.60)	1.47±0.09 (1.25-1.70)	<0.001
MCA abnormal, n (%)	15 (37.5)	7 (11.7)	
Generally abnormal Doppler US, n (%)	31 (77.5)	7 (11.7)	

*Mean±SD (range). PE: Preeclampsia, UtA: Uterine artery, EDN: Early diastolic notching, MCA: Middle cerebral artery, UA: Umbilical artery, RI: Resistance index, PI: Pulsatility index, SD: Standard deviation, US: Ultrasound

women. The proportion of patients with uterine Doppler US abnormalities (and early diastolic notching) was 77.5% in the PE group, compared to no abnormality in non-PE women. The uterine artery mean RI was significantly higher in PE patients compared to non-PE women.

The proportion of umbilical artery abnormalities found by Doppler US in PE patients was 62.5%, compared to 8.3% in non-PE women. The umbilical artery mean RIs were 0.68 and 0.57 in PE and non-PE, respectively, significantly higher for the PE patients. In addition, the umbilical artery mean of PI was significantly higher in PE compared to non-PE (1.30 and 0.99, respectively).

The proportion of middle cerebral artery abnormalities found by Doppler US in PE patients was 37.5%, compared to 11.7% in non-PE women. Moreover, mean middle cerebral artery RI and PI in the PE group were significantly lower (0.72 and 1.37, respectively) than mean RI and PI in the non-PE women (0.80 and 1.47, respectively).

In general, the overall abnormalities found by Doppler US in PE patients were 77.5%, compared to 11.7% in non-PE women, as shown in Table 2.

DISCUSSION

The study showed that the abnormalities in the uterine, middle cerebral, and umbilical arteries diagnosed by Doppler ultrasound in patients with PE were significantly higher compared to pregnant women without preeclampsia.

Comparison between this study and other similar studies may be difficult due to different methodologies, screening time, sampling site, and abnormal waveform definitions. However, as in this study, Lopez-Mendez *et al.* used Doppler US on

pregnant women recruited for a case-control study, with comparable maternal ages and gestation ages.^[1]

The focus of most of previous researches was the uterine artery abnormalities through Doppler US and its parameters, also taking into consideration of the umbilical and the middle cerebral arteries.^[1,3,5] In agreement with this study, Lopez-Mendez *et al.* showed that pregnant women with PE had significantly greater abnormalities in notch proportion and combination parameters in the uterine arteries. In contrast to our study, they examined the PI parameter in the uterine artery as well, but the researchers did not find significant abnormalities.^[1]

In agreement with this study, several authors found that abnormalities in RI and PI parameters of the umbilical artery were significantly higher among women with PE compared to non-PE women.^[1,3,5]

Regarding the middle cerebral arteries, abnormalities found through PI parameter and combined parameters by Lopez-Mendez *et al.*^[1] were in accordance with this study.

Findings, similar to this study, were reported by Mallikarjunappa *et al.*^[12] for analysis of Doppler velocity waveforms in the umbilical, the uterine, and the middle cerebral arteries.

The most frequently studied vessel to predict PE through Doppler US was the uterine artery, being representative of the condition of maternal vascular obstetric circulation.^[13] Some authors only focused on the uterine arteries to predict pregnancy complications. Harrington *et al.* reported results from a cross-sectional study of 191 pregnant women followed up at 24 weeks of gestation through analysis of Doppler US of uterine arteries waveforms (notching). The authors found abnormal uterine Doppler findings (including uni- or bilateral notching) in 110 (57.6%) patients. They concluded that there is a clear link between high-resistance uterine waveforms (RI) and an increase in adverse outcomes of pregnancy, including preeclampsia.^[14] Another study by Papageorgiou *et al.*^[15] confirmed that those with increased mean PI have a six-fold rise likelihood of serious pregnancy complications.

Therefore, screening programs using multi-arterial doppler study is beneficial in the antenatal health care planning.

Other factors for high-risk pregnancy, including smoking history, nulliparity, personal history and/or family of PE, and number of previous abortions/miscarriages,^[16] have not been considered in this study. Therefore, it is possible that adjustment between the cases and the controls has not been strict. In addition, discrepancies between this study and other studies could be due to methodological differences and pathological waveform definitions. Moreover, the side (left or right) of the uterine artery was not taken into consideration in waveform assessment in the study.

CONCLUSIONS

This study demonstrated that Doppler US can reveal the underlying hemodynamic repercussion in the maternal-fetal

circulation and thus can be used to determine the proper level of antenatal care in pregnant women. One-stage color Doppler screening program is recommended for pregnant women with PE, to help determine the level of surveillance aimed at improving pregnancy outcome.

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Conflicts of interest

There are no conflicts of interest.

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