Original Article

Efficiency of placental three dimentional power Doppler ultrasonography for predicting preeclampsia in early pregnancy

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ABSTRACT

Purpose: to evaluate the role of three dimentional power doppler ultrasonography (3D PDUS) of the uteroplacental circulation in early pregnancy as a screening tool for prediction of preeclampsia.

Patients and methods: 50 pregnant women who came to do routine ultrasound scan between 11 and 13.6 weeks of pregnancy during the period from February 2016 to April 2016. Placental volume and vascularization indices were obtained, and vascular index (VI), flow index (FI), blood vessels and blood flow index (VFI) were calculated by three-dimensional Doppler histogram.

Results: Of the included 50 pregnant women, 22% developed preeclampsia and 78% did not develop preeclampsia. The placental blood flow perfusion in patients with pre-eclampsia had a lower VI, FI and VFI compared to non preeclamptic women with highly significant statistical difference ($P < 0.001$)

Conclusion: 3D PDUS can be used as an effective screening tool to predict preeclampsia in early pregnancy.

1. Introduction

Preeclampsia (PE) is one of pregnancy hypertensive disorders, affecting 3–5% of pregnant females and is an important etiology of perinatal mortality and maternal morbidity [1]. In addition, PE is commonly associated with intrauterine growth restriction (IUGR), iatrogenic preterm delivery and placental abruption, which are additional main causes of adverse outcome [2]. Early-onset preeclampsia with pregnancy termination before 34 weeks gestation, and is usually accompanied with intrauterine growth restriction, abnormal doppler waveform-pattern of uterine and umbilical arteries, and adverse outcomes for both the mother and the fetus. On the other hand, late-onset preeclampsia, requiring delivery at/or after 34 weeks gestation, is usually associated with low maternal morbidity, little fetal involvement and its perinatal outcomes are usually favorable. So, prediction of preeclampsia very early in pregnancy makes early prophylactic measures more effective [3]. Novel placental assessment by three dimentional ultrasonography is more available than two dimentional ultrasonography, including volume measurement and surface-rendering imaging. Quantitative and qualitative assessment of placental blood flow and vascularization has become more feasible with recent advances of 3D PDUS and 3D power Doppler histogram analysis. 3D PDUS can detect internal placental vessel features including density, caliber changes, branching and tortuosity [4]. Several previous small-scale studies suggested that the parameters of 3D power doppler ultrasound evaluating the placenta during the first trimester of pregnancy can predict adverse outcomes such as preeclampsia (PE) and fetal growth restriction [5]. 3D power doppler ultrasound done for all cases including 3D power Doppler indices of placental bed (including placental vascularization index, flow index and vascularization flow index) found that the mean vascular indices were lower in pregnant females that subsequently developed pre-eclampsia compared to pregnant females who did not develop pre-eclampsia [6].

The aim of the present study was to assess the role of three dimensional power doppler ultrasound (3D PDUS) of the uteroplacental circulation in early pregnancy as a screening tool for prediction of preeclampsia.

2. Patients and methods

2.1. Patients

A prospective observational study included fifty pregnant women who came to do routine ultrasound scan between 11 and 13.6 weeks of gestation during the period from February 2016 to April 2016. Placental volume and vascularization indices were obtained and

vascular index (VI), flow index (FI), blood vessels and blood flow index (VFI) were calculated by 3D Doppler histogram. The outcome was scored as normal or preeclamptic.

All included cases were with single viable pregnancy, of normal fetal morphology and were free from any other medical disorder with pregnancy as hypertension and diabetes mellitus. Exclusion criteria include: Multiple pregnancy, pregnant women with history of hypertension, all pregnant women with any systemic diseases, congenital fetal anomalies, congenital placental or umbilical artery abnormalities and pregnant women with gestational age < 11 weeks or more than 14 weeks.

After explanation of the whole procedure, a full consent was taken from the patient & then all females included were subjected to the following: measurement of placental blood flow in early pregnancy by 3D power Doppler ultrasound with comparison between normal and preeclamptic women and full history taking: including personal history (regarding name, age, occupation, …etc.), menstrual history and past medical/surgical history.

2.1.1. 3DPD ultrasound examination

All 3PD ultrasound were done by an expert radiologist using Samsung H60 with a convex probe 3D/4D.

Placental volume: A three dimensional volume of the uterus was obtained by transabdominal ultrasonography. The sweep angle was set at 85° and the probe was kept perpendicular to the placental plate. We examined the placenta with the size of the volume box was adapted in such a way that the placenta fitted into it completely. The volume was stored for offline analysis later on. The VOCAL™ (Virtual Organ Computer-aided Analysis) technique was then used to aquire a series of six sections of the imaged placenta, each section obtained after about 30° rotation from the previous one. In each plane, the placental contour was manually drawn, excluding the wall of the uterus, which is mostly thickened underneath the placenta, either due to contraction or hypertrophy. In each of the six planes, the volume was calculated by the machine from the drawn areas and then computed reconstruction of the placenta together with its volume were displayed.

Placental blood flow: After placental volume estimation, vascular indices were obtained using the 3D PD histogram from computer algorithms the whole placenta was put inside the region of interest then the PD was applied to the whole placenta then a 3D volume of this power doppler is acquired and a volume histogram is obtained after accepting the region of interest and applying a VOCAL at 30 degrees. The analyzed vascular indices included: VI (vascularization index), which expresses the presence of blood vessels in the placenta and refers to the color voxel/total voxel ratio, FI (flow index), which expresses the average intensity of blood flow and refers to the mean placental power doppler signal intensity, and VFI (vascularization FI), which combines the informations about both vascularity and blood flow, and refers to the weighted color voxel/total voxel ratio.

Power doppler was used with the same pre-established settings in all studied cases during acquisition of three dimensional images. Placental volume and vascularization indices measurements were done offline by one operator. Follow up was done in third trimester to detect whether the patients developed preeclampsia or not.

2.2. Statistical analysis

Analysis of the data was done using Statistical Program for Social Science (SPSS) version 20.0. Quantitative data were expressed as mean ± standard deviation (SD) and qualitative data were expressed as percentage and frequency. The 3D power Doppler indices were compared between women who developed preeclampsia and unaffected women.

When comparing between two means, independent-samples *t*-test of significance was used. For two-group comparisons in non-parametric data, Mann Whitney *U* test was used. To compare proportions between

Table 1

3D Doppler indices of placental vasculature in included pregnant women. IQR Interquartile range (central 50% of ascendingly ordered set of data) VI Vascularization index FI Flow index VFI Vascularization flow index.

	Range	Median (IQR)
VI	0.44–17.4	4.91 (5.11)
FI	12.17–48.98	24.97 (12.93)
VFI	0.07–5.93	1.12 (1.95)

two qualitative parameters, Chi-square (X2) test of significance was used. Receiver operating characteristic analysis (ROC curve) was used to find out the overall predictivity of the parameters and to find out the best cut-off value with detection of sensitivity and specificity at this cut-off value. P-value ≤ 0.05 was considered significant.

3. Results

A total of 50 singleton pregnant females were included in this study. The average range of age was from 18 to 41 years with a mean ± SD of 29.76 ± 5.9 years. The average range of weight was from 57 to 115 kg with a mean ± SD of 86.21 ± 15.12 kg. The average range of gestational age was from 11 to 13.7 weeks with a mean ± SD of 12.44 ± 0.83 weeks.

The average placental volume was from 21.89 to 145.85 cm^3 in the studied group with a median of 58.18 (35.46). The average VI range was from 0.44 to 17.4 in studied group with a median of 4.91 (5.11), average FI range was from 12.17 to 48.98 with a median of 24.97 (12.93) and average VFI range was from0.07 to 5.93 and a median of 1.12 (1.95) as shown in (Table 1).

Of the included 50 pregnant women, 22% developed preeclampsia (Figs. 1 and 2) and 78% (Figs. 3 and 4) did not develop preeclampsia, as shown in (Table 2). However, there is no statistically significant difference between pregnant females who developed preeclampsia and others who did not regarding the initial characteristics with the p-value 0.313, 0.149and 0.179 respectively (Table 3, Fig. 5).

There is highly statistically significant difference between pregnant females who developed preeclampsia and others who did not regarding 3D Doppler indices of placental vasculature (VI, FI, VFI), all significantly lower in women who developed preeclampsia with the p-value < 0.001, while placental volume show non-significant difference between pregnant females who developed preeclampsia and others who did not with the p-value 0.219 (Table 4, Fig. 6).

Receiver operator characteristics (ROC) curves were constructed for 3D Doppler indices of placental vasculature (VI, FI and VFI) as predictors of preeclampsia in included women (Fig. 7). All Doppler indices were significant predictors as denoted by the significantly large area under the curves (AUCs): with FI being the most significant predictor with AUC 0.969 and p-value < 0.001. Followed by VFI with AUC 0.901with p-value < 0.001 and AUC for VI was 0.838 with p-value < 0.001. There was however, no significant association between placental volume and development of preeclampsia with AUC value of 0.638 and p-value 0.167 (Table 5).

VI (vascularization index) cut-off value ≤ 3.22,sensitivity of 82.05%, specificity of 81.82%, positive predictive value (PPV) of 94.1%, negative predictive value (NPV) of 56.2%, positive likelihood ratio of 4.51 and negative likelihood ratio of 0.22. FI (flow index) cut-off value ≤ 17.73, sensitivity of 94.87%, specificity of 90.91%, positive predictive value (PPV) of 97.4%, negative predictive value (NPV) of 83.3%, positive likelihood ratio of 10.44% and negative likelihood ratio of 0.06. VFI (vascularization flow index) cut-off value ≤ 0.5, sensitivity of 92.31%, specificity of 81.82%, positive predictive value (PPV) of 97.7%, negative predictive value (NPV) of 75%, positive likelihood ratio of 5.08% and negative likelihood ratio of 0.09% (Table 6).