Placental Blood Flow and Uterine Artery Doppler in Early Prediction of Preeclampsia

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Abstract

Background: Preeclampsia is a serious hypertensive disorder that develops during pregnancy and impacts approximately 5-8% of pregnancies worldwide. Hypertension (high blood pressure) is a characteristic of this condition that manifests after the 20th week of gestation and is frequently accompanied by organ dysfunction, primarily affecting the placenta and the mother's kidneys, liver, and cardiovascular system.

Objective: To the understanding of this complex disorder and potentially improve its early detection and management.

Patients and Methods: This prospective observational study was conducted on 183 primigravida women, of them 176 women completed the follow up till the end of the study. Placental volume and vascularization indices were obtained between 11 and 13.6 weeks and calculated by three-dimensional Doppler histogram. We measured the uterine artery doppler during first trimester (between11 and 13.6 weeks) and second trimester (between 20 and 24 weeks) and examined their association with the subsequent development of preeclampsia.

Results: Of the 176 pregnant women studied, 18 (10.23%) developed preeclampsia, this study findings revealed that the women with preeclampsia had significantly low placental volume and low placental vascular incidences (vascularisation index VI, flow index FI, vascularisation flow index VFI) compared with the normotensive women. In contrast, the women with preeclampsia had significantly higher mean uterine artery plustility index and resistance index than the normotensive women. By comparing our study results to the findings of related studies focusing on placental volume, vascularisation of placenta and uterine artery Doppler, we can strengthen the evidence supporting the association between these parameters and the development of preeclampsia.

Conclusion: This study revealed that multivariate logistic regression analysis demonstrated that The first trimester's preeclampsia was significantly predicted by uterine artery PI, placental volume, and vascularization index, as

evidenced by a p-value of less than 0.05. The most precise predictors of preeclampsia in the analyzed population were the combined placental volume, placental vascularization index, and first-trimester uterine artery PI, giving the highest predictive accuracy of 95.5%.

Keywords: Preeclampsia, placental blood flow, uterine artery Doppler.

INTRODUCTION

Preeclampsia is a serious hypertension condition that arises during gestation, impacting around 5-8% of pregnancies globally. Hypertension is characterized by its onset after the 20th week of gestation and is frequently accompanied by organ injury, particularly to the placenta, liver, kidneys, and cardiovascular system of the mother [(1)].

The preeclampsia exact cause is unclear yet, but it is supposed to involve abnormalities in the development and the placenta function. The placenta is essential for delivering oxygen and nutrients to the developing fetus, and any disruption in its blood flow can have adverse effects on both fetal and maternal health [(2)].

Preeclampsia is typically characterized by symptoms such as persistent high blood pressure, proteinuria (protein in urine), rapid weight gain, migraines, vision issues, abdominal pain, and puffiness in the hands, face, and feet (edema). In severe cases, preeclampsia can progress to eclampsia, which is characterized by seizures and may pose a life-threatening risk to both mother and fetus [(3)].

Fetal and maternal health are both threatened by the disease. Maternal complications may include organ damage, stroke, placental abruption, and the development of long-term cardiovascular diseases. For the fetus, preeclampsia can lead to growth restriction, premature birth, and potential developmental issues [(4)].

Early detection and timely management of preeclampsia are crucial to mitigate the risks and guarantee optimal results for both the mother and the infant. Therefore, there is a growing interest in identifying reliable and non-invasive methods for early prediction and monitoring of preeclampsia, which can aid in risk stratification, treatment planning, and close monitoring during pregnancy [(5)].

The 1st-trimester evaluation at 11th-14th weeks, that is usually performed for dating assessment or aneuploidy screening, may facilitate the early detection of pregnancies at elevated risk for several problems associated with placental insufficiency, hence enabling the use of preventive interventions [(6)].

Abdallah et al. conducted a study to estimate the three-dimensional power Doppler ultrasonography (3D PDUS) predictive value, vascularization index, and placental volume for preeclampsia. Utilizing 3D PDUS, the researchers measured placental volume and vascularization index and examined their relationship with the occurrence of preeclampsia. The study findings demonstrated a significant association between abnormal volume of placental and index of vascularization, as determined by 3D PDUS, and a significant likelihood of developing preeclampsia [(1)].

In the study by Song et al. aimed to Assess the clinical utility of uterine artery Doppler velocimetry in the early stages of pregnancy for the prediction of preeclampsia and embryonic growth restriction. Doppler findings of the uterine artery during the first trimester and their correlation with the development of preeclampsia and embryonic growth restriction in the subsequent phase were thoroughly examined. During the first trimester, the researchers identified a significant association between an increased risk of preeclampsia, fetal growth restriction, and anomalous uterine artery Doppler studies [(2)].

Doppler scans at 22–24 weeks and above in patients with strong suspicion have shown to have significantly raised pulsatility index (PI) in various studies with progression to preeclampsia or pregnancy-induced hyper-

tension and further resulted in adverse pregnancy outcomes. There is evidence of abnormalities associated with waveforms where there is low-resistance flow in the early diastole consistent with a notch. This endothelium disease specific to pregnancy shows an otherwise persistent high-resistance pattern of flow in the uterine arteries which indirectly reflects a placentation abnormality [7].

In addition, Tianthong et al. (8) carried out a multicenter study focusing on maternal and neonatal outcomes in preeclampsia which can provide insights into the potential consequences of preeclampsia on both the mother and the neonate, further emphasizing the importance of early prediction and intervention.

AIM OF THE WORK

The utero-placental circulation in early pregnancy was assessed using 3D PDUS and the 1st trimester uterine artery (UA) Doppler (at 11th-13th+6 weeks), and at 2nd trimester (at 20th – 24th weeks) as a diagnostic instrument for predicting preeclampsia.

PATIENTS AND METHODS

Study design: The purpose of this prospective observational study was to investigate the correlation between uterine artery Doppler measurements and the relationship between the two and placental blood flow in the early prediction of preeclampsia.

Study setting: This investigation was accomplished at the Department of Obstetrics and Gynecology of Menoufia University Hospital and the fetomaternal unit unit of Cairo University. Before initiating this investigation, approval was obtained from Menoufia University and Cairo University fetal medicine unit. The study was carried out during the period from July 2021 to August 2023.

Ethical consecration: Informed consent: All participants were fully informed about the study, including the risks, benefits, and procedures involved.

Confidentiality: The privacy of participants was protected, and their personal information would not be disclosed to third parties.

Respect for autonomy: Participants had the right to make decisions regarding their own health and treatment, and their decisions were respected.

Inclusion/Exclusion Criteria: Participants were recruited at the Obstetrics and Gynecology Department of University Hospital of Menoufia and Kasr El-Aini hospital according to these criteria:

Inclusion Criteria: Pregnant women above 18 years. Primigravida. Fetus that is viable. From 11 to 13+6 weeks gestational age. Intact fetal membrane. Normal fetal and umbilical cord structure.

Exclusion Criteria: Molar pregnancy. Multiple pregnancies. Threatened abortion. Structural fetal malformation or any identified abnormality during our sonographic examination (uterine fibroids, umbilical cord irregularities). Maternal comorbidities (hypertensive disorders, diabetes mellitus, ischemic heart diseases, and renal illnesses). History of drug intake (antiepileptic, oral hypoglycemic, and antihypertensive drugs).

Justification of Sample Size: The Statistical Power Analysis Software PASW 11.0 was employed to determine the sample size, and this was scientifically arrived at through study that was conducted by Dar et al. (9) & Ali et al. (10). Sample size of total 183 renders a post-hoc 82-power binomial test for change of sensitivity on 0.5 to 0.8205 for specificity from 0.5 to 0.8182. The significance level is 0,05. In practice the achieved α level is 0.0490 for sensitivity test while the achieved α level for specificity test is 0.0358. The probability of getting the disease is 9.3%.

Method of Allocation: Participants were allocated based on their availability and willingness to take part in the study. However, we aimed to ensure a diverse sample by considering gestational age, maternal age, and other relevant factors during recruitment.

Methods of Data Collection: Included Women who participate in routine ultrasound scans at 11-13+6 weeks of gestation undergo the following procedures: Case history of each patient including, personal, medical, surgical, family history, and general physical examination followed by vital signs (BP, T, pulse rate/ect.) and abdominal examination. Evaluation of probable gestational age according to LMP and fetal CRL measurement. During the 11-13+6 weeks gestation, patients were invited to undergo a uterine artery Doppler assessment and placental blood flow evaluation. Consequently, they were extended an invitation to return for a uterine artery Doppler estimation at 20-24 weeks gestation.

Placental volume:

Using a transabdominal transducer at a frequency of 3.5-5 MHz, all patients were evaluated at 11-13+6 weeks of gestation using a Voluson E8 Expert 3D-US scanner from GE. After the CRL was recorded, the power Doppler was implemented with a fixed configuration (PRF 0.9 MHz, wall motion filter: low1). Following this, the 3D program was activated, resulting in a maximal traversal angle of 85+ degrees. We investigated the placenta by adjusting the volume box's dimensions to ensure that the placenta was fully contained. The instrument was maintained at a point perpendicular to the plate of placenta.

These volumes were saved for later manual analysis when needed in other parts of the study. The planner, that is, the VOCAL™ (Virtual Organ Computer-aided Analysis) program. A sequence of six sections through the placenta was obtained by quantitatively measuring the volume using 30 degrees of rotation. Purposeful ventured line around the edge of the placental silhouette in each plane to avoid including uterine wall. The machine computed the volumes of the placenta in each of the six planes based on the outlined areas, and subsequently displayed the placenta reconstruction along with its volume.

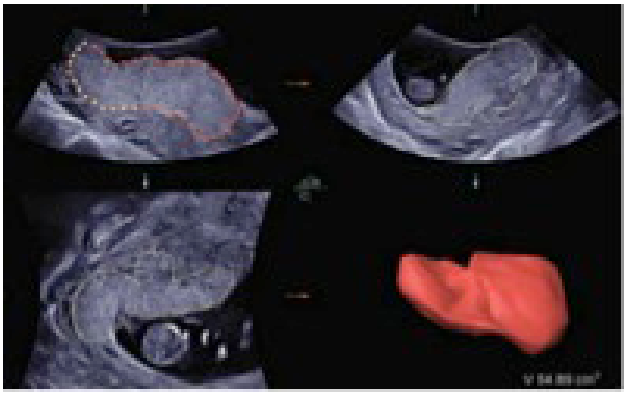


Figure (1): Placental volume by 3D ultrasound in the first trimester of pregnancy.

Placental blood flow:

After the estimated volume of the placenta was determined, vascular indices were determined using computer algorithms and a histogram of 3D power doppler. Power doppler was implemented throughout the entire structure, and the entire placenta was positioned within the region of interest. The power doppler was employed to acquire a 3D volume. Subsequent to the acceptance of the region of interest, a histogram was generated and a VOCAL at 30 degrees was implemented. Flow index (FI), vascularization flow index (VFI), and vascularization index (VI) are the vascular indices that were examined. FI measures the average intensity of blood flow, while VFI integrates data about vascularity and blood flow using weighted color voxel/total voxel ratio and VI indicates the presence of blood vessels in the placenta using color voxel/total voxel ratio and only one person was able to estimate the parameters of placental volume and vascularization offline.

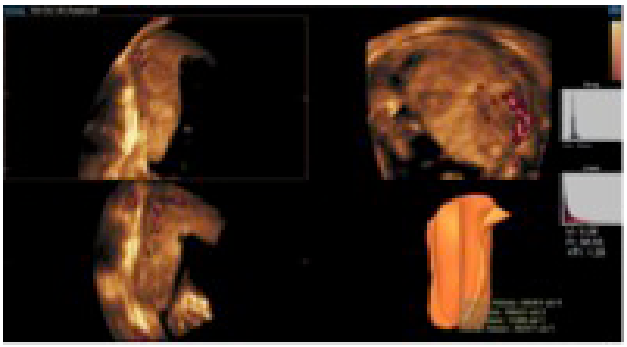


Figure (2): 3D power Doppler with histogram showing vascular indices of the placenta.

Uterine Artery Doppler scan:

Totally, two uterine artery examinations Doppler scans were carried out in the study, one that occurred during the first trimester, from 11–13.6 weeks of gestation, and the other that occurred during the second trimester, from 20–24 weeks of gestation.

Transabdominal ultrasound was implemented during the initial trimester assessment to conduct a doppler examination of the uterine artery (UA). The cervix, cervical canal, and internal cervical os were not visible in the midline ultrasonography segment of the uterus that we discovered. On the side of the uterine cervix, the transducer was programmed to scan laterally at the internal os level, and color flow mapping was used to differentiate between the right and left U(A). As a result, a pulsed-wave Doppler with a sampling gate of 3mm was implemented and a restricted insonation angle of less than 30º was implemented to capture the vessel's entire breadth. From right to left After taking a single electronic reading of the pulsatile index (PI) and index of resistance (RI) of UA, the signal was continuously updated until three consecutive readings of a similar kind were acquired. Then, the average of UA-PI and average of UA-RI were taken.

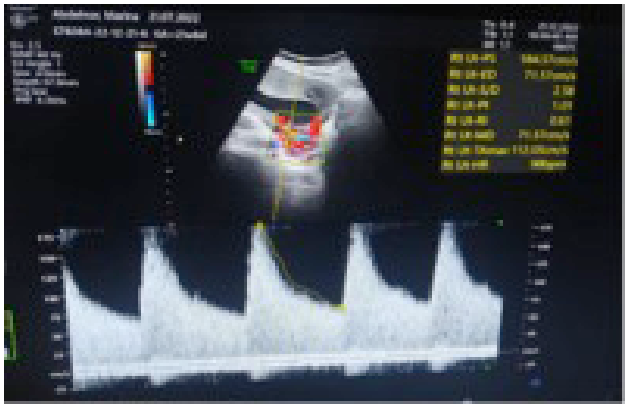


Figure (3): Uterine artery Doppler in the first trimester of pregnancy.

At 20-24 weeks of gestation, the uterine artery was identified on either side of the abdomen of the uterus using color doppler, which is the second trimester. It was then employed the PW Doppler for gaining the artery waveform, whenever three consecutive similar waves had been observed. The resistance index and pulsatility index were assessed for both uterine arteries, mean of UA-PI &mean of UA-RI were then determined.

Figure (4): Uterine artery Doppler in the second trimester of pregnancy.

Third trimester follow up include the following, by serial measurements of blood pressure and complete urine analysis to look for proteinuria and follow up for any signs or symptoms for pre-eclampsia in order to determine whether the patient developed pre-eclampsia or not.

The ISSHP guidelines Magee et al. (11), state that Identifying pre-eclampsia in women After twenty weeks of pregnancy, even patients with normal blood pressure can develop new-onset hypertension. Pre-eclampsia is defined by a systolic blood pressure of 140 mm Hg or higher and/or a diastolic blood pressure of 90 mm Hg or higher, calculated as the average of the two measurements, additionally, a further symptom or sign. Transaminases that are elevated, acute renal injury (creatinine levels exceeding 90 μmol/l), and liver involvement, proteinuria (protein/creatinine ≥ 30mg/mmol in a spot urine sample), such as neurological manifestations (eclampsia, altered mental status, visual blurring or loss, seizures), ALT or AST >40 IU/l), hematological abnormalities (thrombocytopenia (platelet count below 150,000/μl), disseminated intravascular coagulation, haemolysis), or uteroplacental dysfunction (FGR,

angiogenic imbalance, placental abruption), cardiorespiratory complications (pulmonary oedema, myocardial ischaemia, infarction).

Women who developed pre-eclampsia and those who had a normal pregnancy did not exhibit significant variations in uterine artery Doppler indices at 11-13+6 weeks and 20-24 weeks of gestation. Throughout the first trimester (11-13+6 weeks) and found any differences in placental power Doppler indices between normal and preeclamptic women.

Statistical Data Analysis:

The data were collected, examined, coded, and entered, and subsequently analyzed using IBM SPSS 20 for the Statistical Package for Social Science. The data's normality was confirmed using the Shapiro-Wilk Test of Normality. The qualitative data were summarized by use of number and percentages while quantitative data was summarized by use of mean, standard deviations and ranges where the data fit a parametric distribution.

Ethical Statement

The present study is in compliance with the standards of ethical practices followed in other countries and state legal requirements. The study is not likely to present any physical, psychological, social and legal, economic or any other form of risks to the participants of the study. The study can be regarding protection of participants' anonymity. Other researchers have an obligation to abreast the security of data investigators is in charge of. We also ensure that the data of the participants were not used in any other task apart from the one used in this study. Consistent with protecting the identity of the participants, Name, contact information etc. were not encoded in our data entry software, yet each participant was assigned a random identification number.

RESULTS

Table (1): Demographic data distribution in all study population.

	Demographic data
	N=183
Age	
Mean± SD	24.6±2.35
Range (Min-Max)	21:28
Parity	
Primigravida	183(100%)

SD; *standard deviation*

Table (2): Outcome Data distribution in all study population

Preeclampsia	**Outcome**
	N=176
Preeclampsia	
No	158(89.77%)
Yes	18(10.23%)

RESULTS

Table (3): Outcome Data distribution in preeclampsia group:

	Outcome
	N=176
Mild preeclampsia	10
Severe preeclampsia	5
HELLP Syndrome	1
Eclampsia	2

HELLP; *Hemolysis, Elevated liver enzymes, and Low platelet count.*

Table (4): Relations between Examinations data according to Preeclampsia groups

	Preeclampsia		P value	Statistically significant
	No	Yes		
	N=158	N=18		
Weight	76.54±8.71	76.22±8.7	0.8842	N.S
Height	164.14±4.18	164.5±4.15	0.7318	N.S
BMI (kg/m²)	28.37±2.75	28.13±2.75	0.7328	N.S
Blood Pressure at delivery				
SBP (mm Hg)				
Mean±SD	109.36±8.01	149.44±9.38	<0.001	Sig.
Range	93-125	140 -167		
DBP (mm Hg)				
Mean±SD	68.14±6.15	96.61±5.64	<0.001	Sig.
Range	56-80	89-107		
Pulse	81.47±6.42	82.44±7.04	0.5801	N.S
Gestational age at delivery	38.2±1.5	36.6±2.5	<0.001	Sig.
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

SBP; *systolic blood pressure.* ***BMI;*** *body mass index.*

. N.S; *no significant.* ***DBP;*** *diastolic blood pressure*

Table (5): Relations between Placental 3D-ultrasound according to Preeclampsia groups.

First trimester	Preeclampsia		P value	Statistically significant
	No	Yes		
	N=158	N=18		
Placental volume	97.83±9.63	75.55±7.94	0.001	HS
Vascularization index	9.69±1.47	7.26±0.68	0.001	HS
Flow index	45.70±4.44	38.25±4.34	0.001	HS
Vascularization flow index	4.31±0.90	2.71±0.57	0.001	HS
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

Sig.; *significant. N.S; no significant*

Table (6): Relations between Uterine Artery Doppler first trimester(11-13+6 weeks) of pregnancy according to Preeclampsia groups.

Doppler first trimester	Preeclampsia		P value	Statistically significant
	No	Yes		
	N=158	N=18		
Uterine Artery PI	1.09±0.25	1.98±0.47	0.001	HS
Uterine Artery RI	0.63±0.11	0.81±0.09	0.001	HS
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

PI; *pulsatility index.* ***RI;****resistance index.* ***Sig.;*** *significant.* ***N.S;*** *no significant*

Table (7): Relations between Uterine Artery Doppler second trimester (20 - 24 weeks) of pregnancy according to Preeclampsia groups.

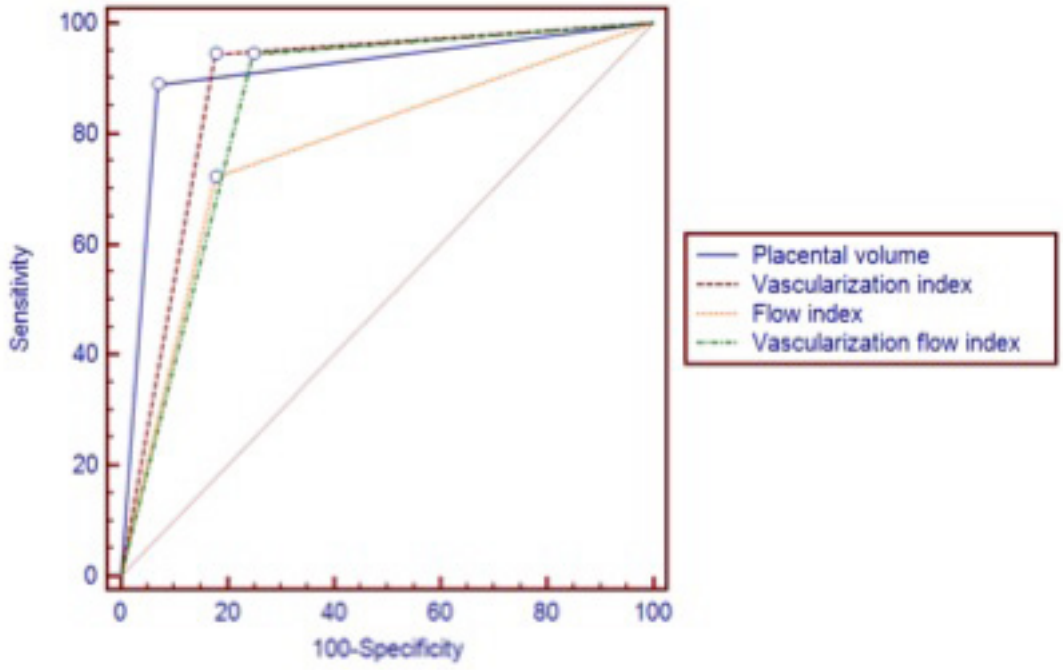
Doppler second trimester	Preeclampsia		P value	Statistically significant
	No	Yes		
	N=158	N=18		
Uterine Artery PI	1.16±0.25	1.57±0.28	0.001	HS
Uterine Artery RI	0.56±0.16	0.72±0.19	0.001	HS
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

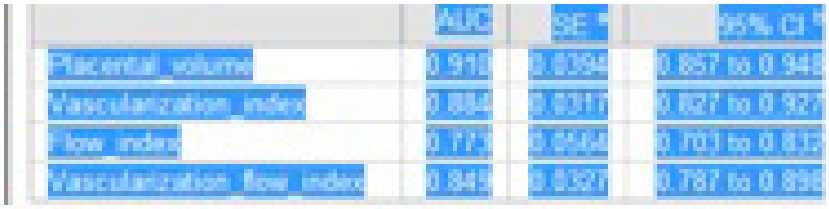
PI; *pulsatility index.* ***RI;*** *resistance index.* ***Sig.;*** *significant.* ***N.S;*** *no significant*

Table (8): Results of ROC curve analysis for sensitivity and specificity of 3DPD parameters (placental volume, FI, VI and VFI) for prediction of preeclampsia among studied population:

3DPD parameters	Cut-off	Preeclampsia		Sens.%	Spec.%	PPV%	NPV%	Accuracy	p-value
		Yes=18	N=158						
Placental volume	≤86.4	16	11	88.9%	93.0%	59.3%	98.7%	92.6%	0.001
	>86.4	2	147						
Vascularization index	≤8.5	17	28	94.4%	82.3%	37.8%	99.2%	83.5%	0.001
	>8.5	1	130						
Flow index	≤42.3	13	28	72.2%	82.3%	31.7%	96.3%	81.3%	0.002
	>42.3	5	130						
Vascularization flow index	≤3.72	17	40	94.4%	75.3%	29.8%	99.2%	77.3%	0.023
	>3.72	1	119						

VI: *vascularization index,* ***FI:*** *flow index,* ***VFI:*** *vascularization flow index.*





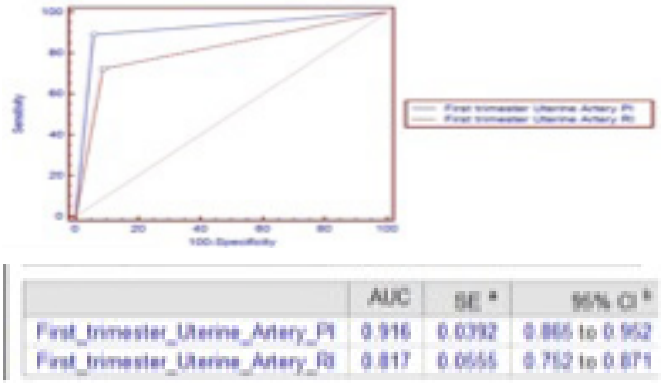
AUC: Area under the curve, **CI:** Asymptotic 95% Confidence Interval of AUC.

Figure (5): Results of ROC curve analysis for sensitivity and specificity of 3DPD parameters (placental volume, FI, VI and VFI) for prediction of pre-eclampsia among studied population.

Table (9): Results of ROC curve analysis for sensitivity and specificity of 1st trimester (11-13+6 weeks) of pregnancy uterine artery Doppler parameters (PI and RI) for prediction of pre-eclampsia among studied population:

1st trimester uterine artery Doppler parameters	Cut-off	Preeclampsia		Sens.	Spec.	PPV	NPV	Accuracy	p-value
		Yes =18	N =158						
Uterine Artery PI	≥1.6	16	9	88.9%	94.3%	64.0%	98.7%	93.8%	0.001
	<1.6	2	149						
Uterine Artery RI	≥0.79	13	14	72.2%	91.1%	48.1%	96.6%	89.2%	0.001
	<0.79	5	144						

PI: *pulsatility index,* ***RI:*** *resistance index.*



	AUC	SE [a]	95% CI [b]
First_trimester_Uterine_Artery_PI	0.916	0.0392	0.865 to 0.952
First_trimester_Uterine_Artery_RI	0.817	0.0555	0.752 to 0.871

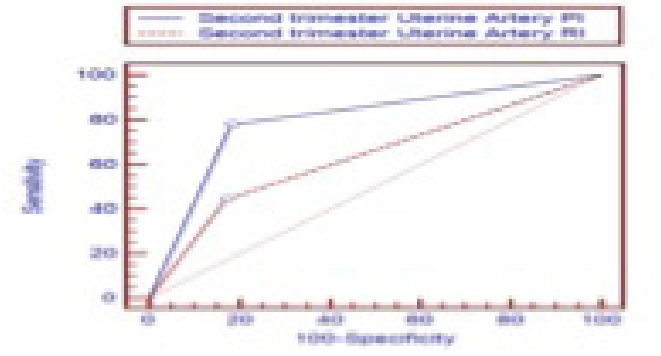
AUC: Area under the curve, **CI:** Asymptotic 95% Confidence Interval of AUC.

Figure (6): Results of ROC curve analysis for sensitivity and specificity of 1st trimester uterine artery Doppler parameters (PI and RI) for prediction of pre-eclampsia among studied population.

Table (10): Results of ROC curve analysis for sensitivity and specificity of 2nd trimester (20 - 24 weeks) of pregnancy uterine artery Doppler parameters (PI and RI) for prediction of preeclampsia among studied population.

2nd trimester uterine artery Doppler parameters	Cut-off	Preeclampsia		Sens.	Spec.	PPV	NPV	Accuracy	p-value
		Yes =18	N =158						
Uterine Artery PI	≥1.4	14	29	77.8%	81.6%	32.6%	97%	81.3%	0.001
	<1.4	4	129						
Uterine Artery RI	≥0.6	8	27	44.4%	82.9%	22.9%	92.9%	79.0%	0.015
	<0.6	10	131						

PI: *pulsatility index,* ***RI:*** *resistance index.*



	AUC	SE [a]	95% CI [b]
Second_trimester_Uterine_Artery_PI	0.797	0.0527	0.730 to 0.854
Second_trimester_Uterine_Artery_RI	0.637	0.0621	0.561 to 0.708

AUC: Area under the curve, **CI:** Asymptotic 95% Confidence Interval of AUC.

Figure (7): Results of ROC curve analysis for sensitivity and specificity of 2nd trimester uterine artery Doppler parameters (PI and RI) for prediction of pre-eclampsia among studied population.

Table (11): Regression analysis for predictive ability of placental blood flow and uterine artery Doppler in early prediction of preeclampsia.

Parameters	β	p-value	Odds ratio	95% C.I. for OR	
				Lower	Upper
Placental blood flow first trimester					
Placental volume	0.969	0.012	0.980	0.905	1.062
Vascularization index	0.380	0.007	0.322	0.156	0.664
Flow index	1.688	0.657	1.057	0.945	1.185
Vascularization flow index	0.269	0.203	0.651	0.304	1.396
Doppler first trimester					
Uterine Artery PI	0.247	0.014	2.383	1.918	10.444
Uterine Artery RI	1.718	0.812	2.795	0.562	12.624
Doppler second trimester					
Uterine Artery PI	0.750	0.046	2.764	2.225	12.115
Uterine Artery RI	0.862	0.560	3.242	0.652	14.644

β:*regression coefficients,* ***PI:*** *pulsatility index,* ***RI:*** *resistance index.*

Table (12): Results of ROC curve analysis for sensitivity and specificity of three parameters most prediction of preeclampsia among studied population.

Combination	Preeclampsia		Sens.	Spec.	PPV	NPV	Accuracy
	Yes =18	N =158					
Placental volume ≤86.4 and Vascularization index ≤8.5 and 1st trimester Uterine Artery PI≥1.6	17	7	94.4%	95.6%	70.8%	99.3%	95.5%
Placental volume >86.4 and Vascularization index >8.5 and 1st trimester Uterine Artery PI<1.6	1	151					

PI: *pulsatility index*

DISCUSSION

Despite many advancements in health care systems, it has been observed that hypertensive disorders of pregnancy are accountable for 10–15 percent of half a million maternal fatalities annually, Due to the fact that pre-eclampsia complex (PE) is still the leading cause of maternal and perinatal mortality and complications globally. In light of recent discoveries, efforts have been undertaken to determine which women are at a high risk of developing PE [(12)].

In order to mitigate the risks and guarantee the best possible outcomes for both the mother and the infant, it is essential to detect preeclampsia early and manage it promptly. Therefore, there is a growing interest in identifying reliable and non-invasive methods for early prediction and monitoring of preeclampsia, which can aid in risk stratification, treatment planning, and close monitoring during pregnancy [(5)].

The objective of this study was to assess the uteroplacental circulation during the first trimester of pregnancy (from 11 weeks to 13

+ 6 weeks) and use 3D Power Doppler and UtA FI screening during the first and second trimesters of pregnancy to predict preeclampsia. The study was a prospective observational done on one hundred and eighty three primigravida women, aged 18 and above, of them 176 women completed the follow up till the end of the study. Out of the studied 176 pregnant women, 18 (10.23%) developed PE during pregnancy in this study.

Salem et al. [13] study, concentrated on the prognosis of preeclampsia in primigravidas using maternal serum PAPPA and PIGF and first trimester uterine artery PI, The incidence rate of preeclampsia in our research is consistent with the findings of his study, which shows that only 30 expectant women (10%) developed the condition out of a total of 300 participants which showed that Preeclampsia was diagnosed in 10.23% of the participants.

In Oancea et al. [14] study to ascertain the degree of accuracy of 1st trimester UA Doppler in predicting (PE) which was encountered by 26 (21.6%) of the 120 expectant women who participated in the study. The study carried out by Ali et al. [10] was a prospective observational study, to estimate the efficiency of placental 3D ultrasound for predicting preeclampsia, which included 50 pregnant women and incidence of preeclampsia was 22%.

In El Tolemy et al. (15) study which aimed to determine placental volume and placental vasculature compared to intrauterine growth restriction and pregnancies with preeclampsia, The study was prospective and randomized, and the study was carried out on a total of 150 expectant women with a gestational age of 11-13.6 weeks. Of these women, only 12 (8.5%) were diagnosed with preeclampsia during pregnancy.

In this study it was possible to demonstrate the features of differences in the ranges of Doppler waves in the uterine arteries and 3D ultrasound data from the placenta in both healthy pregnancies and those impacted by preeclampsia. As we tracked every variable, we were able to examine the placental volume, vascularization index, flow index, vascularization flow index, mean uterine artery PI, and mean uterine artery RI separately.

The emergence of 3D ultrasonography has enabled the measurement measure placental volume. In vitro experiments suggest that the VOCAL approach may be more accurate in estimating the volume of an irregular item, such as the placenta [16]. "The potential of 3D Doppler conducts a comprehensive examination of the vascular placental tree and accurately identifies the villi branches Schiffer et al. (17), but also assesses the number of vessels in the vasculature and the rates of blood flow quantitatively [18].

In this investigation, expectant women diagnosed with preeclampsia exhibited a significantly lower placental volume (75.5±7.9) compared to the control group (97.8±9.6). The ideal placental volume cut-off for predicting preeclampsia is 86.4, with a sensitivity of 88.9% and a specificity of 93%. The area under the curve of placental volume for preeclampsia is (0.910).

This in line with the results of Sweed et al. [19] who assessed the influence of uteroplacental circulation and placental volume from the first trimester on the prediction of preeclampsia using 3D power Doppler. and found that normotensive women had a greater mean placental volume (92±29.6) compared to preeclamptic women, who had a lower mean placental volume (69.3±21).

El Tolemy et al. [15], reported that they found a significant statistical lower in placental volume between these pregnancies that developed PE compared to unaffected gestations (48.7 ± 8.13 vs. 67.5 ± 8.45, $p<0.001$). They postulated that inefficient placentation, as shown by a decrease in placental volume among eleven and thirteen weeks impacts PE eventual development during pregnancy.

Abdallah et al. [1], performed a study to evaluate the 3D PDUs discriminant performance, placental volume, and vascularization index

for preeclampsia and applying the identical placental volume threshold, and specificity on low placental volume as evidence for preeclampsia was 89% with the AUC of placental volume for predicting preeclampsia of (0.970).

Contrary to our results, Odibo et al. [20] study which aimed to assess the potential association between bad pregnancy outcomes, The mean placental volumes of these PE-affected fetuses did not decrease statistically significantly during the first trimester in comparison to controls whose pregnancies were unaffected, as determined by 3D power Doppler measurements of placental volume and vascular flow.

In the study carried out by Ahmed et al. [21], this prospective observational study was conducted on 250 expectant women evaluate the predictive value of the first trimester 3D ultrasound placental volume, which is measured between 11 and 13.6 weeks of gestation, in predicting the development of preeclampsia, the area under curve was (0.593) with no significant value of placental volume in prediction of preeclampsia, with sensitivity power 60 %. A study by Ali et al. [10] which evaluated the efficiency of placental 3D ultrasound for predicting preeclampsia reached to the area under curve (0.638) for prediction of preeclampsia by placental volume.

In this investigation, we noted that women diagnosed with preeclampsia exhibited diminished levels of placental viability, FI, and VFI. 38.2 vs 45.7, 2.7 vs 4.3, 7.26 vs 9.6, respectively) compared to normotensive women, p-value were statistically significant (P>0.001). A decrease in placental vascular density is indicated by low VI values. As placental resistance increases, the blood flow to the placenta decreases, as seen by the observed drop in FI values. Low levels of VFI are indicative of both a reduction in blood flow and a reduction in the number of placental vessels. Examining the three criteria shows that placental blood perfusion, intensity, and speed have all decreased [22]. Hegab et al. [23], conducted a comparative observational cohort study on 200 pregnant women to estimate the accuracy of the pulsatility index of the uterine artery and the placental 3D power Doppler in predicting the development of preeclampsia. Preeclampsia-affected women exhibited decreased mean values of the placental vascularization index (VI), flow index (FI), and vascularization flow index (VFI), according to the research. Specifically, the mean values were 7.5 versus 10.04, 39.6 versus 47.3, and 2.85 versus 4.47, respectively compared to normotensive women with statistically significant differences. El Tolemy et al. [15], discovered that in comparison to pregnancies without preeclampsia (PE), those with PE had much lower mean values for placental vascular indices. In particular, the average placental VI was 8.3, whereas the FI was 32.1 and the VFI was 5.4. These discrepancies were statistically significant, as evidenced by a p-value of less than 0.001.

In this study, the area under curve of placental (FI) for prediction of preeclampsia was (0.773). If preeclampsia could be predicted with a FI below 42.3, the total diagnostic accuracy would be 81.3%, the specificity would be 82.3 %, and the sensitivity would be 72.2 %. The statistical significance of the p-values for VI and VFI was established ($P < 0.001$). With an area under the curve (AUC) of 0.884 for VI and 0.849 for VFI, respectively, the ROC curve analysis showed predicted accuracy of 83.5% and 77.3%.

when placental VI values less than (8.5) and placental VFI value less than (3.7).

In research by Abdallah et al. [1], that conducted a prospective cohort study including over 2019 pregnant women, they found that in terms of predicting preeclampsia, Placental VI, placental FI, and placental VFI all had area under the curve values of 0.964, 0.876, and 0.934, respectively. When they used the same cut-off values, with sensitivity (97%, 76%, 98% respectively).

In contrast to our results , a study by Sweed et al. [19] that assessed the effectiveness of the 3D power throughout the first trimester The sensitivity of 82% was determined for the prediction of preeclampsia using Doppler imaging of the uteroplacental circulation and placental volume, with a placental VI <3.2, (placental FI <17.7) was 94.8% and (placental VFI <0.5) was 92.3% ,while the specificity of placental VI ,placental FI and placental VFI were (81.8%, 90.9%, 81.8 respectively).

Hannaford et al. [24] and Hashish et al. (25) presented enough data on placental (VI) sensitivity and specificity. In the Hannaford study which was conducted on 1200 pregnant women to assess the 3D power function in the first trimester Prediction of preeclampsia through Doppler imaging of placental vascularization indices, The most accurate predictors of PE were placental VI and VFI, according to their report. However, in their study of women at high risk for VFI, Hashish et al. found a sensitivity of 80% and a specificity of 92.1%.

In this study, the placental volume exhibited the maximum diagnostic accuracy for predicting preeclampsia, followed by the index of vascularization. The vascularization flow index demonstrated the lowest accuracy among the metrics, while the flow index had a marginally lower accuracy. Therefore, we should consider placental volume, placental VI, placental FI and Placental VFI as good tools in predicting preeclampsia.

In this study, the uterine artery pulsatility index was considered a valid predictor of hypertensive disorders during pregnancy at 11-13+6 weeks. Uterine PI mean values were significantly different between normotensive women and those with preeclampsia (1.98±0.47 vs 1.09±0.25, P<0.001), The area under the curve of uterine artery PI for predicting preeclampsia was 0.797, and the prediction accuracy was 93.8%, with a sensitivity of 88.9% and a specificity of 94.3%, at a cut-off of 1.6.

In their study, Hegab et al. (23), found the women affected by preeclampsia had higher mean of uterine artery pulsatility index at first trimester than normotensive women (2.05±0.5 vs 1.09±0.3, P<0.001). Elwakel et al. (26), performed cross-sectional observational research on 120 pregnant women to see how well uterine artery Doppler performed in the first trimester could predict future pregnancy difficulties. The study found that uterine artery PI had a high predictive accuracy of 97% for preeclampsia, with an area under the curve (AUC) of 0.948. Assuming a cut-off value of 1.95, the specificity was 98.9% and the sensitivity was 66%.

Contrary to results of this study Eltolemy et al. [15] determined that there was minimal use of uterine artery PI for preeclampsia prediction in the first trimester. Area under the curve (AUC) was 0.646, and sensitivity for uterine artery PI was 58.8% at a cut-off value of 1.9. Das et al. [27] studied 146 pregnant women in a prospective analytical study to detect preeclampsia using a combination of PAPP-A and first trimester uterine artery doppler. They found that when the uterine pulsatility index was greater than 1.48, the area under the curve was 0.664. Additionally, urinary artery PI had a sensitivity of 68% and a specificity of 52.9% in predicting preeclampsia.

Preeclampsia patients had significantly different mean uterine artery resistance indices (RIs) between 11 and 13+6 weeks of gestation, which was 0.81±0.09, compared to the group without preeclampsia (0.63±0.11), with a p-value of <0.001,The uterine artery resistance index (RI) at first trimester had limited accuracy in predicting preeclampsia, and the area under the curve (AUC) for this indicator was 0.637, and it had a sensitivity of 72.2% and a specificity of 92.2% at a score of 0.79.

This is in line with the results of Abdallah et al., (1) who examined the role of uteroplacental circulation and placental volume in the first trimester preeclampsia prediction

utilizing 3D power Doppler to investigate. A greater mean uterine artery resistance index (0.86±0.09 vs 0.64±0.11, P<0.001) was found in women with preeclampsia in comparison to normotensive women, with a sensitivity of 71% and specificity of 92%.

Mohammed et al. [28] conducted to assess the effectiveness of using maternal uterine artery Doppler and serum β-HCG for predicting preeclampsia in 388 pregnant women throughout the first trimester. The overall accuracy in predicting preeclampsia using uterine artery RI was 0.732, according to the study. The uterine artery RI exhibited high specificity (70.3%) and low sensitivity (62.1%) at a threshold of 0.84.

In comparison to patients with a lower PI (1.16±0.25), this study showed that patients with an elevated uterine artery PI (mean value 1.57±0.28) during the second trimester of pregnancy (weeks 20–24) were more likely to develop preeclampsia (PE). At the cut-off, the measurement had a sensitivity of 77.8% and a specificity of 81.6%, with an area under the curve of 0.797.

Those findings were in line with study of Li et al. [29], which carried out a prospective cohort study using uterine artery Doppler during the second trimester that included 800 expectant women to anticipate preeclampsia. Compared to normotensive women, The mean uterine artery PI value was 1.61±0.047 versus 1.02±0.049 in women without preeclampsia (P<0.001). Barati et al. (30) used the same cut-off and noted uterine artery PI sensitivity of (79%) and specificity of (95.5%) in a cross sectional study which investigated the second-trimester predictive efficacy of uterine artery doppler for adverse pregnancy outcomes.

Kumar et al. [31] utilized prospective diagnostic research to evaluate the predictive capacity of uterine artery Doppler as a screening instrument for preeclampsia in the second trimester, which included 680 participants. The study determined that a mean uterine PI exceeding 1.3 showed a specificity of 70.8% and a sensitivity of 79% when it came to predicting preeclampsia.

Contrary to the findings of this study, Adefisan et al. [32], the purpose of this prospective longitudinal study was to determine if uterine artery Doppler performed during the second trimester might reliably predict adverse pregnancy outcomes. One hundred twenty-two pregnant women participated in the research. When the mean uterine artery PI was more than 1.6, the study found that the PI in the second trimester could only predict preeclampsia with a sensitivity of 20%.

Our research found that the mean uterine artery RI during the second trimester was greater in the group that had preeclampsia (0.72±0.19) compared to the group that did not (0.56±0.16), with a p-value of 0.001. the area under curve of uterine artery RI at second trimester for predicting preeclampsia was (0.637), sensitivity of (44.4%) and specificity of (82.9%),positive predictive value of 30%, at a cut-off of 0.6.

In agreement with this finding, Kumar et al. [31] conducted studies on the screening for preeclampsia using uterine artery Doppler during the second trimester. The results demonstrated that the mean RI differed significantly among women who had preeclampsia, with a value of 0.72±0.2 and normotensive pregnant women (0.57±0.17) with a P-value of (0.001). found that the sensitivity of uterine artery RI (44.7%) was lower than the specificity (89.7%), positive predictive value of 32.2% when value of mean of uterine artery RI was higher than 0.7.

Pereira et al. [33], conducted a prospective cohort study to predict preeclampsia in the second trimester by utilizing uterine artery Doppler in 100 singleton pregnancies. The research determined that a uterine resistance index (RI) of 0.6 or higher had a specificity of 91.8% and a sensitivity of 21.4%. These results suggest that the reliability of the uterine artery RI for predicting preeclampsia during the second trimester is low.

Thakur et al. (34) evaluated the accuracy of uterine artery Doppler in predicting pre-eclampsia in 100 pregnant women using a prospective cohort study conducted in the second trimester and found that the uterine artery RI sensitivity (84%) was higher than the specificity (55%) when value of mean of uterine artery RI was higher than 0.5, with AUC value of 0.759, their results weren't consistent with our findings.

CONCLUSION

This study revealed that multivariate logistic regression analysis showed that the vascularization index, volume of placental, and uterine artery PI (measured in the first trimester) were all significant predictors of pre-eclampsia, with a p-value of less than 0.05. The most precise prediction of preeclampsia among the analyzed population was achieved by placental vascularization index, the combination of placental volume, and first-trimester uterine artery PI, with a predictive accuracy of 95.5%.

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