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Predictive Value of Uterine Artery Doppler at 11–14 Weeks for Preeclampsia and Fetal Growth Restriction

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Abstract: Preeclampsia (PE) and fetal growth restriction (FGR) are significant causes of maternal and perinatal morbidity, and effective preventive measures are required to identify them early. Uterine artery Doppler (UtA) monitoring in the late first trimester has turned out to be a possible screening method, with high pulsatility index (PI) and diastolic notching being the two important sonographic findings. The objectives of the study were to determine the predictive ability of uterine artery Doppler, namely, mean UtA-PI and bilateral diastolic notching, at 11-14 gestation weeks, of end result preeclampsia and fetal growth limitation**.** The study was a cross-sectional study that involved 111 singleton pregnancies in Basrah, Iraq, hospitals from May 2024 to May 2025. At 1114 weeks, a UtA Doppler was done to measure the mean UtA-PI and determine bilateral notching. Outcomes of pregnancy were also noted, such as PE (stratified as early-onset <34 weeks, and late-onset ≥34 weeks), FGR (birth weight below the 10th centile), and normotensive appropriate-for-gestational-age (AGA) delivery. Analysis of predictive performance of elevated UtA-PI (>95th percentile) and bilateral notching was done in terms of sensitivity, specificity, positive and negative predictive values (PPV, NPV), and likelihood ratios. The average UtA-PI was strongly increased in the adverse outcome pregnancies (PE: 1.65 and FGR alone: 1.32) as opposed to normal AGA controls (0.95 and all: p<0.001). To predict any adverse outcome (PE or FGR, n=21), elevated UtA-PI was sensitive (57.1), specific (94.4), PPV (70.6), and LR+ (10.3). The sensitivity of bilateral notching was 52.4% and the specificity was 91.1%. Early-onset PE showed the highest performance, UtA-PI >95th percentile had 100% sensitivity and LR+ of 13.3. The presence of uterine artery Doppler evaluation in 1114 weeks of gestation, and especially a high mean UtA-PI (>95th percentile), is a strong and independent predictor of future preeclampsia and fetal growth restriction with a high specificity and a significantly enhanced likelihood of disease. The method is most effective when used in predicting severe and early-onset phenotypes. The addition of UtA Doppler to the screening protocols in the first trimester could be used to improve early case identification of high-risk pregnancy to be targeted and the implementation of preventive measures.

Keywords: Preeclampsia, fetal growth restriction, and prediction of outcomes of uterine artery doppler.

INTRODUCTION

Preeclampsia (PE) and fetal growth restriction (FGR) are among the most important issues in obstetric medicine that have a disproportionately high morbidity and mortality in the mother and newborn in the country [Dimitriadis, E. *et al*., 2023]. Although they are clinically distinct, they have been identified to share a similar pathophysiological cause in the aberrant remodelling of maternal spiral arteries during early placentation [Chappell, L. C. *et al*., 2021; Burton, G. J. *et al*., 2019]. This pathology of physiological change (between 8 and 20 weeks of gestation) results in a condition of periodically increased-resistance uteroplacental circulation [Chaemsaithong, P. *et al*., 2022]. The consequent placental failure is consequently counterbalanced to maternal systemic endothelial malfunction, the PE phenotype, and fetal nutrient deficiency, which lead to FGR [Rana, S. *et al*., 2019]. A clinical identification of pregnancy that is progressing to such complications has been reactive, and it is subject to the late manifestation of clinical symptoms such as hypertension and proteinuria, or ultrasonic monitoring of retarded fetal growth. The treatment decisions at this stage tend to be restricted to improved monitoring and predetermined delivery, which presupposes high requirements to effective early prediction**.** [Mol, B. W. *et al*., 2016]

The implementation of uterine artery Doppler (UtA-Doppler) ultrasonography into the first-trimester screening is a major move in the right direction in evaluating the risks in the proactive way [Park, H. J. *et al*., 2015]. It is a noninvasive technique of in vivo direct hemodynamic examination of uteroplacental blood flow [Cerdeira, A. S. *et al*., 2019]. It relies on its predictive principle that is founded on the already established correlation of impaired placentation with strong resistance Doppler flow patterns [Chappell, L. C. *et al*., 2019]. Endovascular

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trophoblast invasion plays a role in the progressive vasodilation of the spiral arteries in physiologically advancing pregnancy that is ultrasonographically determined by the disappearance of pulsatility index (PI) or resistance index (RI) as well as the disappearance of the early diastolic notch [Khong, S. L. *et al*., 2015]. Quite the contrary, during pregnancies related to aberrant placentation, UtA-Doppler waveforms will never have low PI/RI values, and they will frequently exhibit an incessant diastolic notch. Such findings are indicative of augmented downstream vascular impedance and dyscharacteristic arterial reactivity. [Espinoza, J. 2021]

Consequently, UtA-Doppler in 11 – 14 weeks of gestation was found to construct significant forecasting quality on the subsequent adverse outcome, particularly, early-onset (and severe) PE and FGR. There is strong meta-analytic evidence that high mean UtA-PI (especially above the 95th percentile) is associated with an increased risk of preterm PE, and pooled likelihood ratios have moderate predictive value [Horgan, R. *et al*., 2023]. Nevertheless, UtA-Doppler sensitivity and specificity are not sensitive enough to be used as a single screening modality because the sensitivity and specificity of this technique in relation to the subsequent or milder manifestations of the disease are relatively low. [Demers, S. *et al*., 2019]

Patients & Methods

The study was a cross-sectional study that was performed from May 2024 to May 2025 in Basrah, Iraq, hospitals to test the predictive importance of first-trimester uterine artery Doppler on the aftermath development of preeclampsia (PE) and fetal growth restriction (FGR). A series of singleton pregnancies with a scheduled 11-14 week ultrasound scan of combined aneuploidy screening was recruited. The exclusion criteria were known significant fetal abnormalities, chronic renal dysfunction, pre-gestational diabetes mellitus, and pregnancy due to assisted reproductive technologies that involved oocyte donation. The final study cohort was 111 pregnancies with the inclusion criteria .

Doppler velocimetry of the uterine arteries was done transabdominally by skilled sonographers. Color Doppler identified the uterine arteries at the crossover point with the external iliac arteries. Waveforms were then obtained by using pulse-wave Doppler with an angle of insonation lower than 30. Bilateral pulsatility index (PI) was measured, and the mean UtA-PI was computed. PI values were all made as multiples of the median (MoM) adjusted to gestational age based on known reference curves. The bilateral presence of an early diastolic notch was also checked, and bilateral notching was considered present or absent.

Hospital electronic medical records were used to determine the outcome of pregnancy after delivery. Secondary outcomes were spontaneous preterm birth (<37 weeks) and a composite adverse outcome, which referred to the development of either PE or FGR.

SPSS 24.0 was used to carry out statistical analysis. Mean with standard deviation or number (percentage) was used to show descriptive statistics. The diagnostic value of an elevated mean UtA-PI (>95th percentile on gestational age) and bilateral notching to predict future adverse outcomes was assessed by determining sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios (LR+). The Pearson correlation coefficient was applied to determine the associations between mean UtA-PI MoM and continuous clinical parameters. A multivariate logistic regression model was fitted to identify the independent predictors of the composite adverse outcome (PE or FGR) after controlling for the possible confounding factors such as nulliparity, BMI greater than 30 kg/m², and maternal age more than 35 years. The p-value of less than 0.05 was taken as significant.

RESULTS

The paper examines the predictive value of first-trimester uterine artery Doppler (UtA-PI) and bilateral presence of diastolic notching as a predictor of poor pregnancy outcomes, preeclampsia (PE), and fetus growth restriction (FGR). The cohort analysis of 111 pregnancies indicates a number of crucial results on the topic of early detection of at-risk persons.

Table 1 describes the typical obstetric population in the form of the baseline characteristics. It is important to note that the mean UtA-PI (1.05 MoM) and the incidence of bilateral notching (17.1%) give a point of reference of normal and abnormal values. The results of pregnancy (Table 2) indicate that PE is present in 10.8 percent, and FGR occurs without PE in 8.1 percent, and the combination of these two outcomes led to 18.9 percent.

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Table 1. Baseline and diagnoses features of 111 patients who enrolled in this study.

Parameters	**Findings**
- Maternal Age (years)	30.2 ± 5.8
- Nulliparity	63 (56.8%)
- Body Mass Index (kg/m²)	25.1 ± 4.9
- Smoking Status	12 (10.8%)
- Chronic Hypertension	5 (4.5%)
- Diabetes Mellitus	7 (6.3%)
- UtA-PI (MoM)	1.05 ± 0.35
- Pregnancies with Bilateral Notching	19 (17.1%)

Table 2. Enroll clinical data of pregnancy findings in our study.

Variables	Frequency (%)
Normotensive	85 (76.6%)
Preeclampsia	12 (10.8%)
Early-onset preeclampsia (<34 weeks)	4 (3.6%)
Late-onset preeclampsia (≥34 weeks)	8 (7.2%)
fetal growth restriction, FGR (Birth weight <10th centile)	9 (8.1%)
Spontaneous Preterm Birth (<37 weeks)	6 (5.4%)
Normotensive FGR with Preterm Birth	3 (2.7%)

Our results (Table 3 and Figure 1) reveal that there is a very close statistically significant relation between the presence of abnormal uterine artery Doppler and the negative outcomes. The mean UtA-PI MoM was significantly higher in all the adverse outcome groups compared to the normotensive AGA reference group, and the highest values were found in the early-onset PE (1.98 ± 0.38, $p<0.001$). In the same way, bilateral notching was significantly higher in unfavourable outcome groups (100 percent in early-onset PE and 66.7 percent in all PE). These results demonstrate that disrupted placentation, as indicated by an enhancement of vascular resistance together with abnormal waveform patterns during the first trimester, is a key pathophysiological antecedent to PE and FGR.

Table 3. Identifying pregnancy outcomes throughout the uterine artery resistance index.

Variables	Frequency	Mean UtA-PI [mean ± SD]
Normotensive AGA	85	0.95 ± 0.22
Preeclampsia	12	1.65 ± 0.41
Early-onset Preeclampsia	4	1.98 ± 0.38
Late-onset Preeclampsia	8	1.48 ± 0.32
Fetal Growth Restriction	9	1.32 ± 0.28
Adverse Outcome (PE or FGR)	21	1.53 ± 0.39

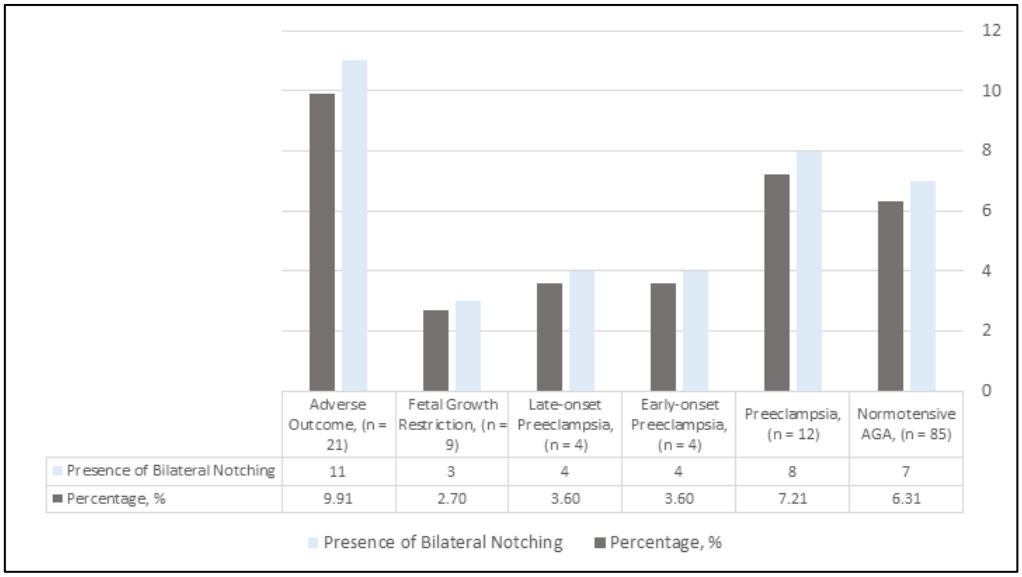

Figure 1. Revealing the presence of bilateral diastolic notching in the patients of pregnant women.

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The predictive performance data of Table 4, Table 5, and Figure 2 are of clinical value. With a cut-off of >95th percentile of UtA-PI, the test had a high specificity (93.9% all PE) and negative predictive value (NPV: 97.9% all PE), but a moderate to low positive predictive value (PPV: 47.1% all PE). The same tendencies are further exhibited by bilateral notching that was slightly less specific and PPV. Nevertheless, the low PPV, especially severe consequences that need to be delivers prior to 34 weeks (PPV 35.3, Table 6). Although the test is able to detect a group of high-risk women, it is possible that a significant number of women with an abnormal result will not get the condition, which is why it may result in unnecessary anxiety and interventions.

Table 4. Assessment of the elevated uterine artery resistance index (UtA-PI) performance in the adverse outcomes.

Outcome	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Positive Likelihood Ratio (LR+)
Preeclampsia (PE) (n=12)	66.7 (8/12)	93.9 (93/99)	47.1 (8/17)	97.9 (93/95)	11.0
Early-onset PE (n=4)	100 (4/4)	92.5 (99/107)	23.5 (4/17)	100 (99/99)	13.3
Late-onset PE (n=8)	50.0 (4/8)	93.2 (96/103)	23.5 (4/17)	97.9 (96/98)	7.3
FGR (n=9)	44.4 (4/9)	92.2 (94/102)	23.5 (4/17)	96.9 (94/97)	5.7
Adverse Outcome (n=21)	57.1 (12/21)	94.4 (85/90)	70.6 (12/17)	90.4 (85/94)	10.3

Table 5. Assessment of the bilateral notching performance into adverse outcomes.

Outcome	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Positive Likelihood Ratio (LR+)
Preeclampsia (PE) (n=12)	66.7 (8/12)	88.9 (88/99)	42.1 (8/19)	95.7 (88/92)	6.0
Early-onset PE (n=4)	100 (4/4)	85.0 (91/107)	21.1 (4/19)	100 (91/91)	6.7
Late-onset PE (n=8)	50.0 (4/8)	86.4 (89/103)	21.1 (4/19)	96.7 (89/92)	3.7
FGR (n=9)	33.3 (3/9)	84.3 (86/102)	15.8 (3/19)	93.5 (86/92)	2.1
Adverse Outcome (n=21)	52.4 (11/21)	91.1 (82/90)	57.9 (11/19)	89.1 (82/92)	5.9

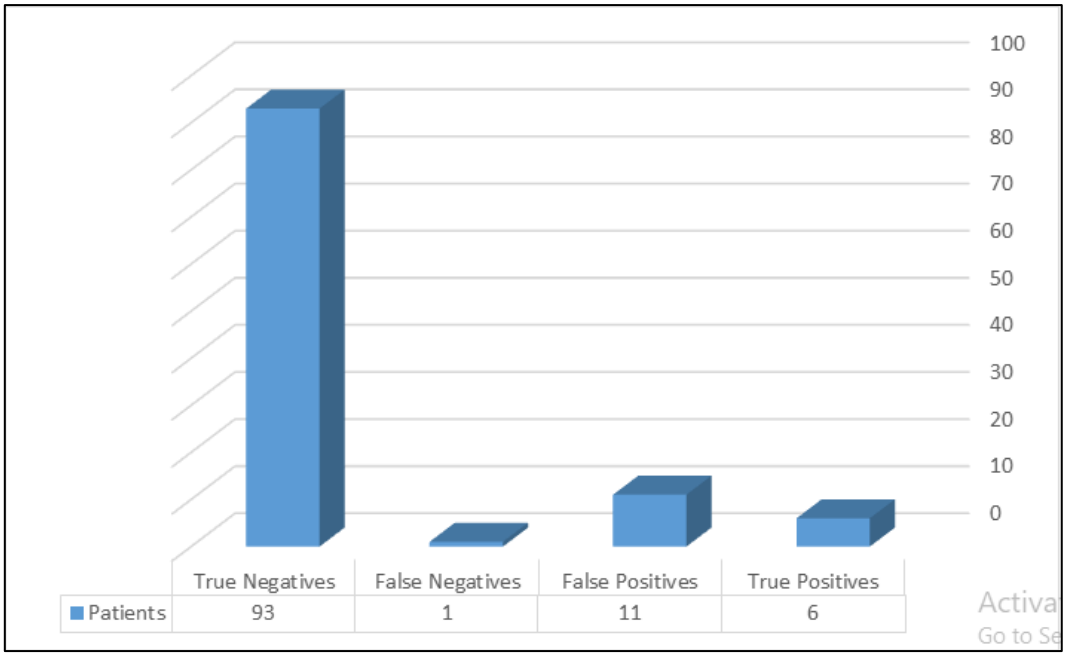

Figure 2. Assessment of delivery outcomes for patients who were diagnosed with severe statuses before 34 weeks of delivery.

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Table 6. Assessment of pregnancy outcomes for patients with adverse outcomes in terms of early preeclampsia and fetal growth restriction requiring delivery before 34 weeks.

Items	Rates
Sensitivity	85.7%
Specificity	89.4%
PPV	35.3%
NPV	98.9%

The mechanistic insights are given in Table 7 with significant negative relationships between UtA-PI MoM and gestational age at delivery (r -0.42) and birth weight centile (r = -0.51). The close positive relationship with the maximum systolic BP (r = 0.58) further associates abnormal placentation with the clinical seriousness of the hypertensive disease.

Table 7. Establishing a Pearson's r correlation among UtA-PI and clinical outcomes.

Parameters	Correlation Coefficient (r)	P-value
Gestational Age at Delivery	-0.42	<0.001
Birthweight Centile	-0.51	<0.001
Systolic BP at 20 weeks	0.38	<0.001
Maximum Systolic BP	0.58	<0.001

As the multivariate logistic regression (Table 8) confirms, another independent and significant predictor of any adverse outcome is an increased UtA-PI (aOR 8.5) and bilateral notching (aOR 4.1) after controlling for confounding factors such as nulliparity and BMI. The nulliparity was a significant risk factor (aOR 3.2), and maternal age over 35 years was not significant, which lends credence to the opinion that the placental factors measured by Doppler are more predictive than are the demographic factors.

Table 8. Analysis of multivariate logistic regression related to adverse outcomes of patients.

Variable	Adjusted Odds Ratio (aOR)	95% Confidence Interval	p-value
UtA-PI >95th percentile	8.5	2.8 – 25.9	<0.001
Bilateral Notching	4.1	1.3 – 12.6	0.015
Nulliparity	3.2	1.1 – 9.3	0.03
BMI >30 kg/m²	2.8	0.9 – 8.4	0.07
Maternal Age >35 years	1.5	0.5 – 4.7	0.48

DISCUSSION

The predictive logic of first-trimester UtA-PI had strong foundations in pathophysiology. A high UtA-PI (usually above the 95th percentile) was used to indicate that the uteroplacental circulation was of high resistance and had identified a population at high risk [Parry, A. H. *et al*., 2025]. In one study, the authors found that a study sample of more than 74,000 women reported that UtA-PI alone detected PE with a detection rate (DR) of about 47 percent at a 10 percent false-positive rate (FPR) when used in early-onset PE (<34 weeks) [Parry, A. H. *et al*., 2025]. The DR was approximately 36 in the case of preterm PE (<37 weeks). FGR performance, especially which of severe early-onset FGR, was also rather impressive, but not as strong as that of early PE, supporting the presence of a common but not identical etiological pathway [Myatt, L. 2022]. UTA-PI in isolation has, however, moderate sensitivity, which is not sufficiently high to be used as a standalone clinical tool in a low-risk population. It is unlocked in its real predictive power when it is incorporated in multivariable screening models. [Tian, Y., & Yang, X. 2022]

Moreover, UtA-PI also provided independent and critical hemodynamic data. The historic ASPRE trial had shown that with this combined regimen, on top of the 11 - 13 weeks, and then prophylaxis of high-risk women with aspirin, the rate of preterm PE was decreased by 62 percent. UtA-PI should not be viewed as an independent gatekeeper but rather a component of a complicated risk calculation model that improved the DR of preterm PE to over 75 percent at 10 percent FPR. [Razavi, M. *et al*., 2019]

Moreover, the test worked much better in severe and early-onset phenotypes of PE and FGR, which are associated with severe placental dysfunction [Li, N. *et al*.,, 2014]. In late-onset PE (>34 weeks) and a less severe FGR, the predictive accuracy of

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first-trimester UtA-PI is much lower. These conditions, which occur later on, might be other, more secondary or maternal cardiovascular pathways [Li, N. *et al*.,, 2014]. A low-risk outcome of first-trimester screening is not a zero risk to be exposed to after complications of the pregnancy in the future. In addition, the standardization of the Doppler method- angle of insonation, position of the sample gate, as well as left and right averaging is essential in ensuring reproducibility [Diguisto, C. *et al*., 2017]. Patient factors such as maternal obesity may complicate the process of acquisition and may also affect the dynamics of the flow on its own. [Karpagam, R. K. *et al*., 2024]

The addition of first-trimester UtA-PI to collectively screened populations is currently considered a best practice in most high-resource environments [GUPTA, U. *et al*., 2022]. It is primarily applied in ranking risks in order to make certain prophylaxis (low-dose aspirin) and enhanced monitoring [Nagpal, A. *et al*., 2020]. Environmental factors, such as timely second-tier tests, such as second-trimester Doppler follow-ups or timely serial growth scans, could be applied to decrease adverse outcomes by detecting high-risk women early. [Oancea, M. *et al*., 2020]

CONCLUSION

We have found a significant, statistically significant correlation between indicators of impaired placentation, namely, an increased UtA-PI (more than 95th percentile) and bilateral diastolic notching. These results are pathophysiologically consistent, with a greatly increased mean UtA-PI in all the affected groups (significantly higher in early-onset PE 1.98 MoM), and a high level of correlation exists between UtA-PI and major severity measures such as birthweight centile (r=-0.51) and maximum systolic BP (r=0.58). With a high specificity (93.9%) and high negative predictive value (NPV 97.9% with all PE), the first strength of the test is that it effectively eliminates future placental dysfunction and gives more reassurance to the majority of patients with a normal result. Nevertheless, the small positive predictive values (PPV 23.547.1% on individual results) indicate its ineffectiveness as a diagnostic instrument on its own, since the majority of women with an abnormal screen will not get the condition. The multivariate analysis continues to support that an increased UtA-PI (aOR 8.5) and bilateral notching (aOR 4.1) are strong and independent predictors of maternal factors.

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