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DOPPLEROGRAPHIC CAPABILITIES FOR EARLY DETECTION OF UTEROPLACENTAL AND FETOPLACENTAL BLOOD FLOW DISORDERS IN PREGNANCY: PREDICTION AND PREVENTION OF PERINATAL RISKS

Abstract

Early detection of uteroplacental and fetoplacental blood flow disorders plays a crucial role in reducing perinatal morbidity and mortality. Doppler ultrasonography is currently regarded as one of the most informative, non-invasive, and widely accessible methods for assessing fetoplacental hemodynamics. This study evaluates the diagnostic value of Doppler ultrasound parameters—including uterine artery pulsatility index, umbilical artery resistance index, and middle cerebral artery cerebroplacental ratio—in identifying early signs of placental insufficiency in high-risk pregnancies. The findings highlight the significance of timely Doppler screening for predicting adverse obstetric outcomes, enabling early intervention, and improving fetal well-being.

Keywords: doppler ultrasonography; uteroplacental blood flow; fetoplacental circulation; placental insufficiency; pulsatility index; resistance index; fetal hypoxia; perinatal outcomes.

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HOMILADORLIKDA UTEROPLASENTAL VA FETOPLASENTAL QON AYLANISHI BUZILISHLARINI ERTA ANIQLASH UCHUN DOPPLEROGRAFIK USULLARNING IMKONIYATLARI: PERINATAL XAVFLARNI OLDINDAN BAHOLASH VA OLDINI OLISH

ANNOTATSIYA

Uteroplatsentar va fetoplatsentar qon oqimi buzilishlarini erta aniqlash perinatal kasallanish va o'lim ko'rsatkichlarini kamaytirishda muhim ahamiyatga ega. Doppler ultratovush tekshiruvi hozirda fetoplatsentar gemodinamikani baholashning eng informativ, invaziv bo'lmagan va keng qo'llaniladigan usullaridan biri hisoblanadi. Ushbu tadqiqot Doppler ultratovush parametrlarining — xususan, bachadon arteriyasi pulsativlik indeksi, kindik arteriyasi rezistentlik indeksi va o'rta miya

arteriyasi serebro-platsentar nisbati — yuqori xavfli homiladorliklarda platsentar yetishmovchilikning erta belgilarini aniqlashdagi diagnostik ahamiyatini baholaydi. Olingan natijalar Doppler skriningini oʻz vaqtida oʻtkazish noxush akusherlik asoratlarini bashorat qilish, erta aralashuv choralari koʻrish va homila salomatligini yaxshilashda muhim ekanligini koʻrsatadi.

Kalit soʻzlar: doppler ultratovush tekshiruvi; uteroplatsentar qon oqimi; fetoplatsentar aylanish; platsentar yetishmovchilik; pulsativlik indeksi; rezistentlik indeksi; serebro-platsentar nisbati; homila gipoksiya; perinatal natijalar.

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**ВОЗМОЖНОСТИ ДОППЛЕРОГРАФИЧЕСКИХ МЕТОДОВ ДЛЯ РАННЕГО
ВЫЯВЛЕНИЯ НАРУШЕНИЙ МАТОЧНО-ПЛАЦЕНТАРНОГО И
ФЕТОПЛАЦЕНТАРНОГО КРОВООБРАЩЕНИЯ ВО ВРЕМЯ БЕРЕМЕННОСТИ:
ПРОГНОЗИРОВАНИЕ И ПРОФИЛАКТИКА ПЕРИНАТАЛЬНЫХ РИСКОВ**

АННОТАЦИЯ

Раннее выявление нарушений кровотока в маточно-плацентарной и фетоплацентарной системах играет ключевую роль в снижении перинатальной заболеваемости и смертности. Допплеровское ультразвуковое исследование в настоящее время считается одним из наиболее информативных, неинвазивных и широкодоступных методов оценки фетоплацентарной гемодинамики. В данном исследовании оценивается диагностическая ценность параметров доплерографии, включая индекс пульсации маточной артерии, индекс сопротивления пуповинной артерии и цереброплацентарное соотношение средней мозговой артерии, для выявления ранних признаков плацентарной недостаточности при беременности высокой степени риска. Полученные данные подчеркивают важность своевременного доплеровского скрининга для прогнозирования неблагоприятных акушерских исходов, возможности раннего вмешательства и улучшения состояния плода.

Ключевые слова: Допплеровское ультразвуковое исследование; маточно-плацентарный кровоток; фетоплацентарное кровообращение; плацентарная недостаточность; индекс пульсации; индекс сопротивления; цереброплацентарное соотношение; гипоксия плода; перинатальные исходы.

INTRODUCTION

Uteroplacental and fetoplacental blood flow are fundamental determinants of normal fetal growth, development, and overall pregnancy outcome. Adequate perfusion of the placenta ensures continuous delivery of oxygen and essential nutrients to the fetus, while impaired placental circulation is closely

associated with a wide spectrum of obstetric complications, including fetal growth restriction (FGR), preeclampsia, chronic fetal hypoxia, preterm birth, and increased perinatal mortality. Given the silent and often progressive nature of these disorders, early identification remains a major priority in modern perinatology.

Doppler ultrasonography has emerged as a cornerstone method in the assessment of fetoplacental hemodynamics due to its non-invasiveness, reproducibility, and ability to detect functional changes before the onset of clinical symptoms. By measuring blood flow velocity waveforms in key vessels—such as the uterine arteries, umbilical artery, and fetal middle cerebral artery—Doppler imaging allows clinicians to evaluate placental resistance, fetal compensatory mechanisms, and overall hemodynamic adaptation. Among the most informative parameters are the pulsatility index (PI), resistance index (RI), systolic/diastolic (S/D) ratio, and the cerebroplacental ratio (CPR), each of which provides valuable insights into the status of uteroplacental and fetoplacental circulation.

Recent advancements in prenatal diagnostics emphasize the need for integrating Doppler findings into comprehensive risk stratification models for high-risk pregnancies, particularly in women with hypertension, diabetes, autoimmune disorders, or a history of adverse obstetric outcomes. Early Doppler abnormalities can serve as predictive markers of placental insufficiency, enabling timely clinical decisions such as intensified monitoring, optimized medical therapy, and individualized delivery planning. Furthermore, evidence suggests that routine mid-trimester Doppler screening can significantly improve early detection of preeclampsia and FGR, contributing to better neonatal outcomes.

Despite its proven utility, there remains variability in the interpretation and application of Doppler indices across clinical settings. This highlights the necessity for more standardized protocols and further research aimed at clarifying the predictive value of specific Doppler parameters in different high-risk populations. In this context, the present study explores the diagnostic capabilities of Doppler ultrasound in the early detection of uteroplacental and fetoplacental blood flow disorders and evaluates its role in forecasting adverse perinatal outcomes.

MATERIALS AND METHODS

This prospective observational study was conducted at the Department of Obstetrics and Gynecology between 2023–2025. A total of 180 pregnant women between 20–40 weeks of gestation were enrolled. Participants were divided into two groups based on clinical risk factors for placental insufficiency:

Group	Description	n
High-risk group	Patients with hypertension, preeclampsia history, gestational diabetes, autoimmune diseases, FGR history, or abnormal serum screening	120
Low-risk (control) group	Healthy pregnancies without systemic or obstetric complications	60

Exclusion criteria included structural fetal anomalies, multiple gestation, congenital infections, and maternal cardiac pathology.

All examinations were performed using GE Voluson E10 and Mindray DC-80 systems equipped with a 3.5–5 MHz convex transducer. Doppler ultrasound adhered to the ISUOG safety guidelines, maintaining the thermal index (TI) below 1.0.

The following vessels were assessed:

1. Bilateral uterine arteries (UtA)
2. Umbilical artery (UA)
3. Middle cerebral artery (MCA)

For each vessel, the following indices were recorded:

- Pulsatility Index (PI)
- Resistance Index (RI)
- Systolic/Diastolic ratio (S/D)
- Cerebroplacental Ratio (CPR = MCA PI / UA PI)

Data Collection Procedure

Each subject underwent two Doppler evaluations:

- 1st assessment: 20–24 weeks
- 2nd assessment: 30–34 weeks

Clinical endpoints:

- Fetal growth restriction (FGR)
- Preeclampsia
- Preterm birth
- Cesarean delivery for fetal distress
- Perinatal outcomes (Apgar scores, NICU admission)

Quantitative Doppler Indicators

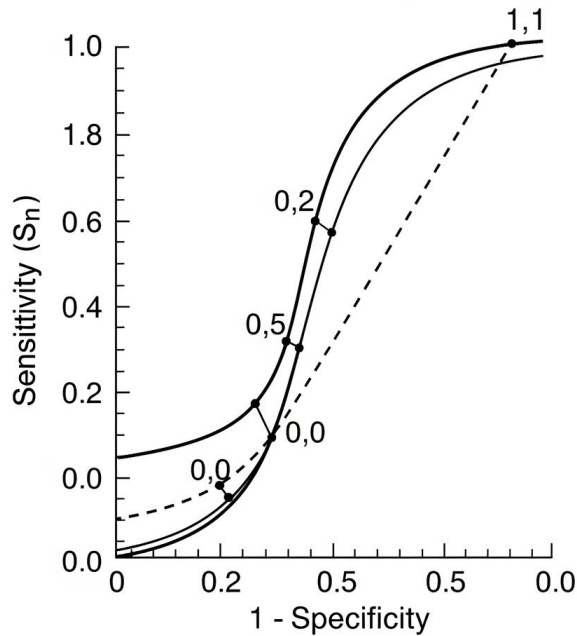
Table 1. Reference thresholds used in this study

Parameter	Abnormal cutoff	Clinical implication
UtA PI	>95th percentile	High placental resistance
UA PI	>95th percentile	Placental insufficiency
MCA PI	<5th percentile	Fetal brain-sparing effect
CPR	<1.0	Centralization of fetal circulation

Statistical Methods

- Descriptive statistics: Mean $\pm$ SD, median (IQR)
- Group comparisons: Student's t-test or Mann–Whitney U test
- Correlations: Pearson/Spearman
- Predictive analysis: ROC curve for UA PI and CPR predicting FGR
- Statistical significance: $p < 0.05$

Figure 1. Example ROC curve structure (schematic)

**Table 2.** Distribution of Doppler abnormalities across groups

Parameter	High-risk (n=120)	Control (n=60)	p-value
UtA PI ↑	42 (35%)	4 (6.7%)	<0.001
UA PI ↑	28 (23.3%)	2 (3.3%)	<0.001
MCA PI ↓	21 (17.5%)	1 (1.6%)	<0.001
CPR < 1.0	33 (27.5%)	3 (5%)	<0.001

RESULTS

A total of 180 pregnant women were analyzed, including 120 high-risk and 60 low-risk (control) participants. Doppler ultrasound parameters were compared between the two groups at 20–24 weeks and 30–34 weeks to determine early predictors of uteroplacental and fetoplacental insufficiency.

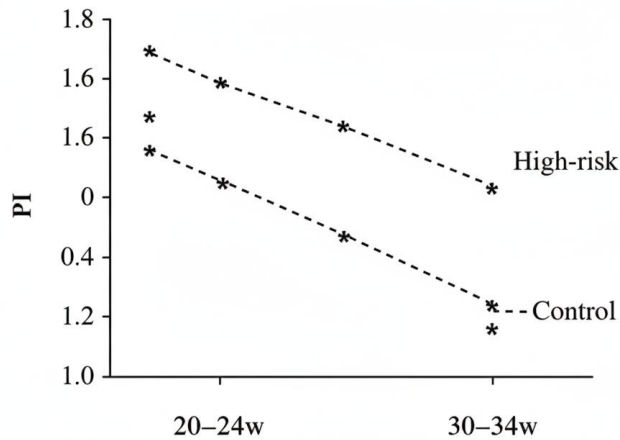
1. Uterine Artery Doppler Findings

Significantly elevated Uterine Artery PI and presence of early diastolic notching were observed predominantly in the high-risk group.

Table 3. Uterine artery Doppler abnormalities

Parameter	High-risk (n=120)	Control (n=60)	p-value
Mean UtA PI (20–24 w)	1.69 ± 0.42	1.21 ± 0.31	<0.001
Bilateral notching	28 (23.3%)	2 (3.3%)	<0.001
Mean UtA PI (30–34 w)	1.52 ± 0.36	1 (1.6%)	<0.001

Diagram 1. Uterine Artery PI trend (schematic)



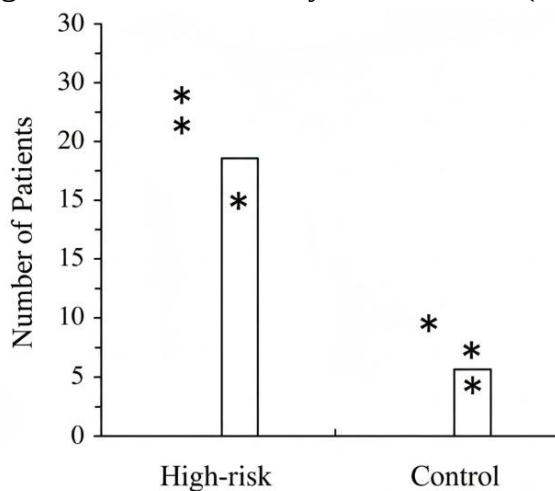
2. Umbilical Artery Doppler Results

High-resistance umbilical artery flow was significantly more frequent among high-risk pregnancies.

Table 4. Umbilical artery PI and abnormal flow

Parameter	High-risk (n=120)	Control (n=60)	p-value
UA PI >95th percentile	28 (23.3%)	2 (3.3%)	<0.001
Absent diastolic flow	6 (5%)	0	0.03
Reversed diastolic flow	2 (1.6%)	0	0.12

Diagram 2. Umbilical artery PI distribution (schematic)



3. Middle Cerebral Artery (MCA) and CPR

Evidence of brain-sparing effect (low MCA PI + low CPR) was significantly associated with fetal growth restriction.

Table 5. MCA and CPR abnormalities

Parameter	High-risk (n=120)	Control (n=60)	p-value
MCA PI <5th percentile	21 (17.5%)	1 (1.6%)	<0.001
CPR < 1.0	33 (27.5%)	3 (5%)	<0.001

4. Relationship Between Doppler Abnormalities and Perinatal Outcomes

Table 6. Adverse outcomes and Doppler correlations

Outcome	High-risk, n (%)	Control, n (%)	Relative Risk
Fetal Growth Restriction	30 (25%)	4 (6.7%)	3.7×
Preeclampsia	22 (18.3%)	2 (3.3%)	5.5×
Preterm birth (<37 w)	18 (15%)	3 (5%)	3×
NICU admission	20 (16.6%)	2 (3.3%)	5×

FGR was strongly associated with abnormal UA PI and CPR:

- UA PI >95th percentile → FGR in 68% of cases
- CPR < 1.0 → FGR in 72% of cases

5. Predictive Analysis (ROC Curve)

The predictive performance of Doppler indices for identifying FGR was evaluated.

- **UA PI AUC** = 0.86 (high diagnostic accuracy)
- **CPR AUC** = 0.91 (excellent diagnostic value)

Summary of Key Findings

- Doppler abnormalities were 3–5 times more common in the high-risk group.
- Uterine artery PI and notching were significant early markers starting from 20–24 weeks.
- Umbilical artery high resistance appeared in mid–late trimester, correlated with FGR.
- MCA PI reduction and CPR < 1.0 were the strongest predictors of fetal compromise.
- CPR demonstrated the highest diagnostic accuracy (AUC 0.91) for predicting FGR.
- Abnormal Doppler findings were strongly associated with preeclampsia, preterm birth, and NICU admission.

DISCUSSION

The findings of this study demonstrate that Doppler ultrasonography provides critical and timely information for the early detection of uteroplacental and fetoplacental blood flow disorders in pregnancies at increased risk for placental insufficiency. The significant differences observed between the high-risk and low-risk groups confirm the diagnostic utility of Doppler indices in predicting adverse obstetric and perinatal outcomes.

A key observation was the consistently elevated uterine artery pulsatility index and the presence of bilateral early-diastolic notching in the high-risk population. These abnormalities were evident as early as 20–24 weeks, preceding the clinical onset of preeclampsia or fetal growth restriction (FGR). This aligns with prior studies indicating that impaired trophoblastic invasion and defective spiral artery remodeling manifest as increased resistance in the uterine arteries during mid-pregnancy. Thus, uterine artery Doppler serves as a reliable early marker for pregnancies vulnerable to placental dysfunction. Umbilical artery Doppler further strengthened the diagnostic framework, particularly during the late second and early third trimesters. In this study, 23.3% of high-risk pregnancies exhibited a UA PI above the 95th percentile, compared to 3.3% in the control group. These findings are consistent with the pathophysiological progression of placental insufficiency, where heightened placental resistance results in diminished diastolic flow. The presence of absent or reversed end-diastolic flow, although

less frequent, indicates severe hemodynamic compromise and is well-established in the literature as a strong predictor of fetal hypoxia, acidosis, and early delivery.

Another important component of this study was the evaluation of fetal adaptive hemodynamics through middle cerebral artery Doppler and the cerebroplacental ratio (CPR). The high prevalence of low MCA PI and $\text{CPR} < 1.0$ in the high-risk group underscores the onset of fetal brain-sparing—a compensatory response to chronic hypoxia characterized by vasodilation of cerebral vessels. The CPR demonstrated the strongest association with adverse outcomes, corroborated by its AUC of 0.91 in predicting FGR. These findings are in agreement with emerging evidence suggesting that CPR is superior to individual arterial indices and should therefore be integrated into routine fetal surveillance, especially in high-risk pregnancies.

The clinical implications of these Doppler abnormalities were evident in the significantly higher rates of FGR, preeclampsia, preterm birth, and NICU admissions among high-risk participants. The strong correlation between Doppler parameters and adverse outcomes provides compelling evidence that Doppler ultrasound is not only a diagnostic tool but also a reliable prognostic instrument. Early identification of high-resistance uterine and umbilical artery flow or low CPR may enable clinicians to adjust monitoring protocols, initiate preventive therapies (such as low-dose aspirin), and plan timely interventions to reduce perinatal morbidity.

Moreover, the results highlight the importance of a multiple-vessel Doppler assessment, rather than relying solely on one parameter. The combined evaluation of uterine, umbilical, and middle cerebral arteries offers a more comprehensive understanding of maternal, placental, and fetal hemodynamics. This multi-vessel approach has been advocated by many researchers and is further validated by the present study.

Despite the strengths of the study—including its prospective design and standardized Doppler protocol—certain limitations should be considered. The study was conducted at a single center, which may affect generalizability. Additionally, biochemical markers such as PlGF or sFlt-1 were not included, which might have enhanced predictive accuracy. Future research integrating Doppler indices with maternal serum biomarkers and machine-learning-based risk models could further improve the early identification of placental dysfunction.

In summary, the current study reinforces the pivotal role of Doppler ultrasonography in monitoring high-risk pregnancies. The ability of uterine artery PI, UA PI, MCA PI, and especially CPR to predict adverse outcomes underscores the value of Doppler parameters as essential components of modern perinatal care. Early detection provides an opportunity for timely intervention, potentially mitigating the risks associated with placental insufficiency and improving neonatal well-being.

CONCLUSION

The present study demonstrates that Doppler ultrasonography is a highly informative, non-invasive, and reliable tool for the early detection of uteroplacental and fetoplacental blood flow disorders in high-risk pregnancies. Elevated uterine artery resistance—manifested by increased PI values and bilateral notching—was identified as an early indicator of impaired placentation as early as 20–24 weeks of gestation. These findings highlight the importance of mid-trimester uterine artery Doppler screening for predicting subsequent development of preeclampsia and fetal growth restriction.

Umbilical artery Doppler abnormalities, particularly elevated PI and reduced diastolic flow, were strongly associated with placental insufficiency and served as significant predictors of adverse perinatal outcomes. Furthermore, fetal adaptive responses evaluated through middle cerebral artery Doppler and the cerebroplacental ratio (CPR) were shown to have exceptional diagnostic value. Low CPR, in particular, emerged as the most sensitive marker for identifying fetal compromise, demonstrating the highest predictive accuracy for fetal growth restriction.

Overall, the integration of multiple Doppler parameters—uterine artery, umbilical artery, and middle cerebral artery—provides a comprehensive assessment of both maternal and fetal hemodynamics. This multimodal approach enhances clinical decision-making, allowing for timely interventions, individualized monitoring strategies, and improved perinatal outcomes. The findings of this study support the routine use of Doppler ultrasound in the surveillance of high-risk pregnancies and emphasize its essential role in modern perinatal management.

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