International Journal of Women's Health

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Application of Serum sFlt-1/PlGF Ratio Combined with Uterine Artery Blood Flow Ultrasound in Predicting Early-Onset Preeclampsia

Han Zhang[1], Cui Xu[2]

[1]Gynecology Department, the Second Affiliated Hospital of Shandong First Medical University, Tai 'an, Shandong, 271000, People's Republic of China; [2]Obstetrics Department, the Second Affiliated Hospital of Shandong First Medical University, Tai 'an, Shandong, 271000, People's Republic of China

Correspondence: Cui Xu, Email sdta2025@163.com

Objective: This study aimed to evaluate the predictive efficacy of combining serum soluble fms-like tyrosine kinase-1/placental growth factor (sFlt-1/PlGF) ratio with uterine artery Doppler ultrasound for early-onset preeclampsia (PE) before 34 weeks' gestation.
Methods: A retrospective cohort analysis was conducted on 148 singleton pregnancies (control group: n = 76; early-onset PE group: n = 72) who delivered at our institution between July 2023 and June 2024. At 24–28 weeks, serum sFlt-1 and PlGF levels were quantified via electrochemiluminescence immunoassay (Roche Elecsys®), and uterine artery pulsatility index (PI), resistance index (RI), and systolic/diastolic ratio (S/D) were measured by Doppler ultrasound (M22 system, standardized settings). Logistic regression and receiver operating characteristic (ROC) curves assessed predictive performance.
Results: Compared to controls, PE patients exhibited significantly elevated sFlt-1 (24.02 ± 6.68 vs 16.38 ± 7.47 μg/L; $P < 0.001$), reduced PlGF (1.22 ± 0.14 vs 1.54 ± 0.30 μg/L; $P < 0.001$), and higher sFlt-1/PlGF ratio (20.76 ± 7.71 vs 10.11 ± 4.10; $P < 0.001$). Doppler indices were markedly increased in PE: PI (1.34 ± 0.26 vs 0.82 ± 0.11; $P < 0.001$), RI (0.78 ± 0.12 vs 0.51 ± 0.07; $P < 0.001$), and S/D (3.89 ± 0.97 vs 2.11 ± 0.41; $P < 0.001$). Multivariate analysis confirmed all parameters as independent predictors ($P < 0.05$), with sFlt-1/PlGF ratio having the highest odds ratio (OR = 1.332, 95% CI: 1.128–1.573). The combined model achieved superior predictive performance: area under curve (AUC)=0.954 (95% CI: 0.92–0.99) vs sFlt-1/PlGF alone (AUC = 0.887; $P = 0.003$) or PI alone (AUC = 0.821; $P < 0.001$), with sensitivity 82.2%, specificity 96.7%, and accuracy 94.7%.
Conclusion: Integration of sFlt-1/PlGF ratio and uterine artery Doppler parameters (particularly uterine artery PI and RI) significantly enhances early-onset PE prediction, providing a robust tool for clinical risk stratification.

Keywords: Serum sFlt-1/PlGF ratio, uterine artery blood flow ultrasound, early-onset preeclampsia, prediction

Introduction

Preeclampsia (PE), a multisystem disorder unique to pregnancy, poses a grave global threat to maternal and fetal health. In China, its incidence reaches approximately 9%,[1] with early-onset PE (diagnosed before 34 gestational weeks) representing a critical subset characterized by rapid progression, severe complications, and significant perinatal mortality.[2] The core pathophysiology involves defective trophoblast invasion and impaired spiral artery remodeling, triggering placental ischemia and systemic endothelial dysfunction through anti-angiogenic and pro-inflammatory cascades.[3]

Despite decades of research, early prediction remains challenging due to the multifactorial etiology. Current single-modality approaches exhibit limited sensitivity, underscoring the need for integrated biomarker and hemodynamic assessment.[4] Notably, the soluble fms-like tyrosine kinase-1/placental growth factor (sFlt-1/PlGF) ratio has emerged as a pivotal angiogenic biomarker. sFlt-1 antagonizes PlGF and VEGF, inducing vascular endothelial damage—a hallmark of PE. Prospective studies confirm its utility in predicting early-onset PE 5–8 weeks before clinical manifestation.[5–7] Concurrently, first-trimester uterine artery Doppler ultrasonography provides direct insight into placental perfusion, where elevated pulsatility index (PI), resistance index (RI), or systolic/diastolic (S/D) ratios signify impaired uteroplacental flow, strongly correlating with early-onset PE.[8,9]

Received: 30 May 2025
Accepted: 30 July 2025
Published: 15 August 2025

While both modalities individually demonstrate prognostic value, previous attempts to combine them have yielded inconsistent outcomes. Key limitations include heterogeneous study populations, varying diagnostic thresholds, and lack of standardized timing for biomarker sampling and Doppler assessment.[10,11] Moreover, existing models often fail to address the dynamic interplay between angiogenic imbalance and hemodynamic changes during the first-trimester "window of opportunity" for early intervention.[12] This knowledge gap impedes clinical consensus on optimal combined screening protocols.

To bridge this deficit, our study rigorously evaluates the synergistic efficacy of sFlt-1/PlGF ratio and first-trimester uterine artery Doppler. We hypothesize that their integration will outperform standalone markers, providing a robust tool for timely risk stratification and guiding targeted prevention strategies in high-risk cohorts.

Materials and Methods

Study Population and Grouping

We retrospectively enrolled 148 pregnant women who received prenatal care and delivered at our institution between July 2023 and June 2024. Participants aged 21–35 years (mean 28.58 ± 3.27) were stratified into two groups per the Diagnosis and Treatment Guidelines for Hypertensive Disorders in Pregnancy (2020): Control group: Normotensive pregnancies (n = 76); Early-onset PE group: Preeclampsia diagnosed before 34 weeks (n = 72). This study was approved by the Ethics Committee of the Second Affiliated Hospital of Shandong First Medical University (Approval No. 2022–032-HK). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion Criteria

① Singleton pregnancy
② Complete clinical/follow-up data.

Exclusion Criteria

① Systemic pathologies (eg, diabetes, chronic hypertension);
② Malignancy;
③ Major fetal anomalies;
④ Medications affecting study parameters.

Research Methods

Biomarker Assessment: At enrollment, demographic and obstetric variables were retrospectively recorded. Venous blood samples (5 mL) were collected from all participants between 24+0 and 27+6 weeks' gestation. After centrifugation at 3,000 rpm for 10 minutes, the serum was separated and aliquoted into two cryovials for storage. Concentrations of soluble fms-like tyrosine kinase-1 (sFlt-1) and placental growth factor (PlGF) were measured using electrochemiluminescence immunoassays (ECLIA) with commercial kits (Elecsys® sFlt-1 and PlGF assays; Cat. No. 05168541 190 and 05168743 190, Roche Diagnostics) on a Cobas e 601 analyzer. The sFlt-1/PlGF ratio was automatically calculated by the instrument's software.

Doppler Ultrasound: Between 24 and 28 weeks of gestation, uterine artery blood flow was assessed using a color Doppler ultrasound system (M22; Wuhan Dongfang Yijing Medical Equipment Co., Ltd.) equipped with a 3–5 MHz convex probe. The following standardized settings were applied: pulse repetition frequency of 1.5–2.5 kHz, wall filter between 50 and 100 Hz, Doppler insonation angle ≤30°, and a sample gate size of 2 mm. Uterine artery pulsatility index (PI), resistance index (RI), and systolic/diastolic velocity ratio (S/D) were measured bilaterally. Three consecutive waveforms were acquired on each side, and the average values for PI, RI, and S/D were recorded for analysis.

Statistical Analysis

Data were analyzed using SPSS 20.0 (IBM Corp). Continuous variables (mean ± SD) were compared via independent t-tests; categorical data (%) via χ^2-tests. Logistic regression identified PE predictors. ROC curves evaluated the predictive

value of sFlt-1/PlGF, Doppler indices (PI/RI/S/D), and their combination. $P < 0.05$ indicated statistical significance. Although the cohort size (n = 148) may appear limited, a post-hoc power analysis confirmed >90% power (α=0.05) to detect AUC differences ≥0.15 – a clinically meaningful threshold for predictive models.

Results

Baseline Characteristics

As shown in Table 1, no significant differences existed in maternal age, pre-pregnancy BML, weight gain, or parity distribution between groups ($P > 0.05$). Gestational age at delivery was significantly lower in the PE group (34.23 +3.04 vs.38.71 +0.81 weeks; $t = 11.65$, $P < 0.001$), consistent with early-onset disease.

Angiogenic Biomarkers and Doppler Parameters

PlGF levels were significantly lower in the PE group (1.22 ± 0.14 vs 1.54 ± 0.30 μg/L; $t = 9.011$, $P < 0.001$). sFlt-1 levels (24.02 + 6.68 vs.16.38 ± 7.47 ug/L; $t = 7.654$, $P < 0.001$) and sFlt-1/PIGFratio (20.76 + 7.71 vs.10.11 ± 4.10; $t = 12.854$, $P < 0.001$) were markedly elevated (Table 2).

Uterine artery Doppler indices (PI, RI, S/D) were significantly increased in the PE group ($P < 0.001$ for all; Table 3). Figure 1 illustrates representative waveforms, showing elevated resistance and diastolic notching in PE cases.

Multivariate Predictors of Early-Onset PE

Logistic regression identified all six parameters as independent predictors ($P < 0.05$; Table 4). The sFlt-1/PlGF ratio demonstrated the highest effect size (OR = 1.332, 95% CI: 1.128–1.573), followed by RI (OR = 1.221, 95% CI: 1.087–1.372).

Table 1 Baseline Characteristics of the Study Cohort

Characteristic	Control (n=76)	PE Group (n=72)	t/χ^2	P
Age (years)	28.14 ± 3.46	29.21 ± 4.02	1.66	0.086
Gestational age at delivery (weeks)	38.71 ± 0.81	34.23 ± 3.04	11.65	<0.001
Pre-pregnancy BMI (kg/m²)	27.46 ± 3.82	28.51 ± 4.16	1.42	0.117
Weight gain (kg)	15.2 ± 4.1	13.8 ± 5.3	1.87	0.063
Nulliparous, n (%)	52 (68.4%)	48 (66.7%)	0.06	0.804

Note: Total weight gain from pre-pregnancy to 28 weeks.

Table 2 Serum Angiogenic Marker Profiles

Group	n	sFlt-1 (μg/L)	PlGF (μg/L)	sFlt-1/PlGF
Control group	76	16.38±7.47	1.54±0.30	10.11±4.10
PE Group	72	24.02±6.68	1.22±0.14	20.76±7.71
t		7.654	9.011	12.854
P		<0.001	<0.001	<0.001

Table 3 Uterine Artery Doppler Parameters

Parameter	n	PI	RI	S/D
Control Group	76	0.82 ± 0.11	0.51 ± 0.07	2.11 ± 0.41
PE Group	72	1.34 ± 0.26	0.78 ± 0.12	3.89 ± 0.97
t		14.22	16.35	14.87
P		<0.001	<0.001	<0.001

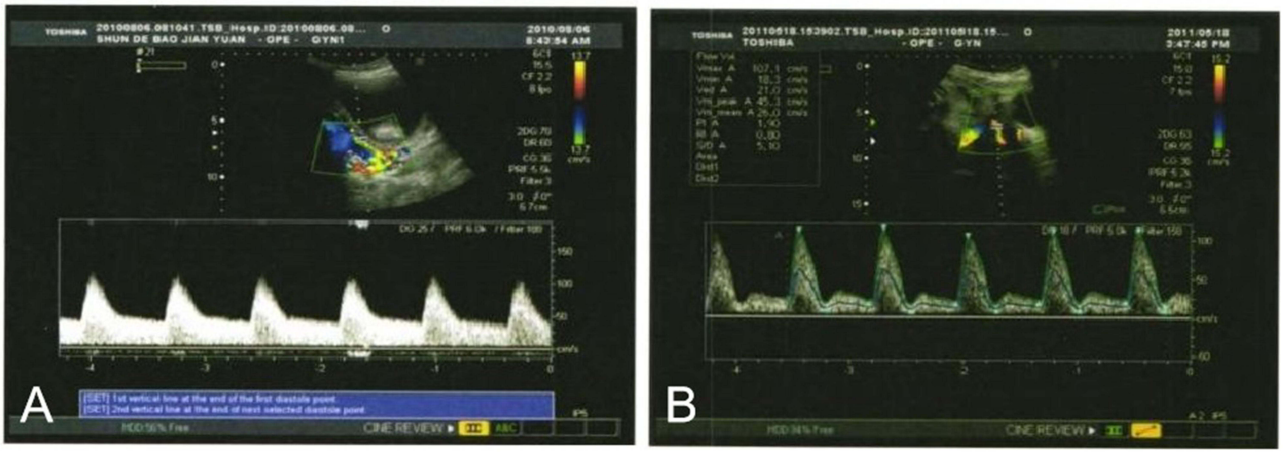

Figure 1 Uterine Artery Doppler at 27+6 Weeks (**A**) Control: Low-resistance flow (normal) (**B**) PE: Elevated resistance with diastolic notch.

Predictive Performance of sFlt-1/PlGF Ratio, Uterine Artery Pulsatility Index (PI), and the Combined Model for Early-Onset Preeclampsia

As shown in Table 5, the predictive performance of the combined model incorporating both the sFlt-1/PlGF ratio and uterine artery PI was superior to either parameter alone. The area under the curve (AUC) for the combined model reached 0.954 (95% CI: 0.92–0.99), with a sensitivity of 82.2% and specificity of 96.7%. This model also achieved a positive predictive value (PPV) of 91.9%, negative predictive value (NPV) of 91.7%, and overall accuracy of 94.7%. In comparison, the sFlt-1/PlGF ratio alone yielded an AUC of 0.887 (95% CI: 0.83–0.94), while uterine artery PI alone had a lower AUC of 0.821 (95% CI: 0.75–0.89). These findings suggest that combining biochemical and hemodynamic markers significantly enhances diagnostic performance for early-onset preeclampsia.

Discussion

This retrospective cohort study systematically evaluated the clinical value of combining serum sFlt-1/PlGF ratio with uterine artery Doppler parameters in predicting early-onset preeclampsia (EOP). The results demonstrated that the PE

Table 4 Multivariate Analysis of PE Predictors

Project	β	S.E.	Waldχ^2	P	OR	95% CI
sFlt-1/PLGF	0.287	0.085	11.373	<0.001	1.332	1.128–1.573
PLGF	−0.165	0.063	6.806	0.009	0.848	0.749–0.960
sFlt-1	0.003	0.001	9.764	0.002	1.003	1.001–1.005
PI	0.15	0.05	9.001	0.003	1.162	1.052–1.283
RI	0.2	0.06	11.111	0.001	1.221	1.087–1.372
S/D	0.18	0.07	6.612	0.01	1.197	1.043–1.375

Abbreviations: PE, preeclampsia; sFlt-l, soluble vascular endothelial growth factor receptor-1; PLGF, placental growth antagonist; PT, pulsatile index; RI, resistance index; S/D, contraction/diastolic flow rate ratio.

Table 5 Predictive Performance of sFlt-1/PlGF Ratio, Uterine Artery Pulsatility Index (PI), and the Combined Model for Early-Onset Preeclampsia

Model	AUC (95% CI)	Sensitivity	Specificity	PPV	NPV	Accuracy
sFlt-1/PlGF	0.887 (0.83–0.94)	0.806	0.855	0.831	0.833	0.831
PI	0.821 (0.75–0.89)	0.764	0.803	0.786	0.782	0.784
Combined	0.954 (0.92–0.99)	0.822	0.967	0.919	0.917	0.947

Group had significantly elevated sFlt-1 levels and decreased PlGF levels, with the sFlt-1/PlGF ratio nearly doubling compared to the control group (20.76 vs 10.11). Moreover, uterine artery Doppler indices (PI, RI, and S/D) exhibited high-resistance flow characteristics. Further multivariate analysis revealed that the sFlt-1/PlGF ratio was the strongest independent predictor of EOP (OR = 1.332), and the combined model (sFlt-1/PlGF + PI) yielded an AUC of 0.954 (95% CI: 0.92–0.99), significantly outperforming individual predictors (sFlt-1/PlGF AUC = 0.887; PI AUC = 0.821).[13] These findings confirm the synergistic predictive power of molecular biomarkers and hemodynamic parameters in EOP and provide a more accurate tool for clinical risk stratification.

The sFlt-1/PlGF ratio, a core indicator of angiogenic imbalance, plays a pivotal role in the pathophysiology of EOP. sFlt-1, a soluble isoform of vascular endothelial growth factor receptor 1 (VEGFR-1), competitively inhibits VEGF and PlGF, leading to endothelial dysfunction and placental ischemia-hypoxia. In this study, the PE Group showed significantly elevated sFlt-1 levels (24.02 vs 16.38 μg/L) and decreased PlGF levels (1.22 vs 1.54 μg/L), indicating an imbalance between anti-angiogenic and pro-angiogenic factors.[14] This imbalance resulted in a markedly increased sFlt-1/PlGF ratio (20.76 vs 10.11), potentially contributing to EOP through the following mechanisms: First, elevated sFlt-1 inhibits PlGF-mediated trophoblast invasion and spiral artery remodeling, reducing placental perfusion and triggering local hypoxia and oxidative stress; second, hypoxia activates the nuclear factor-κB (NF-κB) pathway, inducing pro-inflammatory cytokines (eg, TNF-α, IL-6), which exacerbate systemic endothelial damage and hypertension; third, the sFlt-1/PlGF imbalance directly injures endothelial cells and promotes vasoconstrictors (eg, endothelin-1), increasing peripheral vascular resistance.[15,16] This mechanistic cascade complements findings from previous studies showing that a sFlt-1/PlGF ratio >38 predicts a 36.7% risk of developing EOP within four weeks,[17] highlighting the ratio's dynamic association with disease progression.

Simultaneously, the elevated uterine artery Doppler parameters (PI = 1.34 vs 0.82; RI = 0.78 vs 0.51; S/D = 3.89 vs 2.11) reflect the hemodynamic hallmark of inadequate placental perfusion. In normal pregnancy, uterine arteries undergo low-resistance remodeling (PI < 0.8). The high PI in the PE Group suggests inadequate trophoblast-mediated spiral artery remodeling, leading to narrowed lumens and restricted blood flow.[18] This high-resistance state causes intermittent placental hypoxia, oxidative stress, and subsequent endothelial injury, perpetuating a vicious cycle via inflammatory mediators such as sFlt-1. Moreover, increased uterine artery resistance may activate systemic vasoconstriction pathways, further aggravating hypertension.[19] These findings align with prior studies identifying abnormal uterine artery flow as an early warning sign of EOP.[20] Notably, the sFlt-1/PlGF ratio and uterine artery PI are complementary: the former captures angiogenic imbalance at the molecular level, while the latter reflects macrovascular hemodynamic alterations. Their combined use spans the entire pathological spectrum from molecular disturbance to blood flow compromise.

On this basis, the combined model (sFlt-1/PlGF + PI) demonstrated substantial clinical advantages. The model's AUC (0.954) significantly exceeded that of individual indicators (P < 0.001), achieving sensitivity of 82.2%, specificity of 96.7%, and overall accuracy of 94.7%—meeting the criteria for clinical utility.[13] These results resonate with prior findings that multiparametric models (eg, MAP, PlGF, UTPI, and maternal risk factors) enhance predictive accuracy for EOP.[17] However, the strength of our model lies in its simplicity and potential for dynamic monitoring. It requires only one serum test and one ultrasound scan, making it particularly suitable for resource-limited primary care settings. In addition, longitudinal changes in the sFlt-1/PlGF ratio can reflect ongoing placental function, while the PI remains stable between 24 and 28 weeks of gestation, making it ideal for early prediction. Compared to individual markers, the sFlt-1/PlGF ratio may be influenced by hormonal fluctuations, and PI alone lacks sensitivity for mild cases. By integrating molecular biomarkers with hemodynamic assessments, the combined model overcomes these limitations, offering a scientific basis for EOP stratified management. This integrative approach confirms the synergistic value of biomarkers and Doppler indices and holds promise as a standardized screening strategy for early detection of EOP.[21]

Limitations and Future Directions

Despite the promising findings, this study has some limitations. First, the number of EOP cases (n = 72) was relatively small, which may limit the generalizability of the combined model (sFlt-1/PlGF + PI) across diverse populations. Future validation with larger cohorts is necessary to confirm its stability.[13] Second, participants were exclusively Chinese Han women, and the applicability of the findings to other ethnicities and regions remains uncertain. Multiethnic or international multicenter studies are needed to assess the model's broader applicability. Third, only a single time-point

measurement was performed at 24–28 weeks of gestation. The lack of longitudinal data on sFlt-1/PlGF and uterine artery PI may overlook key pathophysiological transitions. Future studies should incorporate serial measurements to capture the time-dependent dynamics of these biomarkers.[14,16]

To address these limitations, future research should focus on the following areas: (1) Conduct large-scale, multicenter prospective studies involving diverse ethnic and geographic populations to validate the clinical value and universality of the combined model. (2) Utilize cutting-edge technologies such as single-cell sequencing and metabolomics to explore the molecular links between sFlt-1/PlGF imbalance and uterine artery flow abnormalities, thus elucidating the mechanistic basis of placental dysfunction. (3) Based on high-risk stratification using the combined model, design individualized intervention strategies (eg, low-dose aspirin, calcium supplementation) and conduct randomized controlled trials to evaluate their effectiveness in preventing EOP onset. These directions will not only refine our understanding of EOP pathogenesis but also advance obstetric risk management in the era of precision medicine.[15,18,19]

Conclusion

By integrating the serum sFlt-1/PlGF ratio with uterine artery Doppler parameters, this study developed a highly accurate predictive model for early-onset preeclampsia. The results reveal a synergistic role of angiogenic imbalance and hemodynamic changes in EOP pathogenesis and provide a scientific basis for clinical stratified management. This combined strategy has the potential to become a standardized tool for early EOP screening and ultimately improve maternal and fetal outcomes.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Ives CW, Sinkey R, Rajapreyar I, Tita ATN, Oparil S. Preeclampsia-pathophysiology and clinical presentations: JACC state-of-the-art review. *J Am Coll Cardiol*. 2020;76(14):1690–1702. PMID: 33004135. doi:10.1016/j.jacc.2020.08.014
2. Roberts JM. Preeclampsia epidemiology(ies) and pathophysiology(ies). *Best Pract Res Clin Obstet Gynaecol*. 2024;94:102480. PMID: 38490067. doi:10.1016/j.bpobgyn.2024.102480
3. Filipek A, Jurewicz E. Preeklampsja – choroba kobiet w ciąży Preeclampsia - a disease of pregnant women. *Postepy Biochem*. 2018;64(4). PMID: 30656917. doi:10.18388/pb.2018_146
4. Melchiorre K, Giorgione V, Thilaganathan B. The placenta and preeclampsia: villain or victim? *Am J Obstet Gynecol*. 2022;226(2S):S954–S962. PMID: 33771361. doi:10.1016/j.ajog.2020.10.024
5. Roberts JM, Rich-Edwards JW, McElrath TF, Garmire L, Myatt L. Global pregnancy collaboration. subtypes of preeclampsia: recognition and determining clinical usefulness. *Hypertension*. 2021;77(5):1430–1441. PMID: 33775113; PMCID: PMC8103569. doi:10.1161/HYPERTENSIONAHA.120.14781
6. Verlohren S, Brennecke SP, Galindo A, et al. Clinical interpretation and implementation of the sFlt-1/PlGF ratio in the prediction, diagnosis and management of preeclampsia. *Pregnancy Hypertens*. 2022;27:42–50. PMID: 34915395. doi:10.1016/j.preghy.2021.12.003
7. Zeisler H, Llurba E, Chantraine F, et al. Predictive Value of the sFlt-1:PlGF ratio in women with suspected preeclampsia. *N Engl J Med*. 2016;374(1):13–22. PMID: 26735990. doi:10.1056/NEJMoa1414838
8. de Ganzo Suárez T, de Paco Matallana C, Plasencia W. Spiral, uterine artery Doppler and placental ultrasound in relation to preeclampsia. *Best Pract Res Clin Obstet Gynaecol*. 2024;92:102426. PMID: 38039843. doi:10.1016/j.bpobgyn.2023.102426
9. Tan MY, Syngelaki A, Poon LC, et al. Screening for pre-eclampsia by maternal factors and biomarkers at 11-13 weeks' gestation. *Ultrasound Obstet Gynecol*. 2018;52(2):186–195. PMID: 29896812. doi:10.1002/uog.19112
10. Tarasevičienė V, Grybauskienė R, sFltl MR. PlGF, sFlt-1/PlGF ratio and uterine artery Doppler for preeclampsia diagnostics. *Medicina*. 2016;52(6):349–353. PMID: 27940029. doi:10.1016/j.medici.2016.11.008
11. Ramos JGL, Sass N, Costa SHM. Preeclampsia. *Rev Bras Ginecol Obstet*. 2017;39(9):496–512. PMID: 28793357; PMCID: PMC10309474. doi:10.1055/s-0037-1604471
12. Alese MO, Moodley J, Naicker T. Preeclampsia and HELLP syndrome, the role of the liver. *J Matern Fetal Neonatal Med*. 2021;34(1):117–123. PMID: 30704316. doi:10.1080/14767058.2019.1572737
13. Shinohara S, Hiraoka N, Mochizuki K, Yasuda G, Kasai M, Sunami R. sFlt-1/PlGF ratio predicts serious outcomes in confirmed early-onset preeclampsia. *Eur J Obstet Gynecol Reprod Biol*. 2024;300:159–163. PMID: 39003888. doi:10.1016/j.ejogrb.2024.07.023
14. Yusuf AM, Kahane A, Ray JG. First and second trimester serum sflt-1/plgf ratio and subsequent preeclampsia: a systematic review. *J Obstet Gynaecol Can*. 2018;40(5):618–626. PMID: 28927814. doi:10.1016/j.jogc.2017.07.014
15. Pluta K, Januszewski M, Ziuzia-Januszewska L, et al. sFlT-1/PlGF ratio as a predictor of preeclampsia in COVID-19 pregnant patients. *BMC Pregnancy Childbirth*. 2024;24(1):94. PMID: 38297191; PMCID: PMC10829318. doi:10.1186/s12884-024-06263-y
16. Zhang L, Li W, Chi X, et al. Predictive performance of sFlt-1, PlGF and the sFlt-1/PlGF ratio for preeclampsia: a systematic review and meta-analysis. *J Gynecol Obstet Hum Reprod*. 2025;54(4):102925. PMID: 39947348. doi:10.1016/j.jogoh.2025.102925
17. Iannaccone A, Reisch B, Mavarani L, et al. Soluble endoglin versus sFlt-1/PlGF ratio: detection of preeclampsia, HELLP syndrome, and FGR in a high-risk cohort. *Hypertens Pregnancy*. 2022;41(3–4):159–172. PMID: 35475405. doi:10.1080/10641955.2022.2066119

18. Xiao F, Li C, Wang X, Li J. The predictive value of placental growth factor combined with uterine ultrasound arterial blood flow characteristics for preeclampsia. *Pak J Med Sci*. 2025;41(2):426–431. PMID: 39926686; PMCID: PMC11803773. doi:10.12669/pjms.41.2.11349
19. Ventura W, De Paco C, Delgado JL, Blanco JE, Peñalver C, Parrilla JJ. Reliability of examining the external iliac artery with Doppler ultrasound in the first trimester and its relationship with maternal blood pressure and uterine artery blood flow. *Eur J Obstet Gynecol Reprod Biol*. 2012;165(1):42–46. PMID: 22884591. doi:10.1016/j.ejogrb.2012.07.017
20. Xing B, Dai X, Gao G, Liu L, Zhang Y. Magnesium sulfate improves blood flow of uterine, umbilical, and fetal middle cerebral arteries in women with severe preeclampsia at 30-34 gestational weeks. *Hypertens Pregnancy*. 2024;43(1):2404459. PMID: 39305176. doi:10.1080/10641955.2024.2404459
21. Gómez-Arriaga PI, Herraiz I, López-Jiménez EA, Gómez-Montes E, Denk B, Galindo A. Uterine artery Doppler and sFlt-1/PlGF ratio: usefulness in diagnosis of pre-eclampsia. *Ultrasound Obstet Gynecol*. 2013;41(5):530–537. PMID: 23303638. doi:10.1002/uog.12400