e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2026; 17(10); 111-115

Original Research Article

Early Second-Trimester (14–20 Weeks) Uterine Artery Doppler Velocimetry for the Prediction of Fetal Growth Restriction in a Low-Risk Population: A Prospective Cohort Study

Vinayak Jante[1], Anand S. B.[2], Pramod R. Kulkarni[3], Mahesh Reddy[4]

[1]Department of Obstetrics and Gynaecology, Bidar Institute of Medical Sciences (BRIMS), Bidar - 585401, Karnataka, India.

[2]Department of Pediatrics, Bidar Institute of Medical Sciences (BRIMS), Bidar - 585401, Karnataka, India.

[3]Department of Obstetrics and Gynaecology, Bidar Institute of Medical Sciences (BRIMS), Bidar - 585401, Karnataka, India.

[4]MBBS, MD (General Medicine) Assistant Professor, Department of General Medicine, Bidar Institute of Medical Sciences (BRIMS), Bidar - 585401, Karnataka, India.

Received: 25-07-2026 / Revised: 23-08-2026 / Accepted: 26-09-2026

Corresponding Author: Dr. Mahesh Reddy

Conflict of interest: Nil

Abstract:

Background: Fetal growth restriction (FGR) shares common etiopathogenic origins with pre-eclampsia, characterized by defective maternal spiral artery remodeling and heightened uteroplacental vascular impedance measurable by uterine artery Doppler velocimetry. Reliable early detection in low-risk singleton pregnancies offers a significant opportunity for timed clinical and biophysical surveillance.

Objective: To evaluate the diagnostic accuracy and clinical efficacy of uterine artery Doppler indices recorded at 14–20 weeks of gestation—pulsatility index (PI), resistance index (RI), notch depth index (NDI), and bilateral early-diastolic notch, alone and in combination—for predicting fetal growth restriction in an unselected low-risk cohort.

Methods: A hospital-based prospective observational cohort study was carried out among 180 low-risk pregnant women carrying singleton gestations at Bidar Institute of Medical Sciences (BRIMS), Bidar. Transabdominal uterine artery Doppler was conducted at 14–20 weeks and participants were prospectively monitored until delivery. Doppler parameters above the 95th percentile for gestational age (RI ≥ 0.70), an NDI > 0.14, and bilateral protodiastolic notches were deemed abnormal. Predictive indices (sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV], overall diagnostic accuracy) and univariate odds ratios (OR with 95% CI) were evaluated.

Results: FGR occurred in 16 women (8.9%). An abnormal PI > 95th centile (sensitivity 31.25%, specificity 88.41%, PPV 20.83%, NPV 92.95%, accuracy 83.33%; OR 3.47, 95% CI 1.15–10.46; p = 0.014), NDI > 0.14 (OR 3.27, p < 0.001), bilateral diastolic notching (OR 4.32, 95% CI 1.52–12.27; p = 0.003), and the composite of PI > 95th centile with bilateral notching (sensitivity 18.75%, specificity 98.17%, PPV 50.00%, NPV 92.53%, accuracy 91.11%; OR 12.39, 95% CI 3.15–48.76; p < 0.001) were significantly associated with the development of FGR. In contrast, isolated RI > 95th centile (OR 1.32; 95% CI 0.28–6.32; p = 0.363) and RI combined with a notch (OR 3.58; 95% CI 0.40–31.71; p = 0.126) demonstrated no statistically significant predictive value.

Conclusion: At 14–20 weeks of gestation, uterine artery Doppler pulsatility index—especially when combined with a bilateral protodiastolic notch—demonstrates exceptional specificity and high negative predictive value for fetal growth restriction in low-risk women. Conversely, the resistance index is an unreliable predictor in the mid-second trimester. Early Doppler screening enables targeted risk stratification and customized fetal growth monitoring.

Keywords: Uterine artery Doppler; Pulsatility index; Diastolic notch; Fetal growth restriction (FGR); Second trimester; Antenatal surveillance; BRIMS Bidar.

DOI: 10.25258/ijpqa.17.10.17

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0) and the Budapest Open Access Initiative (http://www.budapestopenaccessinitiative.org/read), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

Introduction

Fetal growth restriction (FGR)—defined as the pathological failure of a fetus to attain its genetically predetermined growth potential—remains a major contributor to stillbirth, neonatal

morbidity, perinatal mortality, and long-term metabolic and neurodevelopmental impairments. It frequently coexists with or precedes maternal hypertensive disorders of pregnancy, including pre-eclampsia. Both clinical syndromes share a common morphological and pathophysiological substrate rooted in abnormal placentation.

Under normal physiological conditions, extravillous trophoblasts invade the maternal decidual and myometrial segments of the spiral arteries, destroying their muscular elastic media and replacing it with amorphous fibrinoid material. This physiologic transformation converts the spiral arteries into high-caliber, low-resistance vascular conduits capable of sustaining optimal intervillous hemodynamics. When endovascular trophoblastic invasion is incomplete or impaired, spiral arteries retain their high vascular resistance, leading to persistent uteroplacental hypoperfusion, chronic placental ischemia, oxidative stress, and subsequent fetal growth impairment.

Because placental vascular impedance increases well before biometric lag becomes evident on routine antenatal ultrasound, pulsed Doppler interrogation of the maternal uterine arteries provides an objective, non-invasive assessment of uteroplacental perfusion. While screening strategies have classically focused on pregnancies with established clinical risk factors, more than half of FGR cases arise unexpectedly in low-risk women without any prior obstetric, medical, or family history. Therefore, the present prospective cohort study was conducted to evaluate the diagnostic screening utility of early second-trimester (14–20 weeks) uterine artery Doppler velocimetry parameters—pulsatility index (PI), resistance index (RI), notch depth index (NDI), and bilateral diastolic notching, singly and in combination—for predicting fetal growth restriction in a low-risk cohort.

Materials and Methods

Study Design and Clinical Setting: This hospital-based prospective observational cohort study was carried out over an 18-month duration from Jan 2023 to June 2024 at the Department of Obstetrics and Gynaecology, Bidar Institute of Medical Sciences (BRIMS), Bidar, Karnataka, India, in multidisciplinary collaboration with the Department of Pediatrics and the Department of General Medicine. Formal institutional ethical clearance was obtained from the Institutional Ethics Committee of BRIMS, Bidar, and written informed consent was acquired from all enrolled women prior to participation.

Inclusion and Exclusion Criteria: Consecutive antenatal women attending the outpatient clinic with confirmed singleton pregnancies between 14 and 20 weeks of gestation were screened. Enrolled participants possessed low-risk obstetric profiles. Exclusion criteria comprised multiple gestations, molar pregnancies, major congenital or chromosomal fetal malformations, confirmed chronic hypertension, pre-gestational diabetes, gestational diabetes mellitus, known renal, cardiac, or connective tissue disease, systemic autoimmune conditions (such as antiphospholipid antibody syndrome), pre-pregnancy maternal obesity (BMI $\geq$ 30 kg/m^2), extremes of maternal age (< 20 or > 35 years), and past histories of pre-eclampsia, placental abruption, or fetal growth restriction.

Sample Size Estimation: Assuming an anticipated incidence of pre-eclampsia and placental insufficiency disorders of 7%–10% in the screened demographic, with 10% relative precision and a 95% confidence level, the calculated sample size was 179 using OpenEpi version 3.01. A total cohort of 180 low-risk pregnant women was recruited and monitored prospectively through delivery.

Doppler Examination Technique: Transabdominal uterine artery Doppler examinations were performed between 14 and 20 weeks of gestation using a high-resolution ultrasound platform equipped with a 4–8 MHz curvilinear probe. Following anatomical survey, a mid-sagittal section of the uterine cervix and internal cervical os was visualized. Color Doppler flow mapping was used to identify the ascending branch of the right and left uterine arteries lateral to the internal cervical os. Pulsed-wave Doppler was interrogated with the sample gate adjusted to 3.0 mm and insonation angles maintained below 30°. When at least three uniform, consecutive waveforms were captured, velocimetric indices were calculated and averaged bilaterally.

Definitions of Abnormal Parameters: Mean pulsatility index (PI) and mean resistance index (RI) were categorized as abnormal when values exceeded the 95th percentile for gestational age (RI $\geq$ 0.70). The bilateral early-diastolic notch was classified as present or absent. Notch depth was quantified by NDI = (D − C) / D (where D is peak diastolic velocity and C is the nadir of the diastolic notch), with NDI > 0.14 categorized as abnormal. Composite markers (PI > 95th centile + bilateral notch, and RI > 95th centile + bilateral notch) were also assessed.

Clinical Follow-up and Outcome Definitions: All participants were monitored prospectively through standard antenatal schedules until delivery. At every visit, systolic and diastolic blood pressure, maternal weight gain, symphysis-fundus height, and urinary protein excretion were systematically documented. Fetal growth restriction (FGR) was diagnosed clinically and sonographically as birthweight below the 10th percentile for gestational age accompanied by pathological fetal

Doppler indices or asymmetrical fetal biometric parameters.

Statistical Analysis: Continuous variables were summarized as mean ± standard deviation (SD), and categorical variables were presented as frequencies and percentages. Categorical associations were evaluated using the Chi-square test or Fisher's exact test. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were computed. Univariate odds ratios (OR) with 95% confidence intervals (CI) were determined. Statistical analyses were performed using R statistical software (version 4.2.2). A two-sided p-value < 0.05 was defined as statistically significant.

Results

Cohort Characteristics: A total of 180 low-risk pregnant women completed prospective monitoring through delivery. The mean maternal age was 27.96 ± 5.42 years. Nulliparous women constituted 38.3% (n = 69) and multiparous women accounted for 61.7% (n = 111). Fetal growth restriction complicated 16 pregnancies, representing an overall incidence of 8.9% (Table 1).

Table 1: Baseline clinical and demographic characteristics of the prospective study cohort.

Baseline Clinical Characteristic	Cohort Distribution (n = 180)
Mean Maternal Age (years ± SD)	27.96 ± 5.42
Parity: Primigravida / Multigravida, n (%)	69 (38.3%) / 111 (61.7%)
Mean Uterine Artery PI at 14–20 weeks (Mean ± SD)	1.22 ± 0.34
Mean Uterine Artery RI at 14–20 weeks (Mean ± SD)	0.52 ± 0.12
Incidence of Fetal Growth Restriction (FGR), n (%)	16 (8.9%)

Association between Doppler Parameters and FGR: An abnormal PI > 95th centile was noted in 31.25% of pregnancies developing FGR compared to 11.59% of uncomplicated gestations (p = 0.014). Bilateral diastolic notching was present in 37.50% of FGR cases versus 12.20% of controls (p = 0.003). Similarly, NDI > 0.14 was observed in 31.25% of FGR cases versus 12.19% in unaffected controls (p < 0.001). The composite marker of PI > 95th centile combined with bilateral notching was identified in 18.75% of FGR pregnancies compared to only 1.83% of normal gestations (p < 0.001). In marked contrast, RI > 95th centile (12.50% vs 9.76%, p = 0.363) and the RI–notch composite (6.25% vs 1.83%, p = 0.126) demonstrated no statistically significant difference (Table 2).

Table 2: Association of abnormal uterine artery Doppler parameters at 14–20 weeks with fetal growth restriction.

Doppler Parameter (14–20 wk)	FGR (n = 16) n (%)	No FGR (n = 164) n (%)	p-value
PI > 95th centile	5 (31.25%)	19 (11.59%)	0.014
RI > 95th centile (≥ 0.70)	2 (12.50%)	16 (9.76%)	0.363 (NS)
Notch Depth Index (NDI) > 0.14	5 (31.25%)	20 (12.19%)	< 0.001
Bilateral Diastolic Notch	6 (37.50%)	20 (12.20%)	0.003
PI > 95th centile + Bilateral Notch	3 (18.75%)	3 (1.83%)	< 0.001
RI > 95th centile + Bilateral Notch	1 (6.25%)	3 (1.83%)	0.126 (NS)

Diagnostic Screening Performance: All evaluated Doppler parameters exhibited consistently high negative predictive values (> 90%) and strong specificities (Table 3). Isolated PI > 95th centile attained a sensitivity of 31.25%, specificity of 88.41%, PPV of 20.83%, NPV of 92.95%, and diagnostic accuracy of 83.33%. Bilateral diastolic notching exhibited a sensitivity of 37.50% and specificity of 87.80%.

Combining PI > 95th centile with bilateral diastolic notching demonstrated the highest specificity (98.17%), positive predictive value (50.00%), and overall diagnostic accuracy (91.11%).

Table 3: Diagnostic screening metrics of uterine artery Doppler indices at 14–20 weeks for predicting FGR.

Doppler Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
PI > 95th centile	31.25	88.41	20.83	92.95	83.33
RI > 95th centile	12.50	90.24	11.11	91.36	83.33
NDI > 0.14	31.00	87.00	20.00	92.00	82.22
Bilateral Diastolic Notch	37.50	87.80	23.08	93.51	83.33
PI > 95th + Notch	18.75	98.17	50.00	92.53	91.11
RI > 95th + Notch	6.25	98.17	25.00	91.48	90.00

Univariate Risk Assessment: Odds ratios confirmed statistically significant elevations in FGR risk for PI, bilateral notching, and their composite (Table 4). Women exhibiting PI > 95th centile were 3.47 times more likely to develop FGR (95% CI: 1.15–10.46). Bilateral notching conferred a 4.32-fold increased risk (95% CI: 1.52–12.27). The composite of PI > 95th centile and bilateral notch dramatically elevated the odds of FGR with an odds ratio of 12.39 (95% CI: 3.15–48.76). Conversely, the confidence intervals for RI > 95th centile (OR 1.32; 95% CI 0.28–6.32) and RI combined with notching (OR 3.58; 95% CI 0.40–31.71) crossed unity, confirming lack of statistical significance.

Table 4: Odds ratios (OR) and 95% confidence intervals for FGR prediction.

Doppler Parameter (14–20 weeks)	Odds Ratio (OR)	95% Confidence Interval
PI > 95th centile	3.47	1.15 – 10.46
RI > 95th centile	1.32	0.28 – 6.32 (NS)
Bilateral Diastolic Notch	4.32	1.52 – 12.27
PI > 95th centile + Bilateral Notch	12.39	3.15 – 48.76
RI > 95th centile + Bilateral Notch	3.58	0.40 – 31.71 (NS)

Discussion

In the present prospective cohort study of low-risk singleton pregnancies, uterine artery Doppler velocimetry at 14–20 weeks demonstrated substantial predictive capability for fetal growth restriction. FGR was diagnosed in 8.9% of gestations, closely mirroring incidence figures reported across low-risk populations by Valensise et al. (7.7%) and Steel et al. (7.2%).

The sensitivity of an isolated mean PI > 95th centile was 31.25% with a specificity of 88.41% and an odds ratio of 3.47. This aligns well with existing literature: the sensitivity falls between the 18% reported in the systematic review by Cnossen et al. and the 21% noted by Albaiges et al., while approaching the 45% reported by Verma and Gupta in North India. More importantly, the consistently elevated negative predictive value (> 92%) confirms that normal velocimetric impedance at 14–20 weeks offers substantial clinical reassurance regarding normal fetal growth.

A crucial negative finding from our trial is the diagnostic inadequacy of the resistance index (RI). Neither isolated RI > 95th centile nor RI combined with bilateral notching exhibited a statistically significant association with FGR (OR 1.32 and 3.58, respectively; both 95% CIs crossed unity). This observation supports the pathophysiological concept that studies demonstrating predictive efficacy for RI were predominantly performed earlier in gestation (11–14 weeks). In the mid-second trimester, the pulsatility index—which incorporates continuous mean velocity throughout the cardiac cycle rather than simply the peak systolic and end-diastolic points—provides a significantly superior assessment of vascular compliance and downstream impedance.

The clinical pinnacle of our analysis lies in the composite evaluation: combining a pulsatility index above the 95th percentile with a bilateral protodiastolic notch elevated the odds of developing FGR by over 12-fold (OR 12.39; 95% CI 3.15–48.76), achieving a specificity of 98.17% and an overall diagnostic accuracy of 91.11%. This confirms that the coexistence of heightened vascular resistance and abnormal velocity waveform contour represents severe failure of trophoblastic invasion.

Clinical Relevance: Identifying pregnant women at heightened risk of FGR at 14–20 weeks allows clinicians to initiate customized surveillance protocols, including serial third-trimester biometric scans, umbilical and middle cerebral artery Doppler monitoring, biophysical profiling, and appropriate timing of delivery to mitigate perinatal risks.

Strengths and Limitations: Strengths include the prospective cohort design, complete clinical follow-up through delivery, single-operator standardized Doppler interrogation, and simultaneous evaluation of impedance and waveform indices. Limitations include the single-center setting, reliance on external reference centiles, and sample size constraints that yielded broad confidence intervals for composite subgroups. Future multi-center trials incorporating biochemical angiogenic markers (e.g., sFlt-1/PlGF ratio) alongside second-trimester Doppler indices are recommended.

Conclusion

Transabdominal uterine artery Doppler velocimetry at 14–20 weeks of gestation is an effective, non-invasive method for stratifying fetal growth restriction risk in low-risk singleton pregnancies. An abnormal pulsatility index, notch depth index, and bilateral diastolic notch—particularly the composite of raised PI and bilateral notching—predict FGR with high specificity and negative predictive value, whereas the resistance index is an unreliable predictor in this gestational window. Implementing routine early second-trimester Doppler assessment allows targeted antenatal

surveillance for pregnancies at high risk of placental insufficiency.

References

1. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller AB, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. Lancet Glob Health. 2014;2(6):e323–33.
2. Malik A, Jee B, Gupta SK. Preeclampsia: disease biology and burden, its management strategies with reference to India. Pregnancy Hypertens. 2019;15:23–31.
3. Cunningham FG, editor. Williams Obstetrics. 25th ed. New York: McGraw-Hill; 2018.
4. Brosens IA. Morphological changes in the utero-placental bed in pregnancy hypertension. Clin Obstet Gynaecol. 1977;4(3):573–93.
5. Sciscione AC, Hayes EJ. Uterine artery Doppler flow studies in obstetric practice. Am J Obstet Gynecol. 2009;201(2):121–6.
6. Scandiuzzi RM, Prado CAC, Araújo Júnior E, Duarte G, Quintana SM, da Silva Costa F, et al. Maternal uterine artery Doppler in the first and second trimesters as a screening method for hypertensive disorders and adverse perinatal outcomes in low-risk pregnancies. Obstet Gynecol Sci. 2016;59(5):347–55.
7. Cnossen JS, Morris RK, ter Riet G, Mol BWJ, van der Post JAM, Coomarasamy A, et al. Use of uterine artery Doppler ultrasonography to predict pre-eclampsia and intrauterine growth restriction: a systematic review and bivariable meta-analysis. CMAJ. 2008;178(6):701–11.
8. Verma D, Gupta S. Prediction of adverse pregnancy outcomes using uterine artery Doppler imaging at 22–24 weeks of pregnancy: a north Indian experience. Turk J Obstet Gynecol. 2016;13(2):80–4.
9. Albaiges G, Missfelder-Lobos H, Lees C, Parra M, Nicolaides KH. One-stage screening for pregnancy complications by colour Doppler assessment of the uterine arteries at 23 weeks' gestation. Obstet Gynecol. 2000;96(4):559–64.
10. Gómez O, Figueras F, Fernández S, Bennasar M, Martínez JM, Puerto B, et al. Reference ranges for uterine artery mean pulsatility index at 11–41 weeks of gestation. Ultrasound Obstet Gynecol. 2008;32(2):128–32.
11. Ohkuchi A, Minakami H, Sato I, Mori H, Nakano T, Tateno M. Predicting the risk of pre-eclampsia and a small-for-gestational-age infant by quantitative assessment of the diastolic notch in uterine artery flow velocity waveforms in unselected women. Ultrasound Obstet Gynecol. 2000;16(2):171–8.
12. Harrington K, Cooper D, Lees C, Hecher K, Campbell S. Doppler ultrasound of the uterine arteries: the importance of bilateral notching in the prediction of pre-eclampsia, placental abruption or delivery of a small-for-gestational-age baby. Ultrasound Obstet Gynecol. 1996;7(3): 182–8.
13. Bower S, Bewley S, Campbell S. Improved prediction of preeclampsia by two-stage screening of uterine arteries using the early diastolic notch and colour Doppler imaging. Obstet Gynecol. 1993;82(1):78–83.
14. Irion O, Massé J, Forest JC, Moutquin JM. Prediction of pre-eclampsia, low birthweight for gestation and prematurity by uterine artery blood flow velocity waveform analysis in low-risk nulliparous women. BJOG. 1998;105(4): 422–9.
15. North RA, Ferrier C, Long D, Townend K, Kincaid-Smith P. Uterine artery Doppler flow velocity waveforms in the second trimester for the prediction of preeclampsia and fetal growth retardation.ObstetGynecol.1994;83(3):378–86.
16. Bewley S, Cooper D, Campbell S. Doppler investigation of uteroplacental blood flow resistance in the second trimester: a screening study for pre-eclampsia and intrauterine growth retardation. BJOG. 1991;98(9):871–9.
17. Valensise H. Uterine artery Doppler velocimetry as a screening test: where we are and where we go. Ultrasound Obstet Gynecol. 1998;12(2):81–3.
18. Steel SA, Pearce JM, McParland P, Chamberlain GVP. Early Doppler ultrasound screening in prediction of hypertensive disorders of pregnancy. Lancet. 1990;335(8705):1548–51.
19. Pedroso M, Palmer K, Hodges R, Costa F, Rolnik D. Uterine artery Doppler in screening for preeclampsia and fetal growth restriction. Rev Bras Ginecol Obstet. 2018;40(5):287–93.
20. Myatt L, Clifton RG, Roberts JM, Spong CY, Hauth JC, Varner MW, et al. The utility of uterine artery Doppler velocimetry in prediction of preeclampsia in a low-risk population. Obstet Gynecol. 2012;120(4):815–22.
21. Pai MV. Uterine artery Doppler velocimetry in women with normal pregnancy, PIH and IUGR. Obstet Gynecol. 2001.
22. Park YW, Lim JC, Kim YH, Kwon HS. Uterine artery Doppler velocimetry during mid-second trimester to predict complications of pregnancy based on unilateral or bilateral abnormalities. Yonsei Med J. 2005;46(5):652–7.
23. Venkat Raman N, Backos M, Teoh T, Lo W, Regan L. Uterine artery Doppler in predicting pregnancy outcome in women with antiphospholipid syndrome. Obstet Gynecol. 2001;98 (2):235–42.