

Diagnostic Accuracy of Umbilical Artery and Middle Cerebral Artery Waveform with Color Doppler Study in Detecting the IUGR, Taking Birth Weight as Gold Standard

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ABSTRACT

Background: The early detection of intrauterine growth restriction (IUGR) is important to reduce perinatal morbidity and mortality. Doppler ultrasonography of the umbilical artery (UA) and middle cerebral artery (MCA) has been widely used for fetal surveillance in high-risk pregnancies and assessment of uteroplacental insufficiency.

Objectives: To determine the diagnostic accuracy of umbilical artery and middle cerebral artery waveform with color Doppler study in detecting IUGR, taking birth weight as gold standard.

Study Design & Setting: This cross-sectional validation study was conducted at the Department of Radiology, Sheikh Khalifa Bin Zayed Al Nahyan Hospital, CMH, Muzaffarabad from 18 December 2025 to 18 June 2026.

Methodology: A total of 209 pregnant women aged 18–40 years with singleton pregnancies and gestational age between 34–37 weeks were included through non-probability consecutive sampling. All patients underwent Doppler ultrasonography of the umbilical artery and middle cerebral artery. Patients were followed until delivery and birth weight was used as the gold standard for diagnosis of IUGR. Data were analyzed using SPSS version 25.0. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated using 2×2 contingency tables.

Results: Mean age of the patients was 28.94 ± 5.11 years and mean gestational age was 35.63 ± 1.12 weeks. IUGR at birth was observed in 146 (69.9%) patients. Umbilical artery Doppler showed sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of 92.47%, 90.48%, 95.74%, 83.82%, and 91.87%, respectively. Middle cerebral artery Doppler showed sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of 84.93%, 87.30%, 93.94%, 71.43%, and 85.65%, respectively.

Conclusion: Umbilical artery Doppler showed higher diagnostic accuracy than middle cerebral artery Doppler in detecting IUGR. Color Doppler ultrasonography can be used as a reliable non-invasive modality for early detection and management of IUGR.

Keywords: Birth weight, Color Doppler ultrasonography, Intrauterine growth restriction, Middle cerebral artery, Umbilical artery.

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INTRODUCTION

Intrauterine growth restriction (IUGR) is associated with increased perinatal mortality and morbidity, possibly extending also in adult life, as compared to fetuses and newborns presenting characteristics of normal growth. It is important to make a definite diagnosis based on the best criteria in order to decrease the perinatal mortality and morbidity associated with IUGR.¹ Various studies all over the world have given different modalities to diagnose IUGR; the latest in the series to diagnosis IUGR antenatally is the analysis of Doppler blood flow velocity

waveforms of fetal and maternal vessels.² The clinical and ultrasound measurements diagnose IUGR at a very late stage when the fetus is already compromised, whereas Doppler waveform studies can detect IUGR at an early stage, so that the affected fetus can be delivered without significant compromise.³

Doppler use to assess the blood flow through placenta to baby, it's a non-invasive test. Doppler can detect worsening of situation including reduced or absent blood flow to baby, there by decision to intervene can be taken if Doppler studies shows abnormal result. Abnormal Doppler studies leads to poor baby outcomes.⁴ Increased fetal risks

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in growth restricted babies as compare to SGA babies. Doppler studies provide information about intra-uterine environment. Vessels used in Doppler studies to assess baby growth and blood flow to baby are uterine artery (Ut. A), umbilical artery (UA), middle cerebral artery (MCA) and ductus venosus (DV). Umbilical and middle cerebral artery pulsatility index (PI) is found to be better predictor of baby outcome.^{5,6} In a study, prevalence of IUGR was found to be 69.8% and the sensitivity of PI UA (>1.4) and MCA (<1.5) were 95.14% and 79.73%, respectively.⁷ The specificity of PI UA and MCA were 37% and 90%, respectively by taking birth weight as gold standard.⁷ In another study, middle cerebral artery doppler test has shown sensitivity of 61.3%, specificity 93%, diagnostic accuracy by 76%, PPV 91.5% and NPV 66.1% ($p=0.000$) for diagnosis of Intra uterine growth restriction.⁸ In one study, the sensitivity of PI UA (>1.4) and MCA (<1.5) were 80.0% and 20.0%, respectively.⁹ The specificity of PI UA and MCA were 69.1% and 81.69%, respectively by taking birth weight as gold standard.⁹

Although previously immense body of literature is available on this but as mentioned above, variations in sensitivity and specificity of Doppler ultrasonography in detecting IUGR have been reported worldwide. Therefore, use of Doppler ultrasonography as a predictive test to detect IUGR in our clinical settings is questionable. Hence, the aim of the present study is to re-evaluate the diagnostic value of umbilical artery and middle cerebral artery waveform with color doppler study in detecting the IUGR among the pregnant women in our clinical settings. This study will help to determine the diagnostic value of Doppler ultrasonography in detecting intrauterine growth restriction in our population for better management of IUGR fetuses. Early diagnosis and timely management will help in reduction of perinatal mortality in these fetuses. The objective is to determine the diagnostic accuracy of umbilical artery and middle cerebral artery waveform with color doppler study in detecting the IUGR, taking birth weight as gold standard.

METHODS

This cross-sectional validation study was conducted at the Department of Radiology, Sheikh Khalifa Bin Zayed Al Nahyan Hospital, CMH, Muzaffarabad, over a duration of six months after approval of the synopsis from 18 December 2025 to 18 June 2026. A sample size of 209 cases was calculated by using a sensitivity and specificity calculator with a 95% confidence level, taking the prevalence of IUGR as 69.8%, desired precision of 3.5% for sensitivity of 95.14%, and 12% for specificity of 37% of pulsatility index (PI) of the umbilical artery in predicting IUGR. Non-probability consecutive sampling technique was used.

All pregnant women aged 18–40 years with singleton pregnancy assessed on ultrasonography and gestational age between 34–37 weeks assessed on last menstrual period were included in the study. Both primiparous and multiparous women were included. Women with multiple

pregnancies, fetal congenital anomalies, uncertain last menstrual period, or without an available dating scan were excluded from the study.

After obtaining permission from the local ethical review committee and CPSP, pregnant women presenting to the Department of Radiology, Sheikh Khalifa Bin Zayed Al Nahyan Hospital, CMH, Muzaffarabad, fulfilling the inclusion criteria were selected. Informed consent was taken from each patient. Demographic and clinical variables including age, gestational age, parity, height, weight, body mass index, and pregnancy induced hypertension were recorded. All patients underwent Doppler velocimetry of the umbilical artery and middle cerebral artery close to the transducer. Doppler velocimetry of the umbilical arteries was performed in a free-floating loop of the mid-portion of the umbilical cord away from placental and fetal cord insertion. The umbilical cord was assessed by color flow Doppler and flow velocity waveforms were obtained from each artery. The middle cerebral artery was visualized in a plane immediately caudal to the trans-thalamic plane used for obtaining biparietal diameter and head circumference biometric data. Using color flow Doppler, the middle cerebral artery was identified in the sylvian fissure arising from the circle of Willis. The Doppler sample was placed in the first third of the middle cerebral artery and flow velocity waveform was obtained. IUGR was noted on umbilical artery and middle cerebral artery Doppler ultrasonography. Patients were followed until delivery and IUGR at birth was recorded. All data were entered on a specially designed proforma.

Collected data were analyzed using SPSS version 25.0. Shapiro-Wilk test was used to assess the normality of data. Mean and standard deviation or median with interquartile range were calculated for quantitative variables including age, gestational age, height, weight, and body mass index. Frequency and percentage were calculated for parity, pregnancy induced hypertension, and IUGR diagnosed on umbilical artery Doppler, middle cerebral artery Doppler, and at birth. A 2×2 contingency table was used to calculate sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of umbilical artery and middle cerebral artery waveforms with color Doppler study in detecting IUGR, taking birth weight as the gold standard. Receiver operating characteristic curve and likelihood ratio were also calculated. Stratification was performed for age, gestational age, parity, pregnancy induced hypertension, and body mass index. Post-stratification diagnostic accuracy was also calculated.

OPERATIONAL DEFINITIONS

Diagnostic Accuracy

Diagnostic accuracy was measured in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Sensitivity was defined as the ability of umbilical artery and middle cerebral artery waveforms to correctly diagnose patients with IUGR. Specificity was defined as the ability of umbilical artery and middle cerebral artery waveforms to correctly diagnose patients without IUGR. PPV was defined as the

proportion of patients positive for IUGR on umbilical artery and middle cerebral artery waveforms among all positive cases. NPV was defined as the proportion of patients negative for IUGR on umbilical artery and middle cerebral artery waveforms among all negative cases.

True Positive

True positive was defined as the presence of IUGR on umbilical artery and middle cerebral artery waveforms as well as at birth.

True Negative

True negative was defined as the absence of IUGR on umbilical artery and middle cerebral artery waveforms as well as at birth.

False Positive

False positive was defined as the presence of IUGR on umbilical artery and middle cerebral artery waveforms but absence at birth.

False Negative

False negative was defined as the absence of IUGR on umbilical artery and middle cerebral artery waveforms but presence at birth.

Singleton Pregnancy

All pregnant women with singleton pregnancy, assessed on ultrasonography, having gestational age between 28–40 weeks assessed on last menstrual period (LMP), were included in the study.

IUGR on Umbilical Artery Doppler Ultrasonography

IUGR on umbilical artery Doppler ultrasonography was defined as the presence of umbilical artery pulsatility index (UA-PI) more than the 95th percentile of the reference range. Pulsatility index measured between 28–40 weeks was used to calculate umbilical artery velocimetry. UA-PI >1.42 was taken as positive for IUGR.

Pulsatility index was calculated as:

$PI = \frac{\text{Peak systolic velocity} - \text{End diastolic velocity}}{\text{Mean velocity}}$

IUGR on MCA Doppler Ultrasonography

IUGR on middle cerebral artery (MCA) Doppler ultrasonography was defined as MCA pulsatility index less than the 5th percentile for gestational age. MCA-PI <1.5 was taken as positive for IUGR.

Intrauterine Growth Restriction

IUGR was defined as a fetus small for gestational age having estimated fetal weight less than the 10th centile for gestational age. Estimated fetal weight less than 1313 g at 30 weeks, less than 1470 g at 31 weeks, less than 1635 g at 32 weeks, less than 1807 g at 33 weeks, and less than 1985 g at 34 weeks was taken as IUGR.

Pregnancy Induced Hypertension

Pregnancy induced hypertension was defined as the development of new-onset hypertension in a pregnant woman after 20 weeks of gestation without proteinuria or other signs of pre-eclampsia.

RESULTS

The mean age of the study participants was 28.94 ± 5.11 years and the mean gestational age was 35.63 ± 1.12 weeks. Majority of the patients, 145 (69.4%), were

between 18–30 years of age while 64 (30.6%) were between 31–40 years. Regarding gestational age, 113 (54.1%) patients had gestational age between 34–35 weeks and 96 (45.9%) had gestational age between 36–37 weeks. Primiparous women were 88 (42.1%) whereas multiparous women were 121 (57.9%). The mean height, weight, and BMI of the patients were 158.72 ± 6.84 cm, 67.85 ± 9.73 kg, and 26.91 ± 3.87 kg/m², respectively. According to BMI categories, 93 (44.5%) patients had BMI <25 kg/m² while 116 (55.5%) had BMI ≥25 kg/m². Pregnancy induced hypertension was present in 79 (37.8%) patients and absent in 130 (62.2%) patients, as given in Table 1.

Table 1: Demographic and Clinical Characteristics of Study Participants (n=209)

Variable	Category	Frequency n (%)
Age (years)	18–30 years	145 (69.4)
	31–40 years	64 (30.6)
	Mean ± SD	28.94 ± 5.11
Gestational Age (weeks)	34–35 weeks	113 (54.1)
	36–37 weeks	96 (45.9)
	Mean ± SD	35.63 ± 1.12
Parity	Primiparous	88 (42.1)
	Multiparous	121 (57.9)
Height (cm)	Mean ± SD	158.72 ± 6.84
Weight (kg)	Mean ± SD	67.85 ± 9.73
BMI (kg/m ²)	<25 kg/m ²	93 (44.5)
	≥25 kg/m ²	116 (55.5)
	Mean ± SD	26.91 ± 3.87
Pregnancy Induced Hypertension	Yes	79 (37.8)
	No	130 (62.2)

IUGR on MCA Doppler ultrasonography was present in 132 (63.2%) patients and absent in 77 (36.8%) patients. IUGR on UA Doppler ultrasonography was present in 141 (67.5%) patients and absent in 68 (32.5%) patients. At birth, IUGR was present in 146 (69.9%) neonates and absent in 63 (30.1%) neonates, as given in Table 2.

Table 2: Frequency Distribution of IUGR on MCA Doppler, UA Doppler and at Birth (n=209)

Variable	Category	Frequency n (%)
IUGR on MCA Doppler	Present	132 (63.2)
	Absent	77 (36.8)
IUGR on UA Doppler	Present	141 (67.5)
	Absent	68 (32.5)
IUGR at Birth	Present	146 (69.9)
	Absent	63 (30.1)

For umbilical artery Doppler, 135 true positive, 57 true negative, 6 false positive, and 11 false negative cases were observed. The sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of umbilical artery Doppler in detecting IUGR were 92.47%, 90.48%, 95.74%, 83.82%, and 91.87%, respectively. The positive likelihood ratio was 9.71 while the negative likelihood ratio was 0.08, as given in Table 3.

Table 3: Diagnostic Accuracy of Umbilical Artery Doppler in Detecting IUGR Taking Birth Weight as Gold Standard (n=209)

UA Doppler	IUGR Present n (%)	IUGR Absent n (%)	Total n (%)
Positive	135 (64.6)	6 (2.9)	141 (67.5)
Negative	11 (5.3)	57 (27.3)	68 (32.5)
Total	146 (69.9)	63 (30.1)	209 (100)
Sensitivity = 92.47%, Specificity = 90.48%, Positive Predictive Value = 95.74%, Negative Predictive Value = 83.82%, Diagnostic Accuracy = 91.87%.			

For middle cerebral artery Doppler, 124 true positive, 55 true negative, 8 false positive, and 22 false negative cases were observed. The sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of middle cerebral artery Doppler in detecting IUGR were 84.93%, 87.30%, 93.94%, 71.43%, and 85.65%, respectively. The positive likelihood ratio was 6.69 while the negative likelihood ratio was 0.17, as given in Table 4.

Table 4: Diagnostic Accuracy of Middle Cerebral Artery Doppler in Detecting IUGR Taking Birth Weight as Gold Standard (n=209)

MCA Doppler	IUGR at Birth Present n (%)	IUGR at Birth Absent n (%)	Total n (%)
Positive	124 (59.3)	8 (3.8)	132 (63.2)
Negative	22 (10.5)	55 (26.3)	77 (36.8)
Total	146 (69.9)	63 (30.1)	209 (100)
Sensitivity = 84.93%, Specificity = 87.30%, Positive Predictive Value = 93.94%, Negative Predictive Value = 71.43%, Diagnostic Accuracy = 85.65%.			

Post-stratification analysis of umbilical artery Doppler showed that diagnostic accuracy remained high across all subgroups. In patients aged 18–30 years and 31–40 years, diagnostic accuracy was 92.41% and 90.63%, respectively. According to gestational age, diagnostic accuracy was 91.15% in patients with gestational age 34–35 weeks and 92.71% in those with gestational age 36–37 weeks. Among primiparous and multiparous women, diagnostic accuracy was 92.05% and 91.74%, respectively. In patients with pregnancy induced hypertension, diagnostic accuracy was 93.67%, whereas in patients without pregnancy induced hypertension it was 90.77%. According to BMI categories, diagnostic accuracy was 91.40% in patients with BMI <25 kg/m² and 92.24% in those with BMI ≥25 kg/m², as given in Table 5.

Table 5: Stratification and Post-Stratification Diagnostic Accuracy of Umbilical Artery Doppler

According to Demographic and Clinical Variables (n=209)

Variable	Sensitivity (%)	Specificity (%)	PP V (%)	NP V (%)	Diagnostic Accuracy (%)
Age (years)					
18–30 years	93.10	90.91	96.43	83.33	92.41
31–40 years	91.11	89.47	94.25	80.95	90.63
Gestational Age (weeks)					
34–35 weeks	91.46	90.32	95.54	82.35	91.15
36–37 weeks	93.75	90.63	96.77	85.29	92.71
Parity					
Primiparous	92.42	90.91	95.31	85.71	92.05
Multiparous	92.50	90.24	96.10	81.82	91.74
Pregnancy Induced Hypertension					
Yes	95.45	84.62	96.92	78.57	93.67
No	90.00	92.00	94.74	85.19	90.77
BMI (kg/m²)					
<25 kg/m ²	91.53	91.18	94.74	86.11	91.40
≥25 kg/m ²	93.10	89.66	96.43	81.25	92.24

ROC analysis demonstrated that umbilical artery Doppler had an area under curve of 0.914 (95% CI: 0.868–0.959, p<0.001), while middle cerebral artery Doppler had an area under curve of 0.861 (95% CI: 0.804–0.919, p<0.001) for detecting IUGR, as given in Table 6.

Table 6: ROC Analysis of Umbilical Artery and MCA Doppler in Detecting IUGR

Variable	Area Under Curve (AUC)	95% Confidence Interval	p-value
Umbilical artery Doppler	0.914	0.868 – 0.959	<0.001
MCA Doppler	0.861	0.804 – 0.919	<0.001

DISCUSSION

Intrauterine growth restriction (IUGR) is a major obstetric problem associated with increased perinatal morbidity and mortality. Early identification of IUGR is essential for timely intervention and improved fetal outcomes.^{9,10} Color Doppler ultrasonography is a non-invasive modality commonly used for fetal surveillance in high-risk pregnancies.¹¹ Umbilical artery and middle cerebral artery Doppler studies help in assessing placental insufficiency and fetal hemodynamic changes. Abnormal Doppler waveforms are associated with fetal hypoxia and adverse

perinatal outcomes.^{12,13} Therefore, evaluation of the diagnostic accuracy of these Doppler parameters is important for effective detection and management of IUGR.

In the present study, the mean age of the patients was 28.94 ± 5.11 years and the mean gestational age was 35.63 ± 1.12 weeks. IUGR at birth was observed in 69.9% patients, while IUGR on umbilical artery Doppler and middle cerebral artery Doppler was detected in 67.5% and 63.2% patients, respectively. Umbilical artery Doppler showed sensitivity of 92.47%, specificity of 90.48%, positive predictive value of 95.74%, negative predictive value of 83.82%, and diagnostic accuracy of 91.87% in detecting IUGR taking birth weight as gold standard. Middle cerebral artery Doppler showed sensitivity of 84.93%, specificity of 87.30%, positive predictive value of 93.94%, negative predictive value of 71.43%, and diagnostic accuracy of 85.65%. ROC analysis further demonstrated higher diagnostic performance of umbilical artery Doppler with area under curve of 0.914 compared to 0.861 for MCA Doppler.

Our findings are comparable with the study conducted by Mehdi et al. (2020), who evaluated 129 clinically suspected IUGR pregnancies and reported sensitivity of 90.14%, specificity of 84.49%, positive predictive value of 87.67%, negative predictive value of 87.50%, and diagnostic accuracy of 87.60% for color Doppler ultrasonography in diagnosing IUGR. The slightly higher sensitivity (92.47%) and diagnostic accuracy (91.87%) observed in our study.¹⁴ Similarly, Raza et al. (2021) reported sensitivity of 83.3%, specificity of 93.3%, positive predictive value of 69.0%, negative predictive value of 96.9%, and diagnostic accuracy of 91.8% for Doppler scan in detecting IUGR. Our study demonstrated higher sensitivity (92.47% vs. 83.3%) and positive predictive value (95.74% vs. 69.0%), whereas Raza et al. observed slightly higher specificity (93.3% vs. 90.48%) and negative predictive value (96.9% vs. 83.82%). Despite these variations, diagnostic accuracy in both studies remained almost similar (91.87% vs. 91.8%), further supporting the strong predictive role of Doppler studies in IUGR pregnancies.¹⁵ The present study also showed better diagnostic performance of umbilical artery Doppler compared to middle cerebral artery Doppler. This finding is in agreement with Sanaullah et al. (2021), who evaluated 192 clinically diagnosed IUGR pregnancies and reported sensitivity of 61.3%, specificity of 93%, positive predictive value of 91.5%, negative predictive value of 66.1%, and diagnostic accuracy of 76% for MCA Doppler in diagnosing IUGR. In comparison, our study demonstrated markedly higher sensitivity (84.93%), negative predictive value (71.43%), and diagnostic accuracy (85.65%) for MCA Doppler.¹⁶

Comparable findings were also reported by Mughal et al. (2025), who evaluated MCA and umbilical artery pulsatility index in IUGR pregnancies and observed overall sensitivity of 89.55%, specificity of 83.93%, positive predictive value of 86.96%, negative predictive value of 87.04%, and diagnostic accuracy of 86.99%. Our

study showed slightly higher sensitivity (92.47%), specificity (90.48%), positive predictive value (95.74%), and diagnostic accuracy (91.87%) for umbilical artery Doppler.¹⁷ Khanduri et al. (2013) reported that umbilical artery pulsatility index had higher sensitivity and overall diagnostic accuracy than middle cerebral artery pulsatility index in predicting adverse perinatal outcomes among IUGR pregnancies. Our findings strongly support these observations, as umbilical artery Doppler in the current study showed higher sensitivity (92.47% vs. 84.93%), specificity (90.48% vs. 87.30%), negative predictive value (83.82% vs. 71.43%), and diagnostic accuracy (91.87% vs. 85.65%) compared to MCA Doppler. This may be because placental insufficiency primarily affects umbilical artery blood flow earlier than cerebral redistribution changes.¹⁸ Munikumari et al. (2017) studied 50 clinically suspected IUGR pregnancies and reported mean birth weight of 2.43 ± 0.26 kg, with 60% neonates having birth weight less than 2.5 kg. They observed adverse perinatal outcomes in 48% fetuses, including intrauterine deaths, NICU admissions, low Apgar score, and emergency caesarean sections. The authors further concluded that MCA/UA pulsatility index ratio had higher sensitivity and positive predictive value for adverse perinatal outcome than isolated MCA or UA indices, while MCA PI alone had low specificity. These findings correlate with the present study where MCA Doppler showed relatively lower specificity and diagnostic accuracy than umbilical artery Doppler.¹⁹ Ismail et al. (2022) also concluded that diagnostic accuracy of color Doppler of umbilical and cerebral pulsatility was very high in diagnosing IUGR and reported significantly lower MCA pulsatility index values in IUGR pregnancies compared to normal pregnancies. Our findings are consistent with their results, as both UA and MCA Doppler showed high sensitivity and specificity for detecting IUGR, while umbilical artery Doppler demonstrated comparatively superior overall diagnostic performance.²⁰

STUDY LIMITATIONS

This study was conducted at a single tertiary care hospital, which may limit the generalizability of the findings. The study included only singleton pregnancies between 34–37 weeks of gestation. Long-term neonatal outcomes were not assessed in this study. Inter-observer variability in Doppler measurements was also not evaluated.

CONCLUSION

Umbilical artery and middle cerebral artery Doppler ultrasonography were effective modalities for detecting IUGR. Umbilical artery Doppler showed comparatively higher diagnostic accuracy than middle cerebral artery Doppler. Color Doppler ultrasonography can be used as a reliable non-invasive tool for early diagnosis of IUGR.

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REFERENCE

1. Lokeshwari K, Nazmashamim, Sreenivasa B. Study of Doppler velocimetry in predicting perinatal outcome of clinically suspected intrauterine growth restricted fetuses. *New Indian J Obgyn.* 2023;10(1):60-66.
2. Ismail S, Farooq SMY, Fatima M, Arslan A. Diagnostic accuracy of middle cerebral artery Doppler findings in intrauterine growth restriction taking biophysical profile as gold standard. *Professional Med J.* 2022;29(11):1609-1614.
3. Tsikouras P, Antsaklis P, Nikolettos K, Kotanidou S, Kritsotaki N, Bothou A, Andreou S, Nalmpanti T, Chalkia K, Spanakis V, Iatrakis G. Diagnosis, prevention, and management of fetal growth restriction (FGR). *Journal of Personalized Medicine.* 2024 Jun 28;14(7):698.
4. Danciu BM, Simionescu AA. Optimizing fetal surveillance in fetal growth restriction: A narrative review of the role of the computerized cardiotocographic assessment. *Journal of Clinical Medicine.* 2025;14(19):7010-15.
5. Muchchandi R, Takalaki N. A study to evaluate umbilical artery and middle cerebral artery Doppler indices as predictors of adverse perinatal outcome in clinically suspected IUGR pregnancies. *Int J Radiol.* 2019;12(1):18-22.
6. Ali S, Heuving S, Kawooya MG. Prognostic accuracy of antenatal Doppler ultrasound for adverse perinatal outcomes in low-income and middle-income countries: a systematic review. *BMJ Open.* 2021;11:e049799.
7. Jabeen M, Arif QUA, Naeem K, Irshad TM, Khan B, Gul P. Diagnostic accuracy of pulsatility index of umbilical artery and middle cerebral artery in detecting intrauterine growth restriction. *J Soc Obstet Gynaecol Pak.* 2020;10(1):51-55.
8. Chaipakdi P. Diagnostic accuracy of fetal umbilical artery, middle cerebral artery Doppler indices and cerebroplacental ratios for predicting adverse perinatal outcomes in pregnancy-induced hypertension. *Thai J Obstet Gynaecol.* 2024;32(2):99-106
9. Kamphof HD, Posthuma S, Gordijn SJ, Ganzevoort W. Fetal growth restriction: mechanisms, epidemiology, and management. *Maternal-Fetal Medicine.* 2022 Jul 25;4(03):186-96.
10. Yang L, Feng L, Huang L, Li X, Qiu W, Yang K, Qiu J, Li H. Maternal factors for intrauterine growth retardation: systematic review and meta-analysis of observational studies. *Reproductive Sciences.* 2023 Jun;30(6):1737-45.
11. Kale RM, Tirupathi RG, Sheela SR, Kale M. Role of ultrasonography and color Doppler in the assessment of high-risk pregnancies and their accuracy in predicting fetal outcome. *Cureus.* 2023 May 15;15(5).
12. Zhou P, Sun Y, Tan Y, An Y, Wang X, Wang L. Fetal and neonatal middle cerebral artery hemodynamic changes and significance under ultrasound detection in hypertensive disorder complicating pregnancy patients with different severities. *Computational and mathematical methods in medicine.* 2022;2022(1):6110228.
13. Tu P, Zhang X, Zhong C, Ran Q, Ran S. Hemodynamic changes and perinatal outcome associated with umbilical artery thrombosis: a retrospective study. *Orphanet journal of rare diseases.* 2024 Mar 5;19(1):100.
14. Mehdi S, Bukhari H, Dogar IH, Bukhari H. Diagnostic accuracy of Color Doppler of cerebral and umbilical pulsatility in diagnosing IUGR, taking birth weight as gold standard. *Professional Med J* 2020; 27(3):651-659.
15. Raza A, Awan AS, Gul S, Bokhari NA, Tabassum H, Irshaad S. Diagnostic Accuracy of Umbilical Artery and Middle Cerebral Artery Doppler in Detection of Intrauterine Growth Restriction. *Journal of Islamic International Medical College (JIIMC).* 2021 Dec 24;16(4):219-23.
16. Sanaullah Z, Nazir R, Azam H, Malik A. Comparison of middle cerebral artery and uterine artery doppler in evaluation of intra uterine growth restriction pregnancy. *J Soc Obstet Gynaecol Pak.* 2021; 11(4):242-245.
17. Mughal HH, Riaz H, Maryum M, Alvi S, Haq I, Shan T. Doppler Evaluation of Middle Cerebral Artery and Umbilical Artery Pulsatility Index in the Diagnosis of IUGR Taking Clinical IUGR at Birth as Gold Standard. *Ann Pak Inst Med Sci.* 2025; 21(3):532-536.
18. Khanduri S, Parashari UC, Bashir S, Bhadury S, Bansal A. Comparison of diagnostic efficacy of umbilical artery and middle cerebral artery waveform with color Doppler study for detection of intrauterine growth restriction. *The Journal of Obstetrics and Gynecology of India.* 2013 Aug;63(4):249-55.
19. Munikumari T, Vijetha V, Sree Divya NV. Comparison of diagnostic efficacy of umbilical artery and middle cerebral artery waveform with color Doppler study for detection of intrauterine growth restriction fetuses. *Int J Contemp Med Surg Radiol.* 2017 Apr;2:41-6.
20. Ismail S, Farooq SMY, Fatima M, Arslan A. Diagnostic accuracy of middle cerebral artery Doppler findings in intrauterine growth restriction taking biophysical profile as gold standard. *Professional Med J* 2022; 29(11):1609-1614.