

Color Doppler in Fetal Growth Restriction: A Comprehensive Narrative Review

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Abstract

Fetal growth restriction (FGR) is a common complication of pregnancy, affecting 5–10% of pregnancies, and is associated with a wide range of adverse perinatal outcomes^{1,10}. Differentiating a fetus that is constitutionally small from one that is pathologically growth-restricted remains a major diagnostic challenge, and Doppler ultrasonography of the maternal, placental and fetal circulations provides physiological information that complements conventional fetal biometry in this assessment. To provide a comprehensive narrative review of the physiological basis, technique, clinical application and limitations of Color and spectral Doppler ultrasonography in FGR, covering the uterine artery, umbilical artery (UA), middle cerebral artery (MCA), cerebroplacental ratio (CPR) and ductus venosus (DV), and to compare the recommendations of the major professional societies. This narrative review draws on the current major clinical practice guidelines on FGR and obstetric Doppler ultrasonography, the international Delphi consensus definition of FGR³, the randomized Trial of Randomized Umbilical and Fetal Flow in Europe trial⁸, systematic reviews and meta-analyses of Doppler parameters in suspected FGR, a staging protocol for FGR management¹¹, and recent multi-society clinical opinion papers on the evidence-based approach to suspected FGR and the role of the fetal biophysical profile. Uterine artery Doppler reflects the maternal side of placentation and has a recognized role in risk stratification for placental dysfunction. UA Doppler has the most consistently established role in FGR surveillance across guidelines. The CPR shows better predictive accuracy for adverse perinatal outcome than either UA or MCA Doppler alone in independent meta-analyses. DV Doppler changes characterize progressive cardiovascular compromise in severe early-onset FGR and informed the monitoring approach evaluated in the TRUFFLE trial. Recommendations regarding the routine clinical use of MCA, DV and uterine artery Doppler differ among SMFM, ACOG and ISUOG, and multi-society clinical opinion has called for a more standardized, evidence-based, multimodal approach. Doppler ultrasonography provides physiological information that meaningfully complements fetal biometry in FGR. UA Doppler is the best-established parameter for surveillance, while the clinical application of uterine artery, MCA, CPR and DV Doppler should be individualized according to gestational age, FGR phenotype, disease stage and the guideline framework adopted.

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Introduction

Doppler was used to assess blood flow in the fetoplacental or uteroplacental circulation both of which are essential for fetal nourishment and oxygenation to determine if Doppler criteria were useful for predicting fetal growth restriction¹⁶. Fetal

growth restriction, historically termed intrauterine growth restriction, affects 5–10% of pregnancies and is a leading cause of infant morbidity and mortality^{1,10}. ACOG notes that there is a lack of consensus regarding terminology, etiology and diagno-

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stic criteria for FGR, and that an important clinical challenge is distinguishing the fetus that is constitutionally small and fulfilling its growth potential from the small fetus that is not fulfilling its growth potential because of an underlying pathological process¹⁰.

A multidisciplinary Delphi consensus procedure was undertaken specifically to standardize the definition of FGR for research and clinical use, given the wide variation in criteria previously applied³. SMFM defines FGR as a sonographic estimated fetal weight (EFW) or abdominal circumference (AC) below the 10th percentile for gestational age, using population-based growth references such as Hadlock¹, while ISUOG's guideline incorporates biometry, gestational age and Doppler findings, and places particular emphasis on distinguishing early from late-onset disease².

Figueras and Gratacós have argued that reliance on umbilical artery Doppler alone, or on a fixed centile threshold alone, is insufficient, since UA Doppler abnormality identifies only the more severe, early-onset forms of placental insufficiency; they proposed that FGR should instead be diagnosed in the presence of any of several factors associated with poorer perinatal outcome, including an abnormal cerebroplacental ratio, abnormal uterine artery Doppler, or an estimated weight below the third centile¹¹. This broader, multi-parameter view of diagnosis has informed subsequent multi-society clinical opinion on an evidence-based approach to suspected FGR¹³.

Epidemiology and Clinical Significance

FGR occurs in up to 10% of pregnancies and is a leading cause of infant morbidity and mortality¹, and ACOG similarly describes it as a common pregnancy complication associated with a variety of adverse perinatal outcomes¹⁰. Both societies highlight uncertainty around optimal management and delivery timing as a persistent challenge for clinicians^{1,10}.

Pathophysiological Basis of Doppler Changes in FGR

Placental insufficiency is a central mechanism underlying many cases of FGR. Superficial or ab-

normal trophoblastic invasion of the maternal vasculature increases resistance to flow and impairs maternal–fetal exchange, in contrast to the high-flow, low-resistance circuit established by normal trophoblastic invasion in the first trimester⁵. In response to this hostile intrauterine environment, the growth-restricted fetus mounts metabolic, endocrine, vascular, cardiac, behavioral, hematological and immunological adaptive responses⁵.

A prominent vascular adaptation is redistribution of cardiac output toward the brain, adrenal glands, liver and heart at the expense of somatic growth the brain-sparing effect⁵. If these compensatory mechanisms ultimately fail, permanent organ damage or stillbirth may follow; if placental and fetal adaptation succeeds, restricted nutrient availability may remain clinically silent until it manifests as reduced growth velocity in the third trimester⁵.

Principles and Technique of Doppler Ultrasonography

The updated ISUOG Practice Guideline on Doppler velocimetry describes the modalities used to study the maternal–fetal circulation spectral (pulsed) Doppler, color flow mapping and power Doppler and specifies safety parameters, recommending that the displayed thermal index remain ≤ 1.0 and that exposure time be kept as short as possible, typically no more than 5–10 minutes⁴.

For the MCA, the guideline recommends sampling in the proximal third of the vessel close to its origin from the Circle of Willis, in a transverse plane of the mid-brain caudal to the transthalamic plane, using 3 to 10 consecutive waveforms; autotracing is preferred over manual tracing when calculating the pulsatility index (PI) and resistance index (RI), although manual tracing of peak systolic velocity is acceptable⁴. The ductus venosus is identified by tracing the connection between the umbilical vein and the inferior vena cava⁴. Adherence to these

technical standards underpins the reproducibility of the indices discussed throughout this review⁴.

Uterine Artery Doppler

Uterine artery Doppler assesses the maternal side of the uteroplacental circulation and reflects the adequacy of trophoblastic invasion. In a multicenter screening study, transvaginal uterine artery Doppler performed at 23 weeks of gestation by the Fetal Medicine Foundation Second Trimester Screening Group was evaluated for its ability to identify pregnancies at risk of pre-eclampsia and fetal growth restriction¹⁵. ISUOG's guidelines situate uterine artery Doppler within the broader, multimodal assessment of suspected FGR, to be used according to clinical context², whereas SMFM specifically recommends against its routine use for the clinical management of already-established FGR¹. Figueras and Gratacós include abnormal uterine artery Doppler among the criteria that can support a diagnosis of true FGR, alongside CPR and severe biometric restriction, rather than relying on UA Doppler alone¹¹.

Umbilical Artery Doppler

UA Doppler reflects the resistance of the fetoplacental circulation and has an established role in the

surveillance of FGR in the SMFM, ACOG and ISUOG guidelines^{1,2,10}. SMFM recommends UA Doppler assessment approximately every one to two weeks after the diagnosis of FGR, with more frequent assessment when placental resistance is increased or FGR is severe; when absent end-diastolic velocity is present, assessment two to three times per week has been recommended because of the potential for rapid deterioration¹. SMFM's Consult Series document is accompanied by an interactive algorithm mapping specific UA Doppler findings to corresponding management and delivery-timing recommendations¹.

Abnormal UA Doppler indices have been shown to predict adverse perinatal outcome¹. An estimated fetal weight below the third percentile has additionally been associated with increased risk of adverse perinatal outcome irrespective of UA and MCA Doppler indices, and is therefore regarded as a more severe FGR phenotype¹. Figueras and Gratacós note that UA Doppler alone identifies only the more severe, early-onset forms of placental insufficiency, which is why additional parameters are needed to identify FGR more broadly¹¹.

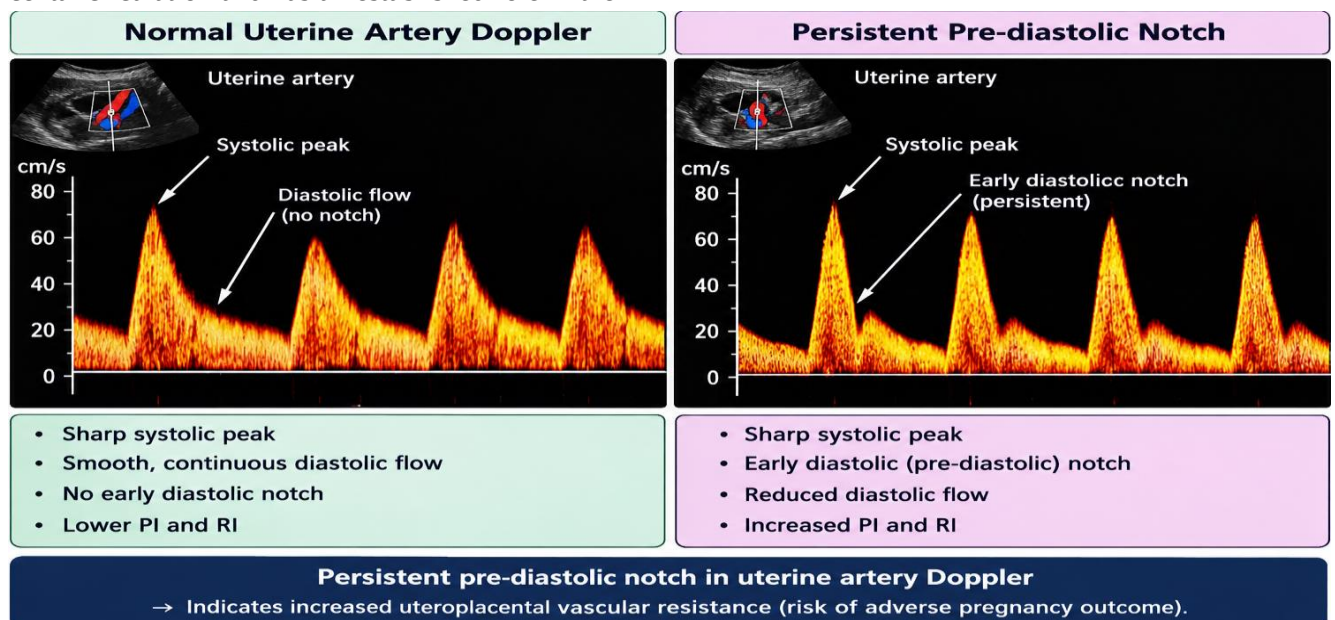


Figure1: Persistent pre-diastolic notch in uterine artery Doppler

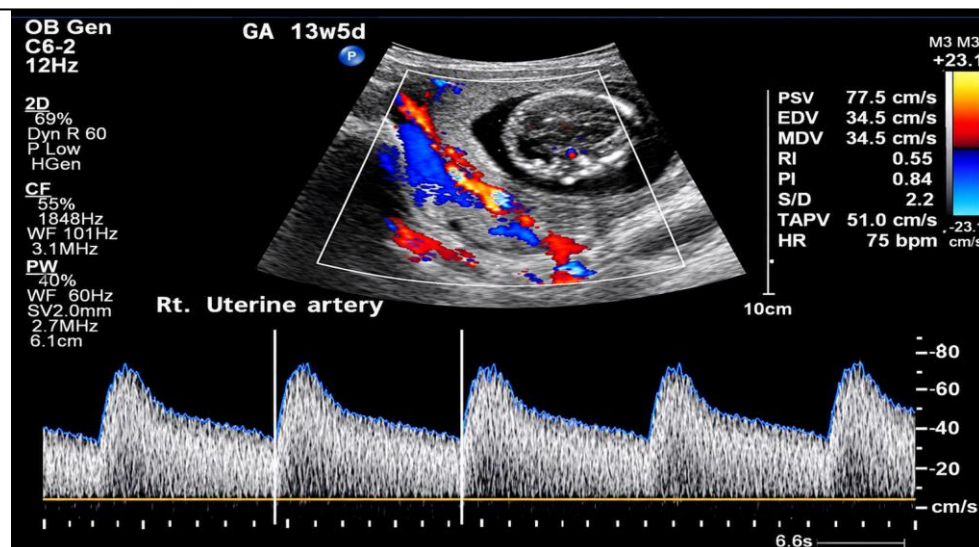


Figure 2: Color Doppler and spectral Doppler assessment of the right uterine artery at 13 weeks and 5 days of gestation, demonstrating systolic peak and persistent diastolic blood flow.

Middle Cerebral Artery Doppler and the Brain-Sparing Effect

As part of the wider sequence of fetal adaptive responses to placental insufficiency, chronic hypoxemia promotes cerebral vasodilatation, reducing impedance to flow in the MCA as cardiac output is redistributed toward the brain the brain-sparing effect described within the broader spectrum of fetal cardiovascular, endocrine and behavioral adaptation⁵. Correct technique for MCA sampling, including vessel location and the number of waveforms averaged, is specified in the ISUOG Doppler velocimetry guideline to support reproducible measurement⁴.

Cerebroplacental Ratio

The CPR, calculated as the MCA pulsatility index divided by the UA pulsatility index, has been proposed for the routine surveillance of pregnancies with suspected FGR because it integrates information from both the placental and cerebral circulations^{6,7}. A systematic review and meta-analysis by Nassr and colleagues, including seven studies of pregnancies at high risk for or diagnosed with FGR, found that abnormal CPR increased the risk of adverse perinatal outcome, with summary receiver-operating-characteristic curves indicating

better predictive accuracy for neonatal complications and admission to the neonatal intensive care unit than either Doppler component alone⁶.

A subsequent systematic review and meta-analysis by Conde-Agudelo and colleagues found that CPR was significantly superior to isolated UA or MCA Doppler in predicting a composite of adverse perinatal outcomes and emergency delivery for fetal distress in suspected FGR⁷, and noted that UA Doppler velocimetry in high-risk pregnancies had previously been shown to be associated with a significant reduction in perinatal mortality and with fewer Cesarean deliveries and inductions of labor⁷. A separate systematic review and meta-analysis by Vollgraff Heidweiller-Schreurs and colleagues similarly evaluated the prognostic accuracy of CPR and MCA Doppler for adverse perinatal outcome across singleton pregnancies of varying risk profiles¹², reinforcing the incremental value of the combined ratio over either vessel assessed in isolation^{7,12}.

Ductus Venosus and Venous Doppler

In severe early-onset FGR, the ductus venosus may show characteristic waveform changes as the fetus develops progressive cardiovascular compromise. Fratelli and colleagues described patterns of DV waveform abnormality, including a reduced, absent

or reversed a-wave the component of the waveform reflecting flow during atrial contraction in fetuses with early growth restriction⁹.

The Trial of Randomized Umbilical and Fetal Flow in Europe (TRUFFLE) was a prospective, multi-centre, randomized management trial conducted in 20 tertiary fetal medicine centres across five European countries (Germany, Italy, the Netherlands, Austria and the United Kingdom), enrolling singleton pregnancies with very preterm FGR⁸. The trial compared changes in the fetal DV Doppler waveform against cardiotocography short-term variation as the trigger for delivery, and reported two-year neurodevelopmental and intermediate perinatal outcomes⁸. SMFM's consult document notes that, within the TRUFFLE cohort, maternal hypertensive disease was present in 50% of pregnancies during the study period and in 70% of pregnancies by the time of delivery, underscoring the frequent overlap between placental insufficiency and maternal hypertensive disorders in early-onset FGR¹.

Integration with the Fetal Biophysical Profile

Beyond Doppler velocimetry alone, a multi-society expert panel has specifically addressed the role of the fetal biophysical profile in the management of FGR, examining how biophysical assessment can be integrated alongside Doppler surveillance in growth-restricted pregnancies¹⁴. This reflects a broader move toward combining several complementary modalities, rather than relying on any single test, when monitoring FGR pregnancies^{13,14}.

Staging and Multimodal Approaches to Management

Figueras and Gratacós proposed a stage-based approach to the management of FGR, in which the first clinically relevant step is distinguishing 'true' FGR associated with signs of abnormal fetoplacental function and poorer perinatal outcome from a constitutionally small-for-gestational-age fetus with near-normal perinatal outcome¹¹. They emphasized that this distinction should not rely on umbilical artery Doppler alone, since it identifies only severe, early-onset forms of placental insufficiency, and proposed that CPR, uterine artery Doppler and a growth centile below the third centile all be considered alongside UA Doppler in establishing the diagnosis¹¹.

More recently, a multi-society Clinical Opinion by Lees and colleagues set out an evidence-based approach to the diagnosis and management of suspected FGR, synthesizing biometric, Doppler and biophysical evidence into a more standardized framework intended to reduce the wide variation in clinical practice that has historically characterized this condition¹³.

Comparison of Major Contemporary Guidelines

The table below summarizes key points of agreement and divergence between the SMFM and ISUOG guidelines on the diagnosis and Doppler-based surveillance of FGR^{1,2}.

Issue	SMFM (2020)	ISUOG (2020)
FGR definition	EFW/AC < 10th percentile	Biometry + gestational age + Doppler; early/late-onset distinction
UA Doppler	Central to surveillance; frequency guided by resistance/AEDV/REDV	Central to surveillance
MCA / CPR	Not recommended for routine clinical management	Included in multimodal assessment, especially late-onset FGR
Ductus venosus	Not recommended routinely	Included, particularly in early-onset FGR
Uterine artery	Not recommended for management of established FGR	Used according to clinical context

ACOG's Practice Bulletin similarly acknowledges the lack of consensus on terminology, etiology and diagnostic criteria for FGR, and the resulting uncertainty about optimal management and timing of delivery, echoing the divergence seen between SMFM and ISUOG¹⁰.

Early-Onset versus Late-Onset FGR

Early-onset FGR, diagnosed before 32 weeks of gestation, is typically more severe, tends to follow an established pattern of Doppler deterioration, shows more significant placental dysfunction than late-onset disease, and is more commonly associated with maternal hypertensive disorders of pregnancy¹. Fetuses with genetic abnormalities can also present with early-onset FGR, commonly alongside fetal or amniotic fluid abnormalities¹. Late-onset FGR, diagnosed at or after 32 weeks, represents approximately 70% to 80% of FGR cases and is typically milder in presentation¹. Figueras and Gratacós note that, once a diagnosis of FGR is established, further classification into early- and late-onset phenotypes is useful mainly because it distinguishes two clinically distinct patterns of disease¹¹.

Limitations of Doppler Assessment

The reproducibility of Doppler indices depends on strict adherence to standardized technique, including correct vessel identification, sampling location, number of waveforms averaged, and use of auto-trace rather than manual tracing where recommended, as detailed in the ISUOG Doppler velocimetry guideline⁴. ACOG and SMFM both highlight the broader difficulty of distinguishing a constitutionally small but healthy fetus from one that is pathologically growth-restricted, which remains a limitation of biometry- and Doppler-based diagnosis alike^{1,10}.

Future Directions

Multi-society clinical opinion has called for a more evidence-based, standardized approach to the diagnosis and management of suspected FGR, integrating biometric, Doppler and biophysical parameters

rather than relying on isolated thresholds¹³. Continued evaluation of how the fetal biophysical profile can be integrated with Doppler surveillance represents an active area of multi-society interest¹⁴, as does further meta-analytic clarification of the incremental predictive value of CPR over its individual components^{6,7,12}.

Discussion

Across the evidence reviewed, UA Doppler emerges as the most consistently established Doppler parameter in FGR surveillance, incorporated centrally into the SMFM, ACOG and ISUOG frameworks^{1,2,10}. Uterine artery Doppler contributes information about the maternal side of placentation and risk stratification but is applied differently in clinical management by SMFM and ISUOG^{1,2,15}. The CPR adds incremental predictive value for adverse perinatal outcome beyond UA or MCA Doppler alone across three independent meta-analyses^{6,7,12}, although SMFM does not recommend its routine use for clinical management¹. DV Doppler abnormalities characterize advancing fetal cardiovascular compromise in severe early-onset FGR⁹, and the TRUFFLE trial provided randomized evidence on how DV-based monitoring compares with cardiotocography-based monitoring in guiding delivery timing for very preterm FGR⁸.

Because SMFM, ACOG and ISUOG differ in their recommendations regarding the routine clinical use of MCA, DV and uterine artery Doppler^{1,2,10}, and because Figueras and Gratacós and the multi-society Clinical Opinion of Lees and colleagues both argue for multi-parameter, staged assessment rather than reliance on any single Doppler test^{11,13}, Doppler findings in FGR should be interpreted according to gestational age, FGR phenotype, disease stage, and the specific guideline framework adopted by the managing unit^{1,2,11,13}. More recent studies that it can play a use full role in determining the prognosis of fetuses with IUGR. In growth restricted fetuses reversed diastolic flow in the umbilical artery carries a grave prognosis and absent diastolic flow or an elevated systolic to diastolic ratio is

associated with poor prognosis, including increased likelihood of fD in labor, admission to the intensive care unit, and perinatal mortality.

Although no single parameter permits confident diagnosis of IUGR.

Conclusion

Color and spectral Doppler ultrasonography provide physiological information that meaningfully complements fetal biometry in the assessment of FGR^{1,2,10}. Umbilical artery Doppler has the best-established role in surveillance across major guidelines^{1,2,10}, uterine artery Doppler contributes to risk stratification for placental dysfunction^{2,15}, the cerebroplacental ratio adds predictive value for adverse perinatal outcome across multiple meta-analyses^{6,7,12}, and ductus venosus Doppler informs the monitoring of severe early-onset disease as evaluated in the TRUFFLE trial^{8,9}. Continuing divergence between SMFM, ACOG and ISUOG on the routine clinical application of MCA, DV and uterine artery Doppler^{1,2,10}, together with the move toward staged, multimodal, evidence-based frameworks^{11,13,14}, means these parameters should be applied and interpreted according to gestational age, disease severity, FGR phenotype and the guideline framework in use, rather than as isolated, universally-thresholded tests.

References

1. Society for Maternal-Fetal Medicine; Martins JG, Biggio JR, Abuhamad A. Society for Maternal-Fetal Medicine Consult Series #52: diagnosis and management of fetal growth restriction. *Am J Obstet Gynecol*. 2020;223(4):B2-B17. doi:10.1016/j.ajog.2020.05.010.
2. Lees CC, Stampalija T, Baschat A, da Silva Costa F, Ferrazzi E, Figueras F, et al. ISUOG Practice Guidelines: diagnosis and management of small-for-gestational-age fetus and fetal growth restriction. *Ultrasound Obstet Gynecol*. 2020;56(2):298-312. doi:10.1002/uog.22134.
3. Gordijn SJ, Beune IM, Thilaganathan B, Papageorghiou A, Baschat AA, Baker PN, et al. Consensus definition of fetal growth restriction: a Delphi procedure. *Ultrasound Obstet Gynecol*. 2016;48(3):333-339. doi:10.1002/uog.15884.
4. Bhide A, Acharya G, Baschat A, Bilardo CM, Brezinka C, Cafici D, et al. ISUOG Practice Guidelines (updated): use of Doppler velocimetry in obstetrics. *Ultrasound Obstet Gynecol*. 2021;58(2):331-339. doi:10.1002/uog.23698.
5. Baschat AA. Fetal responses to placental insufficiency: an update. *BJOG*. 2004;111(10):1031-1041. doi:10.1111/j.1471-0528.2004.00273.x.
6. Nassr AA, Abdelmagied AM, Shazly SA. Fetal cerebro-placental ratio and adverse perinatal outcome: systematic review and meta-analysis of the association and diagnostic performance. *J Perinat Med*. 2016;44(2):249-256. doi:10.1515/jpm-2015-0274.
7. Conde-Agudelo A, Villar J, Kennedy SH, Papageorghiou AT. Predictive accuracy of cerebroplacental ratio for adverse perinatal and neurodevelopmental outcomes in suspected fetal growth restriction: systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2018;52(4):430-441. doi:10.1002/uog.19117.
8. Lees CC, Marlow N, van Wassenhaer-Leemhuis A, Arabin B, Bilardo CM, Brezinka C, et al.; TRUFFLE study group. 2 year neurodevelopmental and intermediate perinatal outcomes in infants with very preterm fetal growth restriction (TRUFFLE): a randomised trial. *Lancet*. 2015;385(9983):2162-2172. doi:10.1016/S0140-6736(14)62049-3.
9. Fratelli N, Amighetti S, Bhide A, Fichera A, Khalil A, Papageorghiou AT, et al. Ductus venosus Doppler waveform pattern in fetuses with early growth restriction. *Acta Obstet Gynecol Scand*. 2020;99(5):608-614. doi:10.1111/aogs.13782.
10. American College of Obstetricians and Gynecologists. Fetal Growth Restriction: ACOG Practice Bulletin, Number 227. *Obstet Gynecol*. 2021;137(2):e16-e28. doi:10.1097/AOG.0000000000004251.
11. Figueras F, Gratacos E. Stage-based approach to the management of fetal growth restriction. *Prenat Diagn*. 2014;34(7):655-659. doi:10.1002/pd.4412.
12. Vollgraff Heidweiller-Schreurs CA, De Boer MA, Heymans MW, Schoonmade LJ, Bossuyt

- PMM, Mol BWJ, et al. Prognostic accuracy of cerebroplacental ratio and middle cerebral artery Doppler for adverse perinatal outcome: systematic review and meta-analysis. *Ultrasound Obstet Gynecol.* 2018;51(3):313-322. doi:10.1002/uog.18809.
13. Lees CC, Romero R, Stampalija T, Dall'Asta A, DeVore GA, Prefumo F, et al. Clinical Opinion: the diagnosis and management of suspected fetal growth restriction: an evidence-based approach. *Am J Obstet Gynecol.* 2022;226(3):366-378. doi:10.1016/j.ajog.2021.11.1357.
14. Baschat AA, Galan HL, Lee W, DeVore GR, Mari G, Hobbins J, et al. The role of the fetal biophysical profile in the management of fetal growth restriction. *Am J Obstet Gynecol.* 2022;226(4):475-486. doi:10.1016/j.ajog.2022.01.020.
15. Papageorghiou AT, Yu CK, Bindra R, Pandis G, Nicolaides KH; Fetal Medicine Foundation Second Trimester Screening Group. Multicenter screening for pre-eclampsia and fetal growth restriction by transvaginal uterine artery Doppler at 23 weeks of gestation. *Ultrasound Obstet Gynecol.* 2001;18(5):441-449. doi:10.1046/j.0960-7692.2001.00572.x.
16. Bari AKMF. *Ultrasound & color Doppler in medical science.* 3rd ed. Dhaka: Bangladesh Institute of Thyroid Medicine & Imaging Research (BITMIR); 2025.