RESEARCH PAPER

Maternal Risk Factors, Doppler Parameters and Perinatal Outcomes in Pregnancies Complicated by Intrauterine Growth Restriction: A Cross Sectional Study

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ABSTRACT

Introduction: Fetal Growth Restriction (FGR) is a major contributor to perinatal morbidity and mortality. Maternal comorbidities, altered fetal growth parameters, and abnormal Doppler indices play a crucial role in disease progression and adverse outcomes. Comprehensive evaluation of these factors is essential for timely intervention and improved neonatal outcomes.

Aim and Objective: To assess maternal risk factors, fetal biometric and Doppler parameters, intrapartum details, and perinatal outcomes in pregnancies complicated by intrauterine growth restriction.

Material and Methods: This observational study included 100 pregnant women diagnosed with FGR. Maternal demographic details, obstetric history, gestational age at diagnosis, associated medical conditions, fetal growth parameters, amniotic fluid assessment, Doppler indices, mode of delivery, and perinatal outcomes were analyzed. Results were expressed as frequencies and percentages.

Results: The majority of women were aged between 26–30 years (42%), and 64% were primigravida. Most cases were diagnosed between 33–36 weeks of gestation (49%). Pregnancy-induced hypertension (31%), anemia (43%), and preeclampsia (26%) were common associated risk factors. Abdominal circumference below the 10th percentile was observed in 81% of fetuses, indicating predominantly asymmetrical FGR. Abnormal umbilical artery Doppler findings were present in 40%, while abnormal cerebroplacental ratio was noted in 37% of cases. Cesarean section was performed in 54% of pregnancies. NICU admission was required in 35%, and perinatal mortality was observed in 3% of cases.

Conclusion: FGR is frequently associated with maternal hypertension, anemia, and abnormal Doppler parameters. Doppler surveillance, particularly umbilical artery and cerebroplacental ratio assessment, is a valuable tool in predicting adverse perinatal outcomes and guiding timely obstetric management.

Keywords: Intrauterine growth restriction, Doppler velocimetry, maternal risk factors, perinatal outcome, umbilical artery.

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INTRODUCTION

Fetal Growth Restriction (FGR), also known as intrauterine growth restriction (IUGR), is a significant obstetric condition characterized by the failure of the fetus to achieve its genetically predetermined growth potential. It represents a major contributor to perinatal morbidity and mortality worldwide, accounting for a substantial proportion of stillbirths, neonatal deaths, and long-term developmental disabilities [1]. The global prevalence of FGR ranges between 3–10% of all pregnancies, with a disproportionately higher burden in low- and middleincome countries due to maternal malnutrition, anemia, infections, and limited access to antenatal care [2].

FGR is a complex and multifactorial disorder resulting from the interplay of maternal, fetal, placental, and environmental factors. Among these, placental insufficiency is considered the most common underlying cause, leading to impaired uteroplacental blood flow and reduced transfer of oxygen and nutrients to the developing fetus [3]. This results in chronic fetal hypoxia, which triggers adaptive mechanisms aimed at preserving oxygen supply to vital organs. Maternal factors such as hypertensive disorders of pregnancy, anemia, diabetes mellitus, malnutrition, renal disease, and autoimmune conditions are strongly associated with FGR [4,5]. In addition, fetal causes such as chromosomal abnormalities, congenital malformations, and intrauterine infections, as well as placental abnormalities like infarction and abnormal implantation, further contribute to growth restriction [6].

The pathophysiology of FGR is closely linked to abnormal placentation during early pregnancy. Inadequate trophoblastic invasion of the spiral arteries leads to high-resistance uteroplacental circulation, resulting in reduced perfusion of the placenta [7]. This impaired perfusion causes oxidative stress, endothelial dysfunction, and altered angiogenesis, ultimately compromising fetal growth. As the condition progresses, the fetus adapts by redistributing blood flow preferentially to essential organs such as the brain, heart, and adrenal glands—a phenomenon known as the “brain-sparing effect” [8]. This adaptive response is reflected in Doppler studies as decreased resistance in the middle cerebral artery (MCA) and altered cerebroplacental ratio (CPR), which serve as important markers of fetal compromise.

FGR is broadly classified into early-onset (<32 weeks) and late-onset (>32 weeks) types, each with distinct etiological, clinical, and prognostic characteristics [9]. Early-onset FGR is usually associated with severe placental insufficiency and carries a higher risk of perinatal mortality and morbidity. In contrast, late-onset FGR is more common but often subtle, making diagnosis challenging despite its association with significant neonatal complications and long-term neurodevelopmental impairment [10].

Advances in obstetric imaging have significantly improved the diagnosis and monitoring of FGR. Ultrasound biometry, including parameters such as abdominal circumference (AC), biparietal diameter (BPD), head circumference (HC), and femur length (FL), remains the cornerstone of diagnosis. Among these, abdominal circumference is considered the most sensitive parameter for detecting growth restriction [11]. Serial measurements of estimated fetal weight (EFW) further aid in assessing growth trends and severity.

In recent years, Doppler velocimetry has emerged as an essential tool in the evaluation of FGR, providing insights into fetal hemodynamics and placental function. The umbilical artery Doppler reflects placental resistance, and abnormalities such as increased pulsatility index, absent end-diastolic flow (AEDF), and reversed end-diastolic flow (REDF) are associated with worsening placental insufficiency and poor perinatal outcomes [12]. Similarly, the middle cerebral artery Doppler assesses fetal adaptation to hypoxia, while the cerebroplacental ratio (CPR) integrates both placental and fetal circulatory changes, serving as a sensitive predictor of adverse outcomes [13].

Recent studies (2024–2025) have emphasized the importance of combining Doppler indices with ultrasound parameters to improve diagnostic accuracy and risk stratification. Wang et al. (2025) demonstrated that integrated ultrasound and Doppler assessment significantly enhances early detection and management of FGR [2]. Hong et al. (2025) reported a strong correlation between abnormal CPR and placental pathology, highlighting its clinical significance [4]. Furthermore, Chen et al. (2025) identified maternal arterial stiffness as an independent predictor of early-onset FGR, underscoring the role of maternal cardiovascular factors in disease pathogenesis [5].

In addition to imaging modalities, emerging research has focused on biochemical markers such as placental growth factor (PlGF) and pregnancy-associated plasma protein-A (PAPP-A) for early prediction of FGR. Reduced levels of these markers are associated with impaired placental development and increased risk of adverse outcomes [6]. Advanced techniques such as magnetic resonance imaging (MRI) and artificial intelligence-based predictive models are also being explored to enhance early diagnosis and improve clinical decision-making [14].

FGR is associated with a wide spectrum of adverse perinatal outcomes, including preterm birth, low birth weight, hypoglycemia, respiratory distress syndrome, sepsis, and long-term neurodevelopmental impairment [15]. Studies have also shown that FGR has implications beyond the neonatal period, contributing to an increased risk of chronic diseases such as hypertension, diabetes, and cardiovascular disorders in adulthood, as proposed by the Barker hypothesis [16].

Despite significant advances in diagnostic techniques and fetal surveillance, the management of FGR remains challenging. The only definitive treatment is timely delivery, which requires careful balancing of the risks of prematurity against the risks of intrauterine hypoxia and fetal demise [17]. Therefore, early identification of high-risk pregnancies and close monitoring using a combination of clinical, biochemical, and imaging parameters are essential to optimize outcomes.

Given the high burden and clinical significance of FGR, especially in developing countries, there is a need for comprehensive evaluation of maternal risk factors, fetal growth parameters, Doppler findings, and perinatal outcomes. The present study was undertaken to assess these parameters in pregnancies complicated by FGR, with the aim of improving understanding, early detection, and management strategies to reduce perinatal morbidity and mortality.

MATERIALS AND METHODS

This was a **prospective observational study** conducted over a period of **12 months (January 2025 - December 2025)** at Integral Institute of Medical Sciences, Lucknow, Uttar Pradesh in the Department of radiology. The study aimed to evaluate maternal risk factors, fetal biometric parameters, Doppler findings, and perinatal outcomes in pregnancies complicated by fetal growth restriction (FGR). The study was approved by the institutional ethics committee, and informed consent was obtained from all participants prior to inclusion.

Study Population

The study included **pregnant women diagnosed with fetal growth restriction** based on ultrasound and clinical findings. All women were evaluated for the study at the time of diagnosis, and follow-up was performed until delivery and the immediate neonatal period.

Inclusion Criteria:

1. Pregnant women aged **18-40 years**.
2. Gestational age between **20–40 weeks** at the time of diagnosis.
3. Diagnosis of **fetal growth restriction (FGR)** based on clinical signs (such as decreased fetal movement, abnormal symphysis-fundal height) and confirmed by **ultrasonography** (abdominal circumference <10th percentile for gestational age).
4. **Singleton pregnancies** with a confirmed **cephalic presentation**.
5. **Consent to participate** in the study was obtained from all enrolled patients.

Exclusion Criteria:

1. **Multiple pregnancies** (twins, triplets, etc.).
2. Women with known **chromosomal abnormalities** or **major congenital malformations** in the fetus.
3. Pregnancies with **severe maternal comorbidities** (e.g., chronic kidney disease, severe cardiac disease, or uncontrolled diabetes).
4. **Pregnancies with incomplete data** or those lost to follow-up during the study period.
5. **Intrauterine fetal demise** prior to the study or during the initial assessment.

Data Collection

Data collection involved both **clinical assessments** and **instrumental evaluations**.

Maternal Assessment:

- **Demographic Data:** Age, parity, gestational age at booking, medical history (hypertension, diabetes, anemia, etc.).
- **Clinical History:** Obstetric history, history of hypertension, diabetes, or any other relevant medical condition.

Fetal Assessment:

1. **Ultrasound Biometry:** Fetal parameters (abdominal circumference, head circumference, biparietal diameter, femur length) were measured using a **high-resolution ultrasound machine**. The **estimated fetal weight (EFW)** was calculated using Hadlock's formula.
2. **Doppler Velocimetry:** Doppler assessments were performed for the **umbilical artery** (UA), **middle cerebral artery** (MCA), and **cerebroplacental ratio** (CPR). Abnormal Doppler findings, including **increased pulsatility index** (PI), **absent end-diastolic flow (AEDF)**, and **reversed end-diastolic flow (REDF)**, were noted and classified according to severity.

Perinatal Outcomes:

- **Mode of delivery** (vaginal vs. cesarean section).
- **Neonatal weight** and **Apgar scores** at 1 and 5 minutes.
- **NICU admission** rates and other **neonatal complications** (e.g., hypoglycemia, respiratory distress syndrome, jaundice).
- **Perinatal mortality** was recorded if applicable.

Statistical Analysis

Data analysis was performed using **SPSS version 25** (SPSS Inc., Chicago, IL). Descriptive statistics, including means, medians, and standard deviations, were used to summarize continuous variables. Categorical variables were analyzed using chi-square or Fisher's exact tests. A **p-value of <0.05** was considered statistically significant. Logistic regression was applied to identify independent risk factors associated with adverse perinatal outcomes.

RESULTS

The maternal demographic profile revealed that the majority of women belonged to the 26–30-year age group (42%), followed by women aged ≤25 years (38%). Primigravida constituted 64% of the study population, indicating that FGR was more commonly observed in first pregnancies. Multigravida women accounted for 36% of cases.

Most cases of FGR were diagnosed in the late third trimester, with 49% identified between 33–36 weeks of gestation. Early-onset FGR (28–32 weeks) was observed in 36% of cases, while only 15% were diagnosed at or beyond 37 weeks. This highlights the predominance of late-onset FGR in the study population.

Pregnancy-induced hypertension was the most common medical disorder, affecting 31% of women, followed by maternal anemia (43%) and preeclampsia (26%). Gestational diabetes mellitus was present in 19% of cases. Approximately 27% of women had no identifiable maternal risk factors, suggesting the multifactorial nature of FGR.

Table 1. Maternal Demographic and Obstetric Profile

Parameter	Number (n)	Percentage (%)
Maternal age ≤25 years	38	38
Maternal age 26–30 years	42	42
Maternal age >30 years	20	20
Primigravida	64	64
Multigravida	36	36

Table 2. Gestational Age at Diagnosis of FGR

Gestational Age (weeks)	Number (n)	Percentage (%)
28–32 weeks	36	36
33–36 weeks	49	49
≥37 weeks	15	15
Total	**100**	**100**

Table 3. Associated Maternal Risk Factors

Risk Factor	Number (n)	Percentage (%)
Pregnancy-induced hypertension (PIH)	31	31
Preeclampsia	26	26
Gestational diabetes mellitus (GDM)	19	19
Maternal anemia	43	43
No associated risk factor	27	27

Table 4. Estimated Fetal Weight (EFW)

Estimated Fetal Weight	Number (n)	Percentage (%)
<1,500 g	24	24
1,500–2,000 g	46	46
>2,000 g	30	30
Total	**100**	**100**

Table 5. Fetal Biometric Parameters

Parameter	Abnormal (<10th percentile) n (%)	Normal n (%)
Abdominal circumference (AC)	81 (81%)	19 (19%)

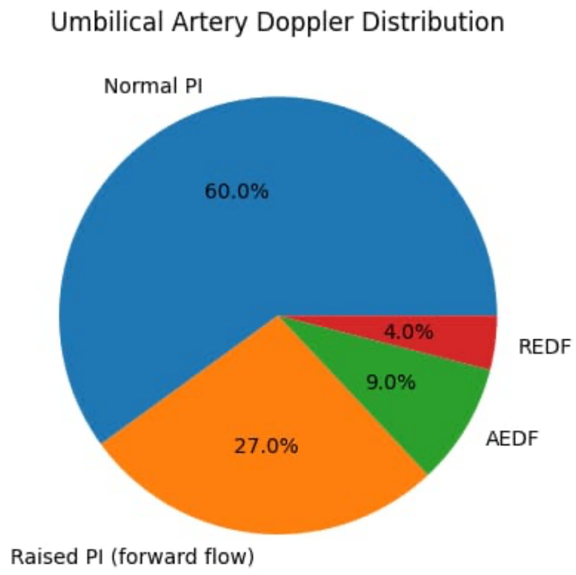
Parameter	Abnormal (<10th percentile) n (%)	Normal n (%)
Biparietal diameter (BPD)	35 (35%)	65 (65%)
Head circumference (HC)	32 (32%)	68 (68%)
Femur length (FL)	28 (28%)	72 (72%)

Table 6. Amniotic Fluid Assessment

Amniotic Fluid Index	Number (n)	Percentage (%)
Normal AFI	56	56
Oligohydramnios	36	36
Severe oligohydramnios	8	8
Total	**100**	**100**

Table 7. Umbilical Artery Doppler Findings

Umbilical Artery Doppler	Number (n)	Percentage (%)
Normal PI	60	60
Raised PI with forward flow	27	27
Absent end-diastolic flow (AEDF)	9	9
Reversed end-diastolic flow (REDF)	4	4
Total	**100**	**100**



Graph 1: Umbilical Artery Doppler Findings

Table 8. Other Doppler Parameters

Doppler Parameter	Abnormal n (%)	Normal n (%)
Middle cerebral artery PI	34 (34%)	66 (66%)
Cerebroplacental ratio (CPR)	37 (37%)	63 (63%)
Uterine artery Doppler	29 (29%)	71 (71%)

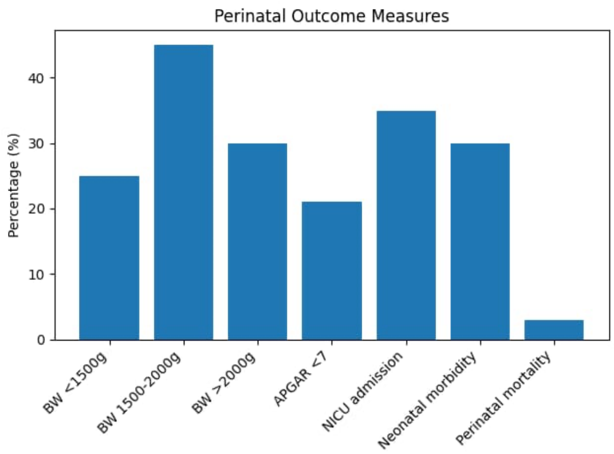
Table 9. Intrapartum Details

Parameter	Number (n)	Percentage (%)
Vaginal delivery	46	46
Cesarean section	54	54
└ Emergency cesarean	40	40
└ Elective cesarean	14	14

Table 10. Perinatal Outcome Measures

Outcome	Number (n)	Percentage (%)

Outcome	Number (n)	Percentage (%)
Birth weight <1,500 g	25	25
Birth weight 1,500–2,000 g	45	45
Birth weight >2,000 g	30	30
APGAR <7 at 5 minutes	21	21
NICU admission	35	35
Neonatal morbidity	30	30
Perinatal mortality	3	3



Graph 2: Perinatal Outcome Measures

Estimated fetal weight assessment showed that 46% of fetuses weighed between 1,500–2,000 g, while 24% had an estimated weight below 1,500 g. Nearly one-third of fetuses (30%) had an estimated fetal weight above 2,000 g, indicating varying severity of growth restriction among the cases

Abdominal circumference below the 10th percentile was observed in 81% of fetuses, making it the most sensitive parameter for diagnosing FGR. Reduced biparietal diameter, head circumference, and femur length were seen in 35%, 32%, and 28% of cases, respectively. Preservation of head circumference in a significant proportion suggests a brain-sparing effect.

More than half of the pregnancies (56%) had a normal amniotic fluid index. Oligohydramnios was present in 36%, while severe oligohydramnios was observed in 8% of cases. Reduced amniotic fluid volume was frequently associated with abnormal Doppler findings and lower estimated fetal weight.

Normal umbilical artery Doppler indices were observed in 60% of cases. Among abnormal findings, raised pulsatility index with forward diastolic flow was the most common (27%), followed by absent (9%) and reversed end-diastolic flow (4%). Severe Doppler abnormalities were associated with increased operative delivery and adverse perinatal outcomes.

Abnormal middle cerebral artery pulsatility index was observed in 34% of cases, suggesting redistribution of fetal circulation. Abnormal cerebroplacental ratio was noted in 37%, and abnormal uterine artery Doppler was found in 29% of cases. These abnormalities were more common in pregnancies complicated by hypertensive disorders.

Vaginal delivery was achieved in 46% of cases, while 54% required cesarean section. Emergency cesarean section accounted for the majority of operative deliveries (40%), primarily due to abnormal Doppler findings and non-reassuring fetal heart rate patterns.

Low birth weight below 1,500 g was observed in 25% of neonates. An APGAR score below 7 at 5 minutes was noted in 21%, and 35% of neonates required NICU admission. Neonatal morbidity was documented in 30%, and perinatal mortality occurred in 3% of cases, predominantly among fetuses with severe growth restriction and abnormal Doppler findings.

DISCUSSION

Fetal growth restriction (FGR) remains a major contributor to perinatal morbidity and mortality, particularly in developing countries where maternal nutritional deficiencies and limited antenatal surveillance are prevalent. The present study provides a comprehensive evaluation of maternal risk factors, fetal biometric parameters, Doppler indices, and perinatal outcomes in pregnancies complicated by FGR, highlighting important clinical correlations and reinforcing existing evidence.

Maternal Demographic and Obstetric Factors

In the present study, the majority of women belonged to the **26–30-year age group (42%)**, followed closely by those aged ≤25 years (38%). Similar age distributions have been reported in previous studies, suggesting that FGR is not limited to advanced maternal age but is also prevalent in younger women, particularly in resource-limited settings [1,15]. The predominance of **primigravida (64%)** in this study is consistent with findings by Sharma et al., who reported an increased risk of FGR in first pregnancies due to inadequate uteroplacental adaptation and higher incidence of hypertensive disorders [15].

Primigravidity has been associated with abnormal trophoblastic invasion and incomplete remodeling of spiral arteries, leading to placental insufficiency and impaired fetal growth [7]. This observation reinforces the importance of close antenatal surveillance in first-time mothers.

Gestational Age at Diagnosis

The majority of FGR cases in this study were diagnosed in the **late third trimester (33–36 weeks, 49%)**, indicating a predominance of late-onset FGR. This finding is consistent with the classification proposed by Figueras and Gratacós, who emphasized that late-onset FGR constitutes the majority of cases but is often underdiagnosed due to subtle clinical presentation [10].

Late-onset FGR is associated with milder placental dysfunction compared to early-onset disease but still carries a significant risk of adverse perinatal outcomes, including fetal distress and operative delivery [9]. Early-onset FGR, observed in 36% of cases in this study, is typically associated with severe placental insufficiency and worse prognosis.

Maternal Risk Factors

Maternal risk factors play a crucial role in the development of FGR. In the present study, **maternal anemia (43%)**, **pregnancy-induced hypertension (31%)**, and **preeclampsia (26%)** were the most common associated conditions. These findings are in agreement with multiple studies highlighting maternal vascular and hematological disorders as key contributors to FGR [3,5].

Maternal anemia leads to reduced oxygen-carrying capacity, resulting in chronic fetal hypoxia and impaired growth. Similarly, hypertensive disorders of pregnancy, including preeclampsia, are characterized by endothelial dysfunction and abnormal placentation, which significantly compromise uteroplacental blood flow [3].

Recent studies (2024–2025) further support these observations. Chen et al. demonstrated that increased maternal arterial stiffness is strongly associated with early-onset FGR, suggesting that maternal cardiovascular health plays a critical role in disease pathogenesis [5]. Additionally, Lee et al. (2024) developed a predictive model identifying maternal hypertension and metabolic abnormalities as significant risk factors for late-onset FGR.

Interestingly, **27% of cases in this study had no identifiable maternal risk factors**, indicating the multifactorial and sometimes idiopathic nature of FGR. This underscores the importance of routine fetal surveillance even in low-risk pregnancies.

Fetal Biometric Parameters

Fetal biometry remains a cornerstone in the diagnosis of FGR. In the present study, **abdominal circumference (AC) was reduced in 81% of cases**, making it the most sensitive parameter for detecting growth restriction. This finding is consistent with the work of Hadlock et al., who established AC as the earliest and most reliable indicator of fetal malnutrition [11].

Other parameters such as biparietal diameter (35%), head circumference (32%), and femur length (28%) were less frequently affected, suggesting a pattern of **asymmetrical FGR**. This pattern reflects preferential preservation of head growth due to redistribution of blood flow to the brain, known as the **brain-sparing effect** [8].

The presence of asymmetrical FGR indicates chronic placental insufficiency and is often associated with better neonatal outcomes compared to symmetrical FGR, which is typically linked to early insults such as infections or chromosomal abnormalities.

Amniotic Fluid Assessment

Amniotic fluid volume is an important indicator of placental function. In this study, **oligohydramnios was observed in 36% of cases**, while severe oligohydramnios was present in 8%. Reduced amniotic fluid is commonly associated with placental insufficiency and decreased fetal renal perfusion.

Studies have shown that oligohydramnios is an independent predictor of adverse perinatal outcomes, including fetal distress and need for operative delivery [17]. The association between low amniotic fluid and abnormal Doppler findings further emphasizes its clinical significance.

Doppler Velocimetry Findings

Doppler studies play a pivotal role in the evaluation of fetal hemodynamics and placental function. In the present study, **abnormal umbilical artery Doppler findings were observed in 40% of cases**, including raised pulsatility index, absent end-diastolic flow (AEDF), and reversed end-diastolic flow (REDF).

These findings are consistent with previous studies demonstrating that abnormal umbilical artery Doppler reflects increased placental resistance and is strongly associated with adverse perinatal outcomes [12]. The TRUFFLE study highlighted the importance of Doppler monitoring in guiding the timing of delivery and improving neonatal outcomes [12].

Abnormal **middle cerebral artery (MCA) Doppler (34%)** and **cerebroplacental ratio (CPR) abnormalities (37%)** observed in this study indicate fetal adaptation to hypoxia. Reduced MCA resistance reflects cerebral vasodilation, while abnormal CPR serves as a sensitive marker of fetal compromise [13].

Recent studies have reinforced the importance of CPR. Hong et al. (2025) demonstrated a strong correlation between abnormal CPR and placental pathology, suggesting its role as a reliable predictor of adverse outcomes [4]. Similarly, Wang et al. (2025) reported that combining Doppler indices with ultrasound significantly improves early detection and management of FGR [2].

Intrapartum Outcomes

In this study, **54% of cases required cesarean section**, with a majority being emergency procedures (40%). This high rate of operative delivery is consistent with previous studies and reflects the increased incidence of fetal distress in FGR pregnancies [17].

Abnormal Doppler findings, particularly AEDF and REDF, are strong indications for early delivery and are often associated with non-reassuring fetal heart rate patterns. These findings highlight the importance of timely intervention to prevent intrauterine fetal demise.

A recent prospective study (2025) evaluating Doppler parameters in 90 pregnancies demonstrated that abnormal Doppler indices were significantly associated with fetal growth restriction and adverse perinatal outcomes ($p < 0.001$). Among all parameters, the cerebroplacental ratio (CPR) showed the highest diagnostic accuracy (89.2%), sensitivity (84.6%), and specificity (91.9%), outperforming individual indices such as umbilical artery and middle cerebral artery Doppler. The study further reported that combined Doppler assessment improved prediction of fetal compromise, and abnormal findings were strongly associated with low birth weight, poor Apgar scores, and increased NICU admissions, emphasizing the clinical utility of integrated Doppler surveillance in FGR management [18].

A 2025 prospective observational study on hypertensive pregnancies found that abnormal cerebroplacental ratio (CPR <1.0) was significantly associated with adverse perinatal outcomes. The study reported higher cesarean section rates (80% vs 40%), increased incidence of low birth weight (67.5% vs 28.8%), low Apgar scores (68.8% vs 25%), and higher NICU admissions (72.5% vs 28.8%) in fetuses with abnormal CPR. These findings indicate that CPR is a highly specific predictor of fetal compromise, and its routine use can facilitate early identification of high-risk fetuses and timely intervention [19] .A large cohort study (2025) involving 432 pregnancies complicated by fetal growth restriction demonstrated that pathological CPR was associated with significantly lower birth weights and higher NICU admission rates (17.4% vs 9.2%, $p = 0.03$). Although cesarean section rates were not significantly different between groups, fetuses with abnormal CPR required earlier delivery and closer monitoring. The study concluded that while CPR may not independently predict mode of delivery, it remains an important indicator of neonatal morbidity and need for intensive care, reinforcing its role in risk stratification of FGR pregnancies [20].

Perinatal Outcomes

The present study reported significant neonatal morbidity, with **NICU admission in 35%**, **neonatal morbidity in 30%**, and **perinatal mortality in 3%** of cases. These findings are consistent with global data indicating that FGR is a major determinant of adverse neonatal outcomes [15].

Low birth weight (<1,500 g) observed in 25% of cases further emphasizes the severity of growth restriction. Neonates with FGR are at increased risk of complications such as hypoglycemia, hypothermia, respiratory distress syndrome, and sepsis.

Recent studies (2025) have also highlighted the long-term consequences of FGR. Sun et al. demonstrated that FGR is associated with delayed motor development in early childhood, although outcomes may improve with appropriate neonatal care [14]. Furthermore, the **Barker hypothesis** suggests that FGR predisposes individuals to chronic diseases such as hypertension, diabetes, and cardiovascular disorders in adulthood [16].

Clinical Implications

The findings of this study have important clinical implications. Early identification of high-risk pregnancies through assessment of maternal risk factors, fetal biometry, and Doppler parameters can facilitate timely intervention and improve perinatal outcomes. Doppler surveillance, particularly assessment of the umbilical artery and cerebroplacental ratio, should be incorporated into routine antenatal care for high-risk pregnancies.

CONCLUSION

Fetal growth restriction (FGR) continues to be a significant obstetric challenge associated with increased perinatal morbidity and mortality. The present study demonstrates that maternal factors such as **anemia, pregnancy-induced hypertension, and preeclampsia** play a crucial role in the development of FGR. Among fetal biometric parameters, **abdominal circumference** emerged as the most sensitive indicator of growth restriction, reflecting early compromise in fetal nutrition.

Doppler velocimetry, particularly **umbilical artery and cerebroplacental ratio (CPR)** assessment, proved to be an invaluable tool in identifying fetal compromise and predicting adverse perinatal outcomes. Abnormal Doppler findings, especially **absent and reversed end-diastolic flow**, were strongly associated with increased rates of **cesarean delivery, NICU admission, and neonatal morbidity**.

The study highlights that a **multimodal approach combining maternal risk assessment, fetal biometry, and Doppler surveillance** is essential for early detection and optimal management of FGR. Timely intervention based on these parameters can significantly improve perinatal outcomes and reduce mortality.

LIMITATIONS OF THE STUDY

1. **Single-center study** – The findings may not be generalizable to broader populations or different healthcare settings.
2. **Relatively small sample size (n = 100)** – Limits the statistical power and ability to detect subtle associations.
3. **Lack of control group** – Absence of a comparison group of normal pregnancies restricts comparative analysis.
4. **No long-term neonatal follow-up** – Outcomes were limited to the immediate perinatal period, without assessment of long-term neurodevelopment.
5. **Limited biochemical evaluation** – Important biomarkers such as **placental growth factor (PlGF)** and **PAPP-A** were not included.
6. **No placental histopathological correlation** – Could have provided deeper insight into underlying pathophysiology.
7. **Observer-dependent variability** – Ultrasound and Doppler measurements may be subject to interobserver variation.
8. **Sociodemographic factors not deeply analyzed** – Factors such as nutrition, socioeconomic status, and access to healthcare were not extensively evaluated.

DECLARATIONS:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this paper.

Authors' contributions: Author equally contributed the work.

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