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Original Article

Umbilical Artery Doppler Indices In Hypertensive Disorders Of Pregnancy And Its Impact On Fetal Outcomes

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ABSTRACT

Background: Hypertensive disorders of pregnancy are major contributors to placental insufficiency and adverse perinatal outcomes. Umbilical artery Doppler can be used to assess fetoplacental vascular resistance, and may be indicative of fetoplacental compromise. Objective: To evaluate umbilical artery Doppler indices in women with hypertensive disorders of pregnancy and determine their association with fetal and neonatal outcomes. Methods: This prospective observational analytical cohort study included 180 singleton pregnant women with hypertensive disorders of pregnancy at Combined Military Hospital, Gujranwala. Umbilical artery Doppler assessment was performed before delivery, and participants were categorized into normal Doppler and abnormal Doppler groups. Doppler parameters included pulsatility index, resistance index, systolic/diastolic ratio, and end-diastolic flow pattern. Outcomes included low birth weight, fetal growth restriction, preterm birth, low Apgar score at five minutes, NICU admission, stillbirth, and early neonatal death. Results: Of 180 participants, 116 (64.4%) had normal Doppler findings and 64 (35.6%) had abnormal Doppler findings. Abnormal Doppler was associated with higher risks of low birth weight (45.3% vs 18.1%; RR 2.50, 95% CI 1.56–4.01), fetal growth restriction (40.6% vs 13.8%; RR 2.95, 95% CI 1.71–5.07), preterm birth (48.4% vs 20.7%; RR 2.34, 95% CI 1.51–3.62), low Apgar score (28.1% vs 8.6%; RR 3.26, 95% CI 1.60–6.64), NICU admission (37.5% vs 15.5%; RR 2.42, 95% CI 1.42–4.10), and stillbirth (10.9% vs 2.6%; RR 4.23, 95% CI 1.13–15.79). Early neonatal death was higher in the abnormal Doppler group but was not statistically significant. Conclusion: Abnormal umbilical artery Doppler indices were associated with a higher burden of adverse fetal and neonatal outcomes in hypertensive pregnancies. Umbilical artery Doppler may support risk stratification, closer surveillance, and delivery planning in pregnancies complicated by hypertensive disorders. Keywords: Umbilical artery Doppler; hypertensive disorders of pregnancy; preeclampsia; gestational hypertension; pulsatility index; resistance index; fetal growth restriction; low birth weight; NICU admission; fetal outcome.

INTRODUCTION

Hypertensive disorders during pregnancy are a major concern in antenatal care, as they can negatively affect the mother's wellbeing, placental performance, fetal development, and overall perinatal outcomes. These include gestational, chronic and preeclampsia and chronic with superimposed preeclampsia. Test for preeclampsia can be conducted if a woman has high blood pressure after 20 weeks of pregnancy, when a problem with the organs or when protein appears in the urine. Their clinical relevance extends

beyond elevated blood pressure because abnormal placentation, endothelial dysfunction, and impaired uteroplacental perfusion can produce progressive fetal compromise before overt deterioration becomes clinically evident (1,2).

The worldwide challenge of hypertensive disorders in antenatal care is substantial, and its consequences are particularly serious in low- and middle-income settings where delayed presentation, variable antenatal booking, limited access to advanced fetal surveillance, and differences in neonatal care capacity may influence maternal and fetal outcomes. Cohort-level and population-based evidence has shown that women with hypertensive disorders in pregnancy face a greater risk of perinatal death, stillbirth, neonatal death, preterm birth, intrauterine growth restriction, small-for-gestational-age birth, and low birth weight. Evidence from India, Pakistan, Mozambique, and Nigeria further indicates that pregnancy hypertension is a frequent obstetric problem in South Asian and other resource-constrained populations, making improved fetal risk stratification highly relevant for local clinical practice (3,4).

The biological link between hypertensive disorders of pregnancy and adverse fetal outcome is mainly mediated through placental insufficiency. In many affected pregnancies, inadequate trophoblastic invasion and incomplete spiral artery remodeling result in high-resistance placental circulation. This restricts oxygen and nutrient transfer to the fetus and may lead to fetal growth restriction, oligohydramnios, low birth weight, fetal distress, preterm delivery, stillbirth, and early neonatal morbidity. These complications often evolve gradually, which creates an opportunity for timely detection of fetoplacental compromise before irreversible fetal injury occurs (5,6).

Umbilical artery Doppler ultrasound is a non-invasive technique that allows one to evaluate the resistance of the vessels downstream from the placenta and the fetal-placental circulation. The commonly used indices are the pulsatility index, resistance index, and systolic/diastolic ratio with the presence or inversion of the end-diastolic flow representing more significant placental vascular changes. During normal pregnancy the resistance to umbilical artery flow decreases as the pregnancy progresses as a consequence of the progressive maturation of the placental vascular bed. In contrast, Doppler indices that remain elevated or abnormal end diastolic flow patterns indicate decreased placental perfusion and fetal risk, especially if the pregnancy is complicated by hypertensive disease or suspected fetal growth restriction (7,8).

Previous studies have demonstrated that abnormal umbilical artery Doppler indices are associated with adverse fetal and neonatal outcomes in hypertensive pregnancies. Raised pulsatility index, resistance index, and systolic/diastolic ratio have been linked with fetal growth restriction, low birth weight, preterm delivery, NICU admission, and perinatal compromise. Studies in severe preeclampsia have also shown that abnormal umbilical artery Doppler may be associated with earlier delivery and adverse neonatal outcomes, even when fetal growth restriction is not initially diagnosed. These findings support the clinical role of Doppler evaluation as more than a descriptive ultrasound measurement; rather, it represents a functional marker of fetoplacental resistance and fetal vulnerability (9–11).

Regional and local evidence remains important because patient characteristics, booking status, referral patterns, disease severity at presentation, and neonatal support differ across institutions. Studies from Pakistan have reported higher umbilical artery pulsatility index, resistance index, and systolic/diastolic ratio in pregnancies affected by pregnancy-induced hypertension compared with normotensive pregnancies, and fetal biometric assessment combined with umbilical artery Doppler has been reported to support the detection of intrauterine growth restriction in the second and third trimesters (12,13). However, hospital-based prospective evidence remains necessary to clarify how abnormal umbilical artery Doppler findings relate to clinically relevant fetal and neonatal outcomes among women with hypertensive disorders of pregnancy in local practice.

The present study was conducted on a PICO framework, which included pregnant women diagnosed with HDP, menstrual age-matched normal and abnormal umbilical artery (UA) Doppler findings, and

adverse fetal and neonatal outcomes such as low birth weight (LBW), fetal growth restriction (FGR), preterm delivery, low Apgar score, and admission to the neonatal intensive care unit (NICU), stillbirth, and early neonatal death. Thus, the research question addressed in this study was: Do abnormal umbilical artery Doppler indices increase the risk for adverse fetal/neonatal outcomes in women with hypertensive disorders of pregnancy when compared with normal Doppler indices?

MATERIALS AND METHODS

This prospective observational analytical cohort study was conducted at Combined Military Hospital, Gujranwala, from 2 March 2025 to 2 June 2025. Pregnant women with hypertensive disorders of pregnancy were recruited through the antenatal clinic, emergency department, and labour room, while umbilical artery Doppler assessment was performed in the hospital ultrasound department. The study was designed to evaluate whether abnormal umbilical artery Doppler indices, considered as the exposure of interest, were associated with adverse fetal and neonatal outcomes recorded after delivery.

Eligible participants were singleton pregnant women beyond the institutional threshold of fetal viability who had a confirmed diagnosis of hypertensive disorder of pregnancy and provided informed consent. Hypertensive disorders in pregnancy comprise gestational hypertension, preeclampsia, chronic hypertension, and chronic hypertension complicated by superimposed preeclampsia. Diagnosis was based on standard clinical criteria using blood pressure records, gestational age at onset, proteinuria status, previous history of hypertension, and relevant maternal clinical findings. Blood pressure was measured after adequate rest with the participant seated or semi-recumbent, and repeat measurements were obtained where clinically required to confirm reliable classification. Women with multiple pregnancy, major congenital fetal anomaly, known fetal chromosomal abnormality, intrauterine fetal death at the time of first Doppler assessment, incomplete delivery records, or delivery outside the hospital with unavailable fetal or neonatal outcome data were excluded from the final analysis.

Participants were enrolled using non-probability consecutive sampling until a total of 180 eligible women had been included. This approach allowed all eligible patients presenting during the study period to be considered for recruitment and supported prospective follow-up from Doppler assessment to delivery. Written informed consent was obtained after explanation of the study purpose and procedures. Maternal identity and clinical records were kept confidential, and ethical approval was obtained from the hospital ethical review committee before data collection.

A structured study proforma was used to gather data at enrolment and at follow-up. Maternal variables were age, parity, booking status, presentation gestational age, type of hypertensive disorder, systolic blood pressure, diastolic blood pressure, proteinuria status and associated clinical conditions. Obstetric findings, relevant laboratory investigations, and management decisions were recorded from clinical files. Treatment decisions, including antihypertensive therapy, admission, corticosteroid administration, induction of labour, caesarean delivery, expectant management, or referral, were made by the treating obstetric team according to maternal and fetal condition and were not determined by the research team.

Umbilical artery Doppler ultrasound was performed for all enrolled participants by a trained radiologist or sonologist using standard obstetric Doppler technique. The participant was placed in a comfortable supine or slight lateral position, and a free loop of the umbilical cord was selected for waveform assessment. Doppler recordings were obtained during fetal quiescence and in the absence of fetal breathing movements to reduce waveform variability. At least three consecutive uniform waveforms were obtained before final measurement. The Doppler indices recorded were pulsatility index, resistance index, and systolic/diastolic ratio, and the end-diastolic flow pattern was categorized as present, absent, or reversed. Doppler findings were classified as abnormal when indices were above the expected range for gestational age or when absent or reversed end-diastolic flow was present. Participants were then classified into two exposure groups: normal umbilical artery Doppler and abnormal umbilical artery Doppler.

All participants were followed prospectively until delivery. Fetal and neonatal outcomes were collected immediately after birth and from neonatal records where applicable. The primary adverse outcomes were low birth weight, fetal growth restriction, preterm birth, low Apgar score at five minutes, neonatal intensive care unit admission, stillbirth, and early neonatal death. Low birth weight was considered when the newborn's weight was less than 2.5 kg, while preterm delivery was defined as childbirth occurring before completion of 37 weeks of gestation. Birth weight was measured immediately after delivery using the hospital's routine neonatal weighing procedure. Apgar scores were recorded at one and five minutes after birth, and low Apgar score was assessed using the documented five-minute score. NICU admission was recorded when the neonate was admitted for observation or treatment due to prematurity, respiratory distress, low birth weight, birth asphyxia, suspected sepsis, or another clinically documented neonatal indication. Stillbirth and early neonatal death were recorded according to hospital delivery and neonatal outcome records.

Bias was addressed through prospective enrolment, standardized proforma-based data collection, Doppler assessment before delivery outcome ascertainment, and use of predefined fetal and neonatal outcomes. Consecutive sampling reduced selective recruitment among eligible patients presenting during the study period, while exclusion of participants with major congenital anomalies, multiple pregnancy, pre-existing intrauterine fetal death at first Doppler assessment, and unavailable outcome data helped reduce outcome misclassification. Potential confounding was considered clinically because fetal outcomes in hypertensive pregnancy may be influenced by gestational age, type and severity of hypertensive disorder, fetal growth status, treatment decisions, and timing of delivery. These factors were recorded where available to support interpretation of group differences between normal and abnormal Doppler findings.

The IBM SPSS Statistics version 26.0 was used for the entry and analysis of data. The quantitative variables were summarized as mean and standard deviation if they were normal. Maternal age, gestational age at Doppler examination, systolic blood pressure, diastolic blood pressure, pulsatility index, resistance index, and the ratio of systolic/diastolic blood pressure were quantitative variables summarized as mean and standard deviation if they were normal. Categorical variables were parities, type of hypertensive disorder, Doppler status, fetal growth restriction, pre-term birth, low Apgar score, admission to NICU, stillbirth and early neonatal death presented as frequency and percentage. The independent-samples t-test was used for quantitative variables with normal distribution, the chi-square test was used for categorical variables with moderate to large cell size, and the Fisher's exact test was used for categorical variables with small cell size, as appropriate based on the cell size of each variable. To measure the strength of association between abnormal Doppler findings and fetal or neonatal complications, measures of association such as relative risk or odds ratio with 95% confidence interval were planned. P-values < 0.05 were regarded as statistically significant.

Data integrity was maintained through structured data collection, prospective follow-up until delivery, cross-checking of Doppler findings with ultrasound records, and verification of delivery and neonatal outcomes from hospital documentation. The observational design ensured that clinical management was not altered by the study protocol, allowing the findings to reflect routine hospital-based practice in pregnancies complicated by hypertensive disorders.

RESULTS

A total of 180 pregnant women with hypertensive disorders of pregnancy were included in the final analysis. The mean maternal age was 28.4 ± 4.9 years, and the mean gestational age at Doppler examination was 34.6 ± 2.8 weeks. Most participants were multigravida, accounting for 108 women (60.0%), while 72 women (40.0%) were primigravida. Gestational hypertension was the most frequent hypertensive disorder, observed in 82 participants (45.6%), followed by preeclampsia in 76 participants (42.2%), chronic hypertension in 14 participants (7.8%), and chronic hypertension with superimposed

preeclampsia in 8 participants (4.4%). Umbilical artery Doppler was normal in 116 women (64.4%) and abnormal in 64 women (35.6%). Among specific Doppler abnormalities, raised systolic/diastolic ratio was the most frequent finding, present in 48 women (26.7%), followed by raised pulsatility index in 42 women (23.3%) and raised resistance index in 38 women (21.1%). More severe flow abnormalities were less frequent, with absent end-diastolic flow in 12 women (6.7%) and reversed end-diastolic flow in 5 women (2.8%), as shown in Table 1.

Table 1. Baseline maternal, obstetric, and umbilical artery Doppler characteristics of the study participants

Variable	Total Participants (n=180)
Maternal age, years	28.4 ± 4.9
Gestational age at Doppler examination, weeks	34.6 ± 2.8
Primigravida	72 (40.0%)
Multigravida	108 (60.0%)
Gestational hypertension	82 (45.6%)
Preeclampsia	76 (42.2%)
Chronic hypertension	14 (7.8%)
Chronic hypertension with superimposed preeclampsia	8 (4.4%)
Normal umbilical artery Doppler	116 (64.4%)
Abnormal umbilical artery Doppler	64 (35.6%)
Raised pulsatility index	42 (23.3%)
Raised resistance index	38 (21.1%)
Raised systolic/diastolic ratio	48 (26.7%)
Absent end-diastolic flow	12 (6.7%)
Reversed end-diastolic flow	5 (2.8%)

Adverse fetal and neonatal outcomes were consistently more frequent among women with abnormal umbilical artery Doppler findings than among those with normal Doppler findings. Low birth weight occurred in 29 of 64 neonates (45.3%) in the abnormal Doppler group compared with 21 of 116 neonates (18.1%) in the normal Doppler group, corresponding to a 2.50-fold higher risk (RR 2.50, 95% CI 1.56–4.01; p=0.001). Fetal growth restriction was observed in 26 neonates (40.6%) in the abnormal Doppler group compared with 16 neonates (13.8%) in the normal Doppler group, giving an almost threefold higher risk among women with abnormal Doppler findings (RR 2.95, 95% CI 1.71–5.07; p=0.001). Preterm birth was also more frequent in the abnormal Doppler group, affecting 31 pregnancies (48.4%) compared with 24 pregnancies (20.7%) in the normal Doppler group, with a relative risk of 2.34 (95% CI 1.51–3.62; p=0.001).

Neonatal compromise was also more common in the abnormal Doppler group. Low Apgar score at five minutes was recorded in 18 neonates (28.1%) in the abnormal Doppler group compared with 10 neonates (8.6%) in the normal Doppler group, indicating more than a threefold higher risk (RR 3.26, 95% CI 1.60–6.64; p=0.001). NICU admission was required in 24 neonates (37.5%) in the abnormal Doppler group compared with 18 neonates (15.5%) in the normal Doppler group, showing a 2.42-fold higher risk (RR 2.42, 95% CI 1.42–4.10; p=0.002). Stillbirth occurred in 7 pregnancies (10.9%) with abnormal Doppler findings and 3 pregnancies (2.6%) with normal Doppler findings, corresponding to a higher relative risk in the abnormal Doppler group (RR 4.23, 95% CI 1.13–15.79; p=0.025). Early neonatal death was numerically higher in the abnormal Doppler group, occurring in 4 neonates (6.3%) compared with 2 neonates (1.7%) in the normal Doppler group, but this difference did not reach statistical significance (RR 3.63, 95% CI 0.68–19.25; p=0.099), as shown in Table 2.

Table 2. Comparison of fetal and neonatal outcomes according to umbilical artery Doppler findings

Fetal/Neonatal Outcome	Normal Doppler (n=116)	Abnormal Doppler (n=64)	Relative Risk (95% CI)	p-value
Low birth weight	21 (18.1%)	29 (45.3%)	2.50 (1.56–4.01)	0.001
Fetal growth restriction	16 (13.8%)	26 (40.6%)	2.95 (1.71–5.07)	0.001
Preterm birth	24 (20.7%)	31 (48.4%)	2.34 (1.51–3.62)	0.001
Low Apgar score at 5 minutes	10 (8.6%)	18 (28.1%)	3.26 (1.60–6.64)	0.001
NICU admission	18 (15.5%)	24 (37.5%)	2.42 (1.42–4.10)	0.002
Stillbirth	3 (2.6%)	7 (10.9%)	4.23 (1.13–15.79)	0.025

Fetal/Neonatal Outcome	Normal Doppler (n=116)	Abnormal Doppler (n=64)	Relative Risk (95% CI)	p-value
Early neonatal death	2 (1.7%)	4 (6.3%)	3.63 (0.68–19.25)	0.099

CI: confidence interval; NICU: neonatal intensive care unit. Categorical variables were compared using the chi-square test or Fisher's exact test where appropriate. Relative risks were calculated using the normal Doppler group as the reference category.

When the outcomes were interpreted collectively, abnormal umbilical artery Doppler findings showed a consistent risk-gradient pattern across growth-related, delivery-related, and neonatal compromise outcomes. The strongest statistically significant relative association was observed for stillbirth, which was more than four times higher among pregnancies with abnormal Doppler findings, although the confidence interval was wide because of the small number of events. Low Apgar score at five minutes and fetal growth restriction also showed strong associations, with risks more than threefold and nearly threefold higher, respectively, in the abnormal Doppler group. Low birth weight, preterm birth, and NICU admission each showed approximately two- to two-and-a-half-fold higher risk among women with abnormal umbilical artery Doppler findings. Early neonatal death followed the same adverse direction but was not statistically significant, suggesting that the available sample was more conclusive for morbidity-related outcomes than for mortality-related endpoints.

In summary, abnormal umbilical artery Doppler flow was linked to increased adverse fetal/neonatal outcomes in the pregnancies with hypertensive disorders. Results suggest that raised Doppler resistance patterns and abnormal end-diastolic flow are clinically significant markers of fetal vulnerability, especially for low birth weight, foetal growth restriction, preterm delivery, low Apgar score, admission to the NICU and foetal death. This study confirms the use of umbilical artery Doppler as a valuable tool for fetal surveillance in identifying a higher-risk hypertensive pregnancy in order to provide closer monitoring and timely obstetric decision making.

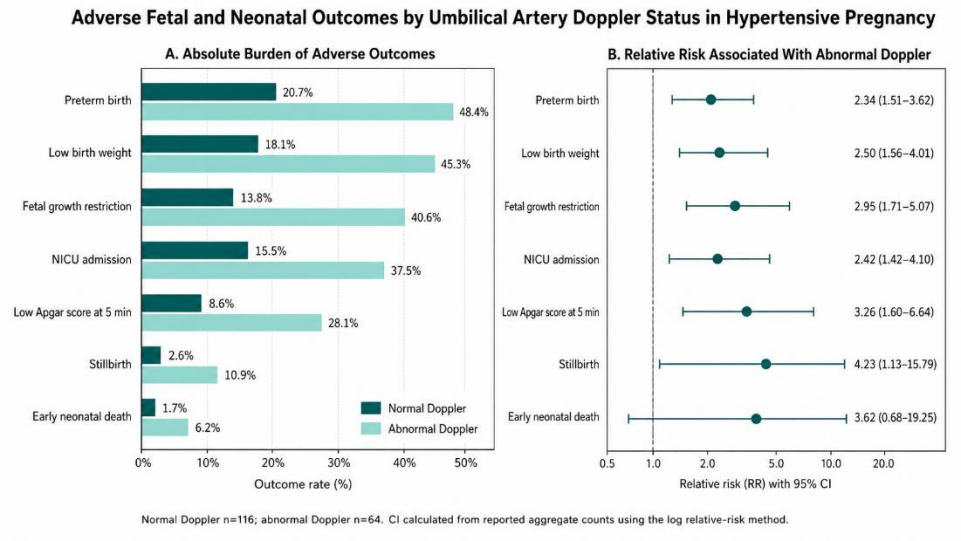

Figure 1 Adverse Fetal and Neonatal Outcomes by Umbilical Artery Doppler Status in Hypertensive Pregnancy.

The panelled figure demonstrates a consistent adverse-outcome gradient among women with abnormal umbilical artery Doppler findings compared with those with normal Doppler findings. In absolute terms, the abnormal Doppler group showed higher rates of preterm birth (48.4% vs 20.7%), low birth weight (45.3% vs 18.1%), fetal growth restriction (40.6% vs 13.8%), NICU admission (37.5% vs 15.5%), low Apgar score at five minutes (28.1% vs 8.6%), stillbirth (10.9% vs 2.6%), and early neonatal death (6.3% vs 1.7%). The relative-risk panel further shows that abnormal Doppler was associated with significantly higher risks of stillbirth (RR 4.23, 95% CI 1.13–15.79), low Apgar score (RR 3.26, 95% CI 1.60–6.64), fetal growth restriction (RR 2.95, 95% CI 1.71–5.07), low birth weight (RR 2.50, 95% CI 1.56–4.01), NICU admission (RR 2.42, 95% CI 1.42–4.10), and preterm birth (RR 2.34, 95% CI 1.51–3.62), while early neonatal death showed a non-significant but clinically concerning trend (RR 3.63, 95% CI 0.68–19.25).

DISCUSSION

The present prospective observational cohort study found that abnormal umbilical artery Doppler findings were consistently associated with a higher frequency of adverse fetal and neonatal outcomes among women with hypertensive disorders of pregnancy. In this cohort of 180 women, abnormal Doppler findings were identified in 64 participants (35.6%), while 116 participants (64.4%) had normal Doppler findings. The abnormal Doppler group had substantially higher rates of low birth weight, fetal growth restriction, preterm birth, low Apgar score at five minutes, NICU admission, and stillbirth. These findings support the clinical relevance of umbilical artery Doppler as a practical marker of fetoplacental compromise in hypertensive pregnancy, while also requiring interpretation within the limits of an observational, hospital-based design.

The association between abnormal umbilical artery Doppler and adverse fetal outcome is biologically plausible because hypertensive disorders of pregnancy are strongly linked with abnormal placentation, endothelial dysfunction, and increased uteroplacental and fetoplacental vascular resistance. In normal pregnancy, progressive placental vascular development reduces downstream resistance, allowing improved diastolic flow in the umbilical artery as gestation advances. When placental vascular development is impaired, as commonly occurs in preeclampsia and related hypertensive disorders, umbilical artery pulsatility index, resistance index, and systolic/diastolic ratio may rise, and severe compromise may present as absent or reversed end-diastolic flow. These Doppler changes reflect increased placental resistance and provide a pathophysiological explanation for the higher burden of fetal growth restriction, low birth weight, and neonatal compromise observed in the abnormal Doppler group (5–8).

Low birth weight was observed in 45.3% of neonates in the abnormal Doppler group compared with 18.1% in the normal Doppler group, corresponding to a 2.50-fold higher risk. This finding is clinically important because low birth weight in hypertensive pregnancy often reflects the cumulative effect of impaired placental perfusion, reduced fetal oxygenation, restricted nutrient transfer, and clinically indicated early delivery. The present finding is consistent with evidence showing that hypertensive disorders of pregnancy increase the risk of low birth weight and small-for-gestational-age birth. It also supports the interpretation that abnormal umbilical artery Doppler is not merely a sonographic abnormality but a clinically meaningful sign of placental dysfunction in pregnancies already complicated by maternal hypertension (3,9).

Fetal growth restriction was also markedly more common among women with abnormal Doppler findings, occurring in 40.6% compared with 13.8% in the normal Doppler group. The relative risk of fetal growth restriction was 2.95, indicating an almost threefold higher risk among pregnancies with abnormal umbilical artery Doppler. This finding is expected because fetal growth restriction and abnormal umbilical artery Doppler share a common placental basis, particularly in hypertensive pregnancies where defective spiral artery remodeling can impair fetal growth. However, this relationship should be interpreted carefully because Doppler abnormality and fetal growth restriction may not be fully independent clinical phenomena. The association remains clinically useful, but the overlap between placental insufficiency, fetal biometric restriction, and Doppler resistance means that future analyses should adjust for gestational age and disease severity where possible (8,14,15).

Preterm birth occurred in 48.4% of pregnancies with abnormal Doppler findings compared with 20.7% among those with normal Doppler findings, giving a relative risk of 2.34. This higher preterm birth rate may reflect both spontaneous and medically indicated early delivery. In hypertensive pregnancy, abnormal Doppler findings may identify fetuses with reduced reserve, and clinicians may decide on earlier delivery when there is evidence of worsening maternal disease, fetal compromise, or abnormal fetal surveillance. Therefore, preterm birth in this context should not be interpreted solely as a direct adverse consequence of abnormal Doppler; it may also represent a clinical intervention intended to

prevent stillbirth or severe neonatal compromise. This distinction is important because the observational design of the study cannot separate the biological effect of placental insufficiency from the effect of obstetric decision-making on timing of delivery (1,14,15).

Low Apgar score at five minutes was more frequent in the abnormal Doppler group, affecting 28.1% compared with 8.6% in the normal Doppler group, with a relative risk of 3.26. NICU admission was also higher in the abnormal Doppler group, occurring in 37.5% compared with 15.5% in the normal Doppler group, with a relative risk of 2.42. These findings suggest that abnormal fetoplacental circulation in hypertensive pregnancy is associated not only with impaired fetal growth but also with early neonatal vulnerability. Neonates exposed to chronic placental insufficiency may have reduced physiological reserve during labour and delivery, particularly when accompanied by prematurity, low birth weight, or fetal growth restriction. The higher NICU admission rate therefore provides clinically relevant evidence that abnormal Doppler findings may identify pregnancies requiring closer intrapartum planning and neonatal preparedness (10,11,16).

Stillbirth occurred in 10.9% of pregnancies with abnormal Doppler findings and 2.6% of pregnancies with normal Doppler findings, corresponding to a relative risk of 4.23. Although the absolute number of stillbirths was small and the confidence interval was wide, this finding is clinically significant because stillbirth is one of the most serious outcomes targeted by antenatal surveillance. Absent or reversed end-diastolic flow represents severe downstream placental resistance and has been recognized as an important warning sign in fetal surveillance. The present study did not provide a separate outcome table for absent and reversed end-diastolic flow subgroups, so conclusions about Doppler severity gradients should remain cautious. Nevertheless, the higher stillbirth frequency in the abnormal Doppler group reinforces the need for timely recognition of abnormal umbilical artery Doppler patterns in hypertensive pregnancies (7,8,15).

Early neonatal death was numerically higher among neonates in the abnormal Doppler group, occurring in 6.3% compared with 1.7% in the normal Doppler group, but the difference was not statistically significant. The relative risk was 3.63, but the 95% confidence interval crossed unity, indicating statistical uncertainty. This non-significant result may be explained by the small number of early neonatal deaths and limited power for mortality endpoints. It is also possible that neonatal care reduced early mortality despite higher rates of prematurity, low birth weight, and NICU admission. Therefore, early neonatal death should be described as a clinically concerning trend rather than a definitive association in this cohort.

The study has several strengths. Its prospective design ensured that Doppler assessment occurred before delivery outcomes were recorded, which reduced recall bias and strengthened temporal interpretation. The study also included clinically relevant outcomes that are meaningful for obstetricians, radiologists, neonatologists, and perinatal care teams. The use of normal and abnormal umbilical artery Doppler groups allowed practical risk comparison in a real hospital setting, making the findings directly relevant to routine care.

The limitations should also be acknowledged. The study was conducted at a single hospital, which may limit generalizability to other settings with different referral patterns, antenatal booking systems, maternal risk profiles, and neonatal care capacity. The analysis was primarily based on unadjusted group comparisons, so residual confounding cannot be excluded. Gestational age at Doppler assessment, type and severity of hypertensive disorder, fetal growth status at enrolment, proteinuria, antihypertensive therapy, corticosteroid exposure, timing of delivery, and mode of delivery may have influenced fetal and neonatal outcomes. In addition, management decisions were made according to clinical need and may have affected outcomes such as preterm birth and NICU admission. The study also did not present continuous Doppler index values by group or a severity-stratified analysis of raised indices, absent end-diastolic flow, and reversed end-diastolic flow. Future studies should include adjusted regression models,

Doppler severity categories, standardized gestational-age-specific Doppler centiles, and larger sample sizes to better estimate mortality-related outcomes.

Overall, the findings indicate that abnormal umbilical artery Doppler indices are associated with a higher burden of adverse fetal and neonatal outcomes in hypertensive pregnancy. Raised Doppler resistance patterns and abnormal end-diastolic flow may help clinicians identify pregnancies requiring closer surveillance, individualized delivery planning, and neonatal preparedness. These results are consistent with previous evidence supporting the role of umbilical artery Doppler in high-risk pregnancies, particularly where placental insufficiency and fetal growth restriction are suspected (14–16).

CONCLUSION

Women with hypertensive disorders of pregnancy who had abnormal Doppler indices of the umbilical artery had significantly increased risk of adverse fetal and neonatal outcomes. Abnormal Doppler was associated with elevated rates of low birth weight, fetal growth restriction, preterm birth, low Apgar score at 5 minutes, NICU admission and stillbirth, and early neonatal death was not significantly associated but clinically concerning. The study results encourage the use of umbilical artery Doppler as an effective non-invasive tool for fetal surveillance in high-risk pregnancies. In hospital-based obstetric care, raising values of the Pulsatility Index, Resistance Index, Systolic/Diastolic ratio and abnormal end-diastolic flow can help guide the clinicians for closer monitoring, delivery time and preparedness for the baby, but larger adjusted studies are required to validate Doppler abnormalities as independent prognostic factors.

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