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Evaluation of blood flow using colour doppler ultrasonography in uterine artery, fetal umblical artery and middle cerebral artery in pregnancy induced hypertension and its correlation with perinatal outcome

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Abstract
Background: Pregnancy-induced hypertension (PIH) is a major obstetric complication that poses significant risks to both the mother and the fetus. PIH affects approximately 5-10% of pregnancies worldwide and is a leading cause of maternal and perinatal morbidity and mortality. Color Doppler ultrasonography has emerged as a valuable non-invasive tool for assessing blood flow in various maternal and fetal vessels during pregnancy. The integration of Doppler ultrasonography findings from the uterine artery, umbilical artery, and MCA provides a comprehensive assessment of the fetal condition in PIH.
Objectives: To evaluate the effectiveness of Doppler ultrasound in managing pregnancy-induced hypertension (PIH) by analyzing blood flow in the uterine artery, umbilical artery, and middle cerebral artery.
Methods: This cross sectional study conducted for 2 years from September 2022 to August 2024 included 75 pregnant women diagnosed with PIH. A high-resolution Duplex Doppler sonography study using GE LOGIQ P9 ultrasound machines with 5-13MHz linear transducer was done. The first scan was performed in each cases, as soon as the patient was registered in order to avoid any influence of treatment on Doppler sonogram. The gestational age was confirmed by menstrual history and ultrasound examination and was followed by color Doppler examination for identification of the uterine artery, flow velocity waveforms from umbilical artery and MCA were done. The data was collected and compiled in MS Excel. Descriptive statistics has been used to present the data. To analyse the data SPSS (Version 26.0) was used. Significance level was fixed as 5% ($\alpha = 0.05$). Qualitative variables are expressed as frequency and percentages and Quantitative variables are expressed as Mean and Standard Deviation. To compare the proportion between variables, chi-square test was used.
Results: Among the 75 pregnant women with PIH, the majority of deliveries were induced (49.3%), followed by elective (17.3%) and emergency (16.0%) cesarean sections. A high percentage (65.3%) of participants exhibited abnormal uterine artery Doppler results, with a mean systolic-diastolic ratio of 2.51 and a mean resistance index of 0.58. Umbilical artery Doppler showed abnormalities in 49.3% of cases, with mean pulsatility and resistance indices of 1.32 and 0.68, respectively. Middle cerebral artery Doppler abnormalities were present in 54.7% of participants, with mean pulsatility and resistance indices of 1.33 and 0.72, respectively.
Conclusion: Overall, the study concluded that Doppler ultrasound is a valuable tool for the early detection and management of PIH, significantly correlating with adverse maternal and fetal outcomes. This non-invasive method allows for timely interventions, potentially improving perinatal health outcomes.

Keywords: Pregnancy-induced hypertension, doppler ultrasound, pulsatility and resistance indices, blood flow

Introduction

Pregnancy-induced hypertension (PIH) is a major obstetric complication that poses significant risks to both the mother and the fetus. It is characterized by the development of hypertension with blood pressure of >140/90 for the first time after 20 weeks of gestation and it encompasses conditions such as gestational hypertension, pre-eclampsia, and eclampsia. PIH affects approximately 5-10% of pregnancies worldwide and is a leading cause of maternal and perinatal morbidity and mortality [1, 2, 3]. The precise etiology of PIH remains unclear, but it is believed to involve a complex interplay of genetic, immunologic, and environmental factors that lead to endothelial dysfunction and abnormal placental development [4, 5, 6].

Color Doppler ultrasonography has emerged as a valuable non-invasive tool for assessing blood flow in various maternal and fetal vessels during pregnancy. It enables the visualization and measurement of blood flow velocity and resistance, providing critical insights into the hemodynamic changes associated with PIH. The primary vessels evaluated using Doppler ultrasonography in the context of PIH include the uterine artery, fetal umbilical artery, and middle cerebral artery (MCA). These assessments help in early detection of fetal compromise and guide clinical management to improve perinatal outcomes [7, 8, 9].

The uterine artery supplies blood to the placenta, and its Doppler waveform analysis can reflect placental resistance and perfusion. In normal pregnancies, the uterine artery demonstrates a low-resistance pattern as the pregnancy progresses. However, in PIH, increased resistance and reduced diastolic flow are commonly observed, indicating impaired placental perfusion and a higher risk of adverse outcomes such as fetal growth restriction (FGR) and stillbirth [10, 11, 12]. The presence of a diastolic notch in the uterine artery waveform is particularly associated with poor placental perfusion and adverse perinatal outcomes [13].

The fetal umbilical artery Doppler is an essential component of fetal surveillance in pregnancies complicated by PIH. It provides information about the resistance to blood flow in the placental circulation. An increased systolic/diastolic

(S/D) ratio, elevated pulsatility index (PI), or absent/reversed end-diastolic flow (AREDF) in the umbilical artery are indicative of placental insufficiency and fetal hypoxia [14, 15, 16]. These Doppler abnormalities are associated with higher risks of perinatal morbidity and mortality, necessitating close monitoring and timely intervention [17].

The middle cerebral artery (MCA) Doppler is used to evaluate fetal adaptive responses to hypoxia. In the setting of placental insufficiency, the fetus may redistribute blood flow preferentially to vital organs such as the brain, heart, and adrenal glands, a phenomenon known as the brain-sparing effect. This adaptive response is reflected in the MCA Doppler as decreased resistance and increased diastolic flow [18, 19, 20]. The cerebroplacental ratio (CPR), which is the ratio of MCA PI to umbilical artery PI, is a valuable index for assessing fetal well-being. A low CPR is associated with adverse perinatal outcomes and can guide clinical decisions regarding the timing of delivery [21].

The integration of Doppler ultrasonography findings from the uterine artery, umbilical artery, and MCA provides a comprehensive assessment of the fetal condition in PIH. Abnormal Doppler indices correlate with adverse perinatal outcomes such as preterm delivery, low birth weight, neonatal intensive care unit (NICU) admission, and perinatal death [22, 23, 24]. Early identification of these abnormalities allows for timely interventions, including corticosteroid administration for fetal lung maturation, close surveillance, and planned early delivery, to optimize perinatal outcomes.

Objective of the study

This study was conducted to analyse the blood flow in uterine artery, umbilical artery and middle cerebral artery using Doppler ultrasound in a group of patients with pregnancy induced hypertension, to assess the value of Doppler ultrasound in analysing the perinatal outcome in patients with pregnancy induced hypertension, to evaluate the role of Doppler ultrasound in the management of pregnancy induced hypertension. To identify early high-risk foetuses by changes in Doppler flow velocity waveforms and to know the various maternal and foetal complications in women who developed pre-eclampsia in the abnormal uterine artery Doppler indices group.

Methodology

We conducted a cross sectional study for 2 years from September 2022 to August 2024 among women diagnosed with PIH in the department of Obstetrics and Gynecology at Al-Ameen Medical College and Hospital Bijapur. We included all women with singleton pregnancy at or more than 28 weeks of gestation clinically diagnosed as pregnancy induced hypertension. The study was conducted on 75 patients who were referred to the Department of Radiodiagnosis, with clinically diagnosed pregnancy induced hypertension.

Clearance from the institutional ethical committee was taken before starting the study. Written consent was obtained from all the study participants. A high-resolution Duplex Doppler sonography study using GE LOGIQ P9 ultrasound machines with 5-13MHz linear transducer was done. The first scan was performed in each cases, as soon as the patient was registered in order to avoid any influence of treatment on Doppler sonogram. The gestational age was confirmed by menstrual history and ultrasound examination and was followed by color

The patient was explained about the non-invasive/ atraumatic nature of the procedure. Synthetic ultra-gel was applied liberally over the abdomen to get a good acoustic coupling. The instruments used were Toshiba NEMIO-XG iSTYLE Color Doppler ultrasound machine with a convex transducer of 2-5 MHz frequency. Doppler waveform was obtained after localizing the vessels by B- mode real time scanner. Pulsed Doppler was used to get the Doppler signals after localizing the vessels. The maximum Doppler shift frequencies were obtained and various ratios were calculated from each vessel. Doppler examination was done when fetus was in apneic state to avoid the influence of fetal respiration on Doppler signals.

Doppler examination for identification of the uterine artery where S/D >2.6, RI > 0.58 and persistent early diastolic notch was considered abnormal. Flow velocity waveforms from umbilical artery was obtained, where S/D ratio of umbilical artery >3, RI>0.7, presence of absent end diastolic velocity (AEDV) and reversed end diastolic velocity (REDV) were considered abnormal. The Middle Cerebral Artery (MCA) was visualized in transverse axial view of fetal head at a slightly more caudal plane than the one used for BPD. PI <1.3 and RI <0.7 were considered abnormal.

The data was collected and compiled in MS Excel. Descriptive statistics has been used to present the data. To analyse the data SPSS (Version 26.0) was used. Significance level was fixed as 5% ($\alpha = 0.05$). Qualitative variables are expressed as frequency and percentages and Quantitative variables are expressed as Mean and Standard Deviation. To compare the proportion between variables, chi-square test was used.

Results

This study included 75 participants whose ages ranged from 18 to 40 years. The distribution across different age groups was as follows: 18-20 years (14 participants, 18.7%), 21-25 years (28 participants, 37.3%), 26-30 years (22 participants, 29.3%), 31-35 years (7 participants, 9.3%), and 36-40 years (4 participants, 5.3%). The mean age of the participants was 25.17 ± 4.86 years.

The parity of the participants was categorized into primiparous and multiparous. Among the participants, 23 were primiparous (30.7%) and 52 were multiparous (69.3%).

The mean systolic-diastolic (SD) ratio of the uterine artery was 2.51 ± 0.56, and the mean resistance index (RI) was 0.58 ± 0.11. The presence of a diastolic notch was observed in 31 participants (41.3%), while it was absent in 44 participants (58.7%). Out of the total participants, 26 (34.7%) had normal uterine artery Doppler results, while 49 (65.3%) exhibited abnormalities.

The mean pulsatility index (PI) for the umbilical artery was 1.32 ± 0.32, the mean resistance index (RI) was 0.68 ± 0.10, and the mean systolic-diastolic (SD) ratio was 3.24 ± 0.90. The umbilical artery Doppler was normal in 38 participants (50.7%) and abnormal in 37 participants (49.3%).

The mean PI for the MCA was 1.33 ± 0.16, and the mean RI was 0.72 ± 0.15. Normal MCA Doppler results were found in 34 participants (45.3%), while 41 participants (54.7%) had abnormal results.

The mean estimated fetal weight (EFW) was 1.73 ± 0.48 kilograms. The mode of delivery among participants was

categorized as follows: elective lower segment cesarean section (LSCS) in 13 participants (17.3%), emergency LSCS in 12 participants (16.0%), induced labor in 37 participants (49.3%), and normal vaginal delivery (NVD) in 13 participants (17.3%).

The mean APGAR score at 1 minute was 4.29 ± 1.81, while the mean APGAR score at 5 minutes was 6.19 ± 2.32. When categorized by APGAR scores at 5 minutes, 36 participants (48.0%) had an APGAR score more than 7, whereas 39 participants (52.0%) had a score lesser than 7.

There were 5 stillbirths (6.7%) reported, with the remaining 70 participants (93.3%) having live births. A total of 52 newborns (69.3%) were admitted to the NICU, while 18 newborns (24.0%) were not admitted. IUGR was present in 45 participants (60.0%) and absent in 30 participants (40.0%).

The complications observed were birth asphyxia in 1 participant (1.3%), hypoxic-ischemic encephalopathy (HIE) in 5 participants (6.7%), hyperbilirubinemia in 3 participants (4.0%), hypoglycemia in 7 participants (9.3%), meconium aspiration syndrome in 8 participants (10.7%), preterm care in 5 participants (6.7%), and sepsis in 1 participant (1.3%).

In the study, the association between uterine artery Doppler parameters and APGAR scores at the 5th minute was examined. The results showed that among participants with abnormal uterine artery Doppler parameters, 32 (65.3%) had an APGAR score of less than 7, while only 17 (34.7%) had an APGAR score greater than 7. In contrast, among those with normal uterine artery Doppler parameters, only 7 (26.9%) had an APGAR score of less than 7, and 19 (73.1%) had an APGAR score greater than 7. The statistical analysis revealed a significant association ($p < 0.001$), indicating that abnormal uterine artery Doppler parameters are strongly associated with lower APGAR scores at 5 minutes.

The study also evaluated the relationship between umbilical artery Doppler parameters and APGAR scores at the 5th minute. Among those with abnormal umbilical artery Doppler parameters, 27 (73.0%) had an APGAR score of less than 7, while 10 (27.0%) had an APGAR score greater than 7. Conversely, among participants with normal umbilical artery Doppler parameters, 12 (31.6%) had an APGAR score of less than 7, and 26 (68.4%) had an APGAR score greater than 7. The association was statistically significant ($p < 0.001$), suggesting that abnormal umbilical artery Doppler parameters are significantly linked to lower APGAR scores at 5 minutes.

For the middle cerebral artery (MCA) Doppler parameters, the study found that 25 (61.0%) participants with abnormal MCA Doppler had an APGAR score of less than 7, while 16 (39.0%) had an APGAR score greater than 7. Among those with normal MCA Doppler parameters, 14 (41.2%) had an APGAR score of less than 7, and 20 (58.8%) had an APGAR score greater than 7. Although the trend suggests that abnormal MCA Doppler parameters might be associated with lower APGAR scores, the statistical significance was not strong ($p = 0.088$).

The study explored the association between uterine artery Doppler parameters and NICU admission. Results showed that among participants with abnormal uterine artery Doppler parameters, 33 (67.3%) required NICU admission, whereas only 11 (22.4%) did not require NICU admission. On the other hand, among those with normal uterine artery Doppler parameters, 19 (73.1%) did not require NICU admission, while 7 (26.9%) did. The association was statistically significant ($p = 0.001$), indicating a strong link between abnormal uterine artery Doppler parameters and increased NICU admissions.

In terms of the umbilical artery Doppler parameters and NICU admission, the study found that 28 (75.7%) participants with abnormal umbilical artery Doppler parameters required NICU admission, whereas only 4 (10.8%) did not. Among participants with normal umbilical artery Doppler parameters, 24 (63.2%) did not require NICU admission, while 14 (36.8%) did. The association was statistically significant ($p = 0.004$), demonstrating a significant correlation between abnormal umbilical artery Doppler parameters and higher rates of NICU admissions.

Regarding MCA Doppler parameters, the study showed that 31 (75.6%) participants with abnormal MCA Doppler parameters required NICU admission, while only 5 (12.2%) did not. Among those with normal MCA Doppler parameters, 21 (61.8%) did not require NICU admission, and 13 (38.2%) did. The association was statistically significant ($p = 0.007$), indicating that abnormal MCA Doppler parameters are associated with increased NICU admissions.

The study investigated the relationship between uterine artery Doppler parameters and intrauterine growth restriction (IUGR). Results indicated that among participants with abnormal uterine artery Doppler parameters, 29 (59.2%) had IUGR, while 20 (40.8%) did not. In the group with normal uterine artery Doppler parameters, 16 (61.5%) had IUGR, and 10 (38.5%) did not. The association was not statistically significant ($p = 1.000$), suggesting no strong correlation between uterine artery Doppler parameters and IUGR.

For the umbilical artery Doppler parameters, the study found that 23 (62.2%) participants with abnormal Doppler results had IUGR, while 14 (37.8%) did not. Among those with normal umbilical artery Doppler parameters, 22 (57.9%) had IUGR, and 16 (42.1%) did not. The association was not statistically significant ($p = 0.706$), indicating no strong correlation between umbilical artery Doppler parameters and IUGR.

Lastly, the study examined the association between MCA Doppler parameters and IUGR. Among participants with abnormal MCA Doppler parameters, 24 (58.5%) had IUGR, while 17 (41.5%) did not. In the group with normal MCA Doppler parameters, 21 (61.8%) had IUGR, and 13 (38.2%) did not. The association was not statistically significant ($p = 0.706$), indicating no strong correlation between MCA Doppler parameters and IUGR.

Discussion

Worldwide, hypertensive disorders impact between 5 and 10% of pregnancies. It is the most common pregnancy-related medical problem. It is responsible for roughly 10–20% of pregnancy-related deaths in low- and middle-income countries and is a major risk factor for maternal and perinatal mortality and morbidity worldwide. Preeclampsia affects 8%–10% of expectant mothers, according to the National Health Portal of India. Uteroplacental insufficiency is the outcome of hypertension during pregnancy. Negative postpartum outcomes, including hospitalization to the newborn intensive care unit (NICU), low birth weight, asphyxia at birth, preterm birth, perinatal death, intrauterine

growth restriction, and stillbirth, are thought to be significantly influenced by it [25, 26, 27, 28, 29].

In high-risk pregnancies, a range of techniques are employed to assess the health of fetuses, such as non-stress testing (NST), biophysical profile (BPP), and daily fetal movements. Due to their low levels of sensitivity, specificity, and positive predictive value (PPV), all of the aforementioned tests are less preferred. The use of Color Doppler flow velocimetry in ultrasound (USG) has revolutionized the diagnosis of aberrant blood flow in fetoplacental beds. Early diagnosis of intrauterine growth restriction (IUGR), which lowers fetal mortality and morbidity, and the best time to deliver the baby are both aided by these anomalies [30].

This study was conducted to evaluate the blood flow using colour Doppler ultrasonography in uterine artery, fetal umblical artery and middle cerebral artery in pregnancy induced hypertension (PIH) and its correlation with perinatal outcome.

Our study included a sample size of 75 participants, ranging in age from 18 to 40 years, with a mean age of 25.17 ± 4.86 years. Most of our study participants were in the age group of, 21-25 years (37.3%) followed by 26-30 years (29.3%), 18-20 years (18.7%), 31-35 years (9.3%), and 36-40 years (5.3%). Similar to our study, the study by Konwar *et al* [32]. had a sample size of 50 participants aged between 21 and 33 years, with a mean age of 26.6 ± 3.1 years. Also, in the Kale *et al* [30]. study included a sample of 90 participants with a mean age of 25.4 years, ranging from 18 to 37 years, where most participants were between 21 and 25 years old (43.3%), followed by 26-30 years (28.9%), less than 20 years (16.7%), and over 30 years (11.1%). The age distribution was 26–30 years (46%), 31–35 years (24%), 21–25 years (16%), and 36–50 years (14%) in the Malhan *et al* [31]. study, which was almost similar to our study.

Among our study participants, 23 were primiparous (30.7%) and 52 were multiparous (69.3%). Similar to our study, in the Kale *et al* [30]. Study, 54.4% of participants were multigravida, and 45.6% were primigravida and the Malhan *et al* [31]. study observed multiparous women (64%) in their research. The study by Konwar *et al* [32]. showed most of their participants (70%) were between 38 and 40 weeks of gestation at the time of the Doppler examination, and a significant proportion (68%) were primigravida, which was in contrary to our study.

The S/D ratio provides a straightforward assessment of blood flow during diastolic flow and calculates downstream resistance. The resistance index (RI) or pourcelot index, is helpful in comparing wave forms regardless of their diastolic flow when the diastolic flow is absent or reversed and the S/D cannot be calculated. The pulsatality index takes into account the mean velocity as a diameter, meaning that the entire flow is taken into account rather than just the diastolic flow, and can therefore be used to analyze data from different vessels without encountering the excessive variation that can occur from division by small numbers, as with the other two indexes [33, 34].

In the present study, the mean systolic-diastolic (SD) ratio of the uterine artery was 2.51 ± 0.56, and the mean resistance index (RI) was 0.58 ± 0.11. The presence of a diastolic notch was observed in 31 participants (41.3%), while it was absent in 44 participants (58.7%). Out of the total participants, 26 (34.7%) had normal uterine artery Doppler results, while 49 (65.3%) exhibited abnormalities.

The mean pulsatility index (PI) for the umbilical artery was 1.32 ± 0.32, the mean resistance index (RI) was 0.68 ± 0.10, and the mean systolic-diastolic (SD) ratio was 3.24 ± 0.90. The umbilical artery Doppler was normal in 38 participants (50.7%) and abnormal in 37 participants (49.3%). Meanwhile, Konwar *et al* [32]. found that the umbilical artery PI was significantly higher in severe PIH cases (1.18 ± 1.21) compared to mild PIH cases (0.98 ± 0.94) with a p-value of 0.02.

In our study, the mean PI for the MCA was 1.33 ± 0.16, and the mean RI was 0.72 ± 0.15. Normal MCA Doppler results were found in 34 participants (45.3%), while 41 participants (54.7%) had abnormal results. Similar to our study, Konwar *et al* [32]. reported that the MCA RI (0.65 ± 0.66) and PI (1.15 ± 1.13) were significantly lower in severe PIH cases compared to mild cases ($p < 0.01$). Additionally, the cerebroplacental ratio (CPR) was significantly lower in severe PIH cases in their study.

Comparatively, in the study by Kale, *et al.* [30], abnormal Doppler parameters were identified as follows: 46.7% of subjects had abnormal MCA PI, 31.1% had abnormal MCA RI, 62.2% had abnormal UA PI, 47.8% had abnormal UA RI, 52.2% had abnormal UTA PI, and 50.0% had abnormal UTA RI. Additionally, 44.4% of subjects had normal UA flow, 18.9% had reduced UA flow, 16.7% had absent end-diastolic flow (AEDF), and 20.0% had reversed end-diastolic flow (REDF).

In our study, the mean estimated fetal weight (EFW) was 1.73 ± 0.48 kilograms. The mode of delivery among participants was categorized as follows: elective lower segment cesarean section (LSCS) in 13 participants (17.3%), emergency LSCS in 12 participants (16.0%), induced labor in 37 participants (49.3%), and normal vaginal delivery (NVD) in 13 participants (17.3%). A total of 52 newborns (69.3%) were admitted to the NICU, while 18 newborns (24.0%) were not admitted. IUGR was present in 45 participants (60.0%) and absent in 30 participants (40.0%). Similar to our study, Kale *et al* [30]. reported that 34.4% of subjects had normal vaginal deliveries, while 65.6% underwent lower segment cesarean sections.

In concordance to our study, in the study by Konwar *et al* [32], NICU admissions were 58.8%, low birth weight was 55.9%, and emergency caesarean section rates were 44.1%. They found that the RI abnormality of the umbilical artery was significantly related to adverse pregnancy outcomes ($p < 0.05$). The CPR (MCA PI/UmA PI) had the highest sensitivity (84.8%) and accuracy (82.0%) in predicting adverse outcomes, highlighting its diagnostic value.

Also, in the study by Malhan, *et al* [31], 48% of patients had normal uterine artery Doppler and spectral waveforms. Abnormal patterns included high-resistance flow (32%), early diastolic notch (16%), and a combination of both (4%). The umbilical artery showed normal Doppler in 16% of patients. Abnormal patterns included high-resistance flow (56%), absent diastolic flow (22%), and diastolic reversal (6%). The MCA Doppler was normal in 82% of patients, with abnormal low-resistance flow in 18%.

In our study, the mean APGAR score at 1 minute was 4.29 ± 1.81, while the mean APGAR score at 5 minutes was 6.19 ± 2.32. When categorized by APGAR scores at 5 minutes, 36 participants (48.0%) had an APGAR score more than 7, whereas 39 participants (52.0%) had a score lesser than 7. There were 5 stillbirths (6.7%) reported, with the remaining 70 participants (93.3%) having live births.

We observed the complications in our study as birth asphyxia (1.3%), hypoxic-ischemic encephalopathy (HIE) (6.7%), hyperbilirubinemia (4.0%), hypoglycemia (9.3%), meconium aspiration syndrome (10.7%), preterm care (6.7%), and sepsis (1.3%). Similar to our study, Kale *et al* [30]. reported adverse fetal outcomes were observed in 65.6% of subjects. They also reported preeclampsia with severe features (77.7%), eclampsia (79.2%), and preeclampsia without severe features (70.3%), Gestational diabetes had the lowest rate of adverse outcomes (33.3%) in their research.

In the study, the association between uterine artery Doppler parameters and APGAR scores at the 5th minute was examined. The results showed that among participants with abnormal uterine artery Doppler parameters, 32 (65.3%) had an APGAR score of less than 7, while only 17 (34.7%) had an APGAR score greater than 7. In contrast, among those with normal uterine artery Doppler parameters, only 7 (26.9%) had an APGAR score of less than 7, and 19 (73.1%) had an APGAR score greater than 7. The statistical analysis revealed a significant association ($p < 0.001$), indicating that abnormal uterine artery Doppler parameters are strongly associated with lower APGAR scores at 5 minutes.

Waveforms of the umbilical artery show placental blood flow and downstream vascular resistance. Increased vascular resistance in the umbilicoplacental microcirculation is strongly correlated with the lower end-diastolic velocity of the umbilical artery [35]. In the Malhan *et al* [31]. study, the presence of missing and reversed diastolic flow in the spectral waveform was found to be significantly important for both the newborn's status and the length of stay in the NICU. Also, the umbilical artery spectral waveform shown a sensitivity of over 85% in forecasting the perinatal result, including birth weight, rate of NICU admission, and the ultimate neonatal outcome in their study.

The present study also evaluated the relationship between umbilical artery Doppler parameters and APGAR scores at the 5th minute. Among those with abnormal umbilical artery Doppler parameters, 27 (73.0%) had an APGAR score of less than 7, while 10 (27.0%) had an APGAR score greater than 7. Conversely, among participants with normal umbilical artery Doppler parameters, 12 (31.6%) had an APGAR score of less than 7, and 26 (68.4%) had an APGAR score greater than 7. The association was statistically significant ($p < 0.001$), suggesting that abnormal umbilical artery Doppler parameters are significantly linked to lower APGAR scores at 5 minutes.

For the middle cerebral artery (MCA) Doppler parameters, the study found that 25 (61.0%) participants with abnormal MCA Doppler had an APGAR score of less than 7, while 16 (39.0%) had an APGAR score greater than 7. Among those with normal MCA Doppler parameters, 14 (41.2%) had an APGAR score of less than 7, and 20 (58.8%) had an APGAR score greater than 7. Although the trend suggests that abnormal MCA Doppler parameters might be associated with lower APGAR scores, the statistical significance was not strong ($p = 0.088$).

The current study explored the association between uterine artery Doppler parameters and NICU admission. Results showed that among participants with abnormal uterine artery Doppler parameters, 33 (67.3%) required NICU admission. On the other hand, among those with normal uterine artery Doppler parameters, 19 (73.1%) did not require NICU admission, while 7 (26.9%) did. The association was statistically significant ($p = 0.001$), indicating a strong link between abnormal uterine artery Doppler parameters and increased NICU admissions.

However, Malhan *et al* [31]. reported that 41 patients delivered preterm and 9 delivered at term. The study showed a combined perinatal and neonatal mortality rate of 24%. Of the live births, 35 were admitted to the NICU, with some requiring intensive care such as bag and mask ventilation (44%) and intubation (20%) in their study.

In terms of the umbilical artery Doppler parameters and NICU admission in our research, this study found that 28 (75.7%) participants with abnormal umbilical artery Doppler parameters required NICU admission. Among participants with normal umbilical artery Doppler parameters, 24 (63.2%) did not require NICU admission, while 14 (36.8%) did. The association was statistically significant ($p = 0.004$), demonstrating a significant correlation between abnormal umbilical artery Doppler parameters and higher rates of NICU admissions.

Regarding MCA Doppler parameters, the current study showed that 31 (75.6%) participants with abnormal MCA Doppler parameters required NICU admission, while only 5 (12.2%) did not. Among those with normal MCA Doppler parameters, 21 (61.8%) did not require NICU admission, and 13 (38.2%) did. The association was statistically significant ($p = 0.007$), indicating that abnormal MCA Doppler parameters are associated with increased NICU admissions. Similar to our study, high incidence of LSCS for fetal distress, NICU admissions, and low Apgar scores in cases with abnormal UA and MCA Doppler indices were observed in the Singh *et al* [36]. Study.

In IUGR, there is a decrease in diastolic flow in the umbilical artery due to increased resistance in small arteries and arterioles soft the tertiary villi. This increases the S/D ratio, or Pl and Rl of the umbilical artery. As placental insufficiency worsens, diastolic flow decreases, then becomes absent, and finally reverses. Some fetuses have decreased diastolic flow that remains constant with advancing gestation and never becomes absent or reversed, which may be related to a milder form of placental insufficiency. The prevalence of perinatal diabetes among those with absent or reversed diastolic flow velocity is reported to be higher than 40% [37].

The present study investigated the relationship between uterine artery Doppler parameters and intrauterine growth restriction (IUGR). Results indicated that among participants with abnormal uterine artery Doppler parameters, 29 (59.2%) had IUGR. In the group with normal uterine artery Doppler parameters, 16 (61.5%) had IUGR. For the umbilical artery Doppler parameters, the current study found that 23 (62.2%) participants with abnormal Doppler results had IUGR. Among those with normal umbilical artery Doppler parameters, 22 (57.9%) had IUGR. Lastly, we examined the association between MCA Doppler parameters and IUGR. Among participants with abnormal MCA Doppler parameters, 24 (58.5%) had IUGR. In the group with normal MCA Doppler parameters, 21 (61.8%) had IUGR. As per our study results, uterine artery Doppler is showing superiority in predicting adverse outcomes followed by umbilical artery doppler and MCA doppler.

Conclusion

Our study demonstrated that abnormal Doppler ultrasound findings in the uterine artery, umbilical artery, and middle cerebral artery were significantly associated with adverse

perinatal outcomes in pregnancies complicated by hypertension. Specifically, abnormal uterine and umbilical artery Doppler parameters were strongly linked to lower APGAR scores at 5 minutes and higher rates of NICU admissions, while abnormal MCA Doppler parameters also showed a significant association with increased NICU admissions.

These findings suggest that Doppler ultrasound can be a valuable tool in the antenatal surveillance of pregnancies with hypertension, aiding in the early identification of fetuses at risk for adverse outcomes. However, the lack of a significant correlation between Doppler parameters and intrauterine growth restriction (IUGR) indicates that Doppler ultrasound should be used in conjunction with other clinical assessments for comprehensive fetal evaluation.

Future research should focus on larger, multi-center studies to confirm these findings and explore the potential for integrating Doppler ultrasound into routine clinical practice for better management of pregnancy-induced hypertension. Additionally, longitudinal studies could provide more insights into the causal relationships between Doppler findings and perinatal outcomes.

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