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**Original Research Article**

# Uterine artery diastolic notch and S/D ratio as early markers for predicting neonatal morbidity in patients with hypertensive disorders of pregnancy

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## ABSTRACT

**Background:** Hypertensive disorders of pregnancy (HDP) affect 5-10% of pregnancies globally and are major contributors to neonatal morbidity. This study evaluated the correlation between Doppler indices of the uterine (UtA), umbilical (UA), and middle cerebral (MCA) arteries and fetal outcomes in HDP.
**Methods:** This prospective observational study, conducted at a tertiary care center in south Gujarat from September 2023 to February 2025, enrolled 138 pregnant women with a gestational age beyond 28 weeks diagnosed with HDP. Doppler indices, including the systolic/diastolic (S/D) ratio, resistance index (RI), and pulsatility index (PI), were recorded for the UtA, UA, and MCA.
**Results:** Preeclampsia was the most frequent diagnosis (53.6%). The UtA S/D ratio and the presence of a diastolic notch were significantly associated with neonatal morbidity (p=0.01), whereas UtA PI and RI were not significant predictors. All UA and MCA indices showed significant correlations with adverse outcomes (p=0.01). Notable outcomes included 63.04% low birth weight, 57.25% NICU admissions, and 10.8% neonatal deaths. The UtA notch achieved a diagnostic accuracy of 75.36%.
**Conclusions:** Abnormal Doppler indices, specifically in the UA and MCA, are reliable markers for predicting neonatal risk. Routine triple-vessel Doppler screening is recommended for early risk stratification and timely intervention in HDP.

**Keywords:** Doppler indices, Hypertensive disorder of pregnancy, Middle cerebral artery, Neonatal morbidity, Umbilical artery, Uterine artery

## INTRODUCTION

Hypertensive disorders of pregnancy (HDP) remain a major cause of maternal and neonatal morbidity worldwide. Early identification of fetuses at risk for complications such as intrauterine growth restriction (IUGR), low birth weight, preterm birth, and increased NICU admissions continues to be challenging. Because HDP is rooted in abnormal trophoblastic invasion and impaired uteroplacental remodelling, uterine artery Doppler velocimetry has become a valuable non-invasive method to assess early placental insufficiency.[1,2]

Extensive research demonstrates that abnormal uterine artery Doppler waveforms- especially increased resistance indices and the persistence of an early diastolic notch- are strongly associated with the development of preeclampsia, fetal growth restriction, and adverse perinatal outcomes.[3,4] While pulsatility index (PI) and resistance index (RI) are widely used, the systolic/diastolic (S/D) ratio and the

presence of unilateral or bilateral diastolic notch offer additional insight into uteroplacental vascular resistance.[5,6]

Recent studies focused specifically on hypertensive pregnancies have shown that elevated S/D ratio and the persistence of a diastolic notch correlate significantly with higher rates of low birth weight, NICU admission, preterm delivery, and composite neonatal morbidity.[7-9] Classic work has similarly highlighted the prognostic value of severe notching in preeclamptic women, linking it to higher maternal and perinatal risk.[6] Contemporary data from diverse populations reinforce that Doppler abnormalities in HDP are not only indicators of disease severity but also early predictors of fetal compromise.[3]

Despite substantial literature on uterine artery Doppler, there remains limited focused evidence evaluating how uterine artery diastolic notch and the S/D ratio, specifically, perform as early markers for neonatal morbidity in women with HDP. Strengthening predictive models in this population is crucial for early risk stratification and optimizing antenatal surveillance.

Therefore, the present study aimed to evaluate the predictive value of the uterine artery diastolic notch and S/D ratio for neonatal morbidity in pregnancies complicated by hypertensive disorders.

### *Aim and objectives*

*Aim*

To correlate uterine artery (UtA) Doppler markers (S/D ratio and diastolic notch), along with umbilical artery (UA) and middle cerebral artery (MCA) indices, with neonatal morbidity in patients with hypertensive disorders of pregnancy (HDP).

*Objectives*

To determine the correlation between abnormal uterine artery Doppler indices (S/D ratio and diastolic notch) and neonatal morbidity in HDP. To determine the correlation between abnormal umbilical artery Doppler indices (S/D ratio, RI, PI) and neonatal morbidity in HDP. To determine the correlation between abnormal middle cerebral artery Doppler indices (S/D ratio, RI, PI) and neonatal morbidity in HDP.

## METHODS

### *Study design*

It was a prospective observational study.

### *Study site*

The study took place at a tertiary care centre, south Gujarat.

### *Duration of study*

The duration of study was from September 2023 to February 2025 (18 Months).

### *Size of sample*

The study enrolled 138 patients.

### *Inclusion criteria*

Hypertensive pregnant women with singleton pregnancy and gestational age beyond 28 weeks, diagnosed with HDP and having obstetric Doppler parameter changes.

### *Exclusion criteria*

Pregnant women with renal/liver/heart/auto-immune disorders, history of chronic illness, multiple pregnancy, assisted conception, or fetal abnormality.

### *Methodology*

After valid, informed, consent pregnant women fulfilling the eligibility criteria were recruited in the study. Demographic details of the study subject were obtained according to the study proforma. Detailed clinical and obstetrical examination was done and laboratory investigations were performed for hypertensive disorder of pregnancy according to the protocols. These women were then subjected to obstetric ultrasound and colour doppler examination in the department of radiodiagnosis of study site after completion of formalities related to the PCPNDT act. Obstetric ultrasound and colour doppler were performed by sonologist of radiodiagnosis, on machine operational bias was reduced by performance of USG and colour doppler by same sonologist.

The BPD (bi parietal diameter), FL (femur length) AC (abdominal circumference) and MGA (mean gestational age) and other relevant data were obtained initially.

### *Sampling technique*

Doppler measurements were taken with the mother in recumbent position during fetal inactivity and apnoea. Gestational age of the patient was obtained using B mode 2-D 3.5-5 MHz convex trans abdominal probe and Doppler examination was done by pulsed Doppler method with the same probe, in the same sitting. Once the equal wave of at least five consecutive pulsatile arterial waveforms was obtained, the image is frozen and the S/D ratios, pulsatililty index (PI) and resistance index (RI) were calculated with formula during the absence of fetal breathing and body movement.

### *Doppler physics and indices*

The Doppler effect relies on the observed variations in frequency when a moving object (red blood cells) reflects

a sound wave. Doppler velocimetry indices, such as the systolic/diastolic ratio (S/D), resistance index (RI), and pulsatility index (PI), are used to quantify flow characteristics independent of the angle of insonation.

### *Uterine artery (UtA) Doppler*

The UtA waveform reflects the state of uteroplacental circulation. A persistent diastolic notch after 22-24 weeks is considered abnormal and may be linked to a poor fetal outcome. UtA flow waveforms were considered abnormal in the study with the presence of an early diastolic notch, S/D ratio >2.6, or PI/RI >95$^{th}$ percentile for the reference range.

### *Umbilical artery (UA) Doppler*

The UA Doppler reflects downstream (placental) vascular resistance. Abnormal UA flow patterns, including decreased, absent (AEDF), or reversed (REDF) end-diastolic flow, are associated with increased peripheral resistance and placental insufficiency. UA S/D ratio was considered abnormal when >3.

### *Middle cerebral artery (MCA) Doppler*

The MCA is important for assessing fetal cardiovascular distress, anemia, or hypoxia. In the presence of fetal hypoxemia, blood flow redistributes to the brain, heart, and adrenals- known as the brain-sparing effect- resulting in a decrease in cerebral vascular resistance. Abnormal MCA indices are defined as PI or RI being more than the 5th percentile of the range of reference.

## RESULTS

The analysis was performed on 138 patients of HDP with Doppler changes. The demographic profile of the participants revealed that 43.5% of the 138 patients were in the 20-24 age group, and the vast majority (92.1%) resided in rural areas. Table 1 outlines the demographic and obstetric characteristics of the study population. Analysis of these data shows that HDP is most prevalent among primigravida women (67.4%) and frequently leads to preterm deliveries, with 51.5% occurring between 33 and 36 weeks.

**Table 1: Demographics and obstetric factors.**

| Factors | No. of patients (n=138) | Percentage |
|---|---|---|
| **Age 20-24 years** | 60 | 43.5 |
| **Socio-economic status (lower class)** | 65 | 47.10 |
| **Residence (rural)** | 127 | 92.1 |
| **Type of HDP (preeclampsia)** | 74 | 53.6 |
| **Parity (primigravida)** | 93 | 67.4 |
| **Gestational age at delivery (33-36 weeks)** | 71 | 51.5 |
| **Mode of delivery (LSCS)** | 73 | 52.9 |

**Table 2: Doppler indices distribution and descriptive data.**

| Artery parameters | Abnormal cases (n=138) | Percentage | Mean±SD |
|---|---|---|---|
| **UtA RI** | 90 | 65.21 | 0.61±0.38 |
| **UtA notch** | 43 | 31.15 | N/A |
| **UA RI** | 47 | 34.05 | 0.96±0.28 |
| **MCA S/D ratio** | 33 | 23.92 | 3.01±1.73 |
| **MCA PI** | 33 | 23.92 | 1.38±0.86 |

The distribution of abnormal Doppler indices is presented in Table 2. In this cohort, 65.21% of patients displayed an abnormal UtA RI, while the presence of a UtA diastolic notch was observed in 31.15% of cases. The findings highlight that while many patients show some resistance in the uterine artery, the presence of the notch is a more specific marker.

Neonatal outcomes were notably poor among the study population, as shown in Table 3. Low birth weight was the most common adverse outcome, affecting 63.04% of neonates. More than half of the infants required NICU admission, and the neonatal death rate was 10.8%. These figures underscore the high risk associated with HDP in this demographic.

**Table 3: Neonatal outcomes.**

| Neonatal morbidity factors | Cases (n=138) | Percentage |
|---|---|---|
| **Low birth weight (<2.5 kg)** | 87 | 63.04 |
| **APGAR <7 at 5$^{th}$ minute** | 71 | 51.4 |
| **NICU admission** | 79 | 57.25 |
| **Neonatal deaths** | 15 | 10.8 |

**Table 4: Correlation of Doppler indices with neonatal morbidity.**

| Artery parameters | Correlation with neonatal morbidity | P value |
|---|---|---|
| **UtA S/D ratio** | Significant (S) | 0.01 |
| **UtA PI** | Not significant (NS) | 0.38 |
| **UtA RI** | Not significant (NS) | 0.37 |
| **UtA Notch** | Significant (S) | 0.01 |
| **UA S/D ratio, RI, PI** | Significant (S) | 0.01 |
| **MCA S/D ratio, RI, PI** | Significant (S) | 0.01 |

Table 4 details the correlation between specific Doppler parameters and neonatal morbidity. The statistical analysis confirms that the UtA S/D ratio and the diastolic notch have a significant positive correlation with morbidity (p=0.01). However, in a divergence from some previous literature, UtA PI and RI did not show a statistically significant correlation within this specific study group.

## DISCUSSION

The efficacy of Doppler velocimetry as a non-invasive screening tool lies in its ability to anticipate adverse outcomes arising from impaired placental perfusion. In the present study, the presence of a UtA diastolic notch and an elevated S/D ratio were highly significant indicators of neonatal morbidity. This aligns with findings from other studies suggesting that the notch reflects increased vascular resistance and poor placentation.[10] For instance, studies indicates that women with a diastolic notch are nearly twice as likely to develop preeclampsia.[11] In our study, the UtA notch achieved a high diagnostic accuracy of 75.36%. Interestingly, while some literature suggests that an abnormal UtA PI is a significant indicator of adverse outcomes, with some women being four times more likely to develop preeclampsia, our study found no significant correlation for UtA PI or RI.[11] This discrepancy may be due to the specific characteristics of our rural, predominantly primigravida study population as the resources and demography contributed to the incidence and diagnosis of the condition.[12] Conversely, the findings regarding the umbilical artery and middle cerebral artery were consistent with established research. The UA indices reflect downstream placental resistance, and the MCA indices reveal the "brain-sparing" effect.[13] In our study, all UA and MCA indices were reliable predictors of morbidity, with MCA PI showing a remarkable specificity of 92.05%. This suggests that while uterine artery markers are useful for early screening, umbilical and cerebral markers are more definitive indicators of immediate fetal distress. However, there are studies showing other parameters (CO, HRPH, MAP, PLGF, TSH and 25-OH) as individuals or in combination to be of greater significance and diagnostic accuracy in terms of predicting the occurrence of pre-eclampsia.[14,15] Comparing these results to previous studies reinforces the concept that multi-vessel Doppler can provide a more comprehensive picture of fetal well-being than any single index alone.[9,16]

The limitations of this study include its conduct at a single tertiary hospital with a relatively small sample size of 138 patients, which may limit the generalizability of the findings to the broader population. The 18-month duration also precluded the evaluation of long-term developmental outcomes for the neonates. Additionally, the exclusion of high-risk factors such as multiple gestations and co-morbidities like renal or heart disease means the findings are specifically tailored to HDP and may not apply to pregnancies with complex medical histories. Larger, multicentric studies are required to develop a standardized global protocol for these markers with long term follow ups.

### *Summary*

The study confirmed that Doppler indices can reliably anticipate neonatal morbidity in obstetric patients with HDP. The maximum patients were primigravida (67.4%) and delivered preterm (51.5% between 33-36 weeks). Among UtA indices, the S/D ratio and the presence of a notch were significantly correlated with neonatal morbidity, while PI and RI were not significant. UA and MCA indices (S/D ratio, PI, and RI) all showed significant correlations with neonatal morbidity (p<0.01). The need for NICU admission (57.25%) and low birth weight (63.04%) were the most common adverse outcomes observed.

## CONCLUSION

This study advances the clinical understanding of HDP by demonstrating that specific uterine artery markers- the diastolic notch and S/D ratio- are superior to PI and RI for the early prediction of neonatal morbidity in this population. When combined with umbilical and middle cerebral artery indices, these Doppler parameters provide a robust framework for identifying high-risk fetuses, allowing for timely medical intervention and optimized referral to feto-maternal units. The findings support the routine integration of triple-vessel Doppler screening for all pregnant women with HDP, facilitating a proactive approach to antenatal care that can significantly reduce the incidence of low birth weight and NICU admissions.

### *Recommendations*

Triple vessel Doppler ultrasound study is highly advantageous in anticipating neonatal morbidity in hypertensive disorders of pregnancy when velocimetry is abnormal. It is recommended to perform colour Doppler studies for all pregnant women, not just those in high-risk pregnancies, to help in the earlier identification of fetuses at risk. Early detection of any abnormality in the Doppler velocimetry can facilitate timely referrals to higher institutes with comprehensive feto-maternal unit set-ups.

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