Comparison of Doppler Indices in Diabetic and Non-Diabetic Populations during the Third Trimester of Pregnancy

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ABSTRACT

Background: Maternal diabetes mellitus is associated with altered placental function and adverse perinatal outcomes. Doppler ultrasonography provides a non-invasive method for assessing uteroplacental and fetal hemodynamics, particularly during the third trimester when circulatory adaptations are most pronounced. **Aim of the study:** To compare umbilical artery (UA), middle cerebral artery (MCA), and cerebroplacental ratio (CPR) Doppler indices in diabetic and non-diabetic pregnant women during the third trimester. **Methods & Materials:** This hospital-based comparative cross-sectional study included 100 third-trimester pregnant women (≥32 weeks of gestation), comprising 50 diabetic and 50 non-diabetic participants. Doppler ultrasonography was performed to measure UA and MCA systolic/diastolic (S/D) ratio, resistance index (RI), pulsatility index (PI), and CPR. Data were analyzed using SPSS version 26.0, and intergroup comparisons were made using independent sample t-tests and chi-square tests, with a p-value <0.05 considered statistically significant. **Result:** Diabetic pregnancies demonstrated significantly higher UA S/D ratio, RI, and PI compared with non-diabetic pregnancies (p <0.001 for all). Conversely, MCA Doppler indices (S/D ratio, RI, and PI) were significantly lower in the diabetic group (p ≤0.01). The mean CPR was significantly reduced in diabetic pregnancies (1.14 ± 0.26 vs. 1.52 ± 0.31; p <0.001), and abnormal CPR (<1.1) was more frequent among diabetic women (36.0% vs. 12.0%; p = 0.006). Overall, abnormal Doppler findings were significantly more prevalent in diabetic pregnancies. **Conclusion:** Diabetes in pregnancy is associated with significant alterations in fetal Doppler indices during the third trimester, reflecting increased placental resistance and fetal circulatory redistribution. Routine Doppler surveillance may help identify high-risk diabetic pregnancies and guide timely clinical intervention.

Keywords: *Diabetes in pregnancy; Doppler ultrasonography; Umbilical artery; Middle cerebral artery; Cerebroplacental ratio.*

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Introduction

Doppler indices are simple numerical ratios derived from Doppler ultrasound waveforms, such as the pulsatility index, resistance index, and systolic/diastolic ratio, that quantify blood flow resistance in vessels [1]. In a global context, roughly 20–30% of third-trimester diabetic pregnancies may demonstrate altered Doppler indices compared to non-diabetic pregnancies, while most non-diabetic pregnancies maintain normal Doppler flow values [2]. In Bangladesh, about 35% of pregnant women may have gestational diabetes in the third trimester, and many of these diabetic pregnancies are likely to show altered Doppler indices compared with most non-diabetic pregnancies, which typically have normal Doppler flow patterns [3]. The pulsatility index (PI) indicates vascular resistance; an increased PI during pregnancy suggests elevated resistance and placental hypoperfusion, which can impair fetal growth and signal maternal hemodynamic failure. The resistance index (RI) correlates with placental vascular impedance by quantifying resistance to blood flow, with higher RI values in late gestation indicating increased placental resistance and compromised fetal blood supply [4]. The S/D ratio assesses the relationship between systolic and diastolic blood flow velocities, where an elevated S/D ratio reflects increased downstream resistance and potential fetal distress, serving as a marker of fetal well-being [5]. Changes in these Doppler indices are used clinically to monitor fetal growth restriction, preeclampsia, and other complications by detecting abnormal placental and fetal circulation patterns [6]. Maternal hyperglycemia can transiently increase uteroplacental vascular resistance, as shown by elevated uterine artery pulsatility index (PI) and resistance index (RI) following glucose challenge tests, although fetal Doppler indices may remain unchanged in healthy pregnancies [7]. Gestational diabetes mellitus (GDM) alters fetal vascular resistance through mechanisms including endothelial dysfunction, insulin resistance, oxidative stress, inflammation, and impaired nitric oxide signaling, which reduce vasodilation and increase placental vascular resistance [8]. Hyperglycemia disrupts trophoblast function and uterine spiral artery remodeling by inhibiting trophoblast invasion and altering angiogenic factors, leading to poor placental blood flow and increased vascular resistance [9]. The third trimester is critical for detecting these hemodynamic changes via Doppler indices because placental and fetal circulatory adaptations peak, and abnormalities in blood flow patterns become more pronounced, correlating with adverse pregnancy outcomes in diabetic pregnancies [10]. Changes in uterine and umbilical artery Doppler indices can predict adverse perinatal outcomes in diabetic pregnancies by reflecting abnormal placental and fetal hemodynamics; for example, abnormal umbilical artery half peak systolic velocity deceleration time (UA hPSV-DT) is strongly associated with composite adverse perinatal outcomes (CAPO) in gestational diabetes mellitus (GDM), even when conventional Doppler indices are normal [11]. Compared to non-diabetic pregnancies, diabetic pregnancies often exhibit altered Doppler parameters such as lower middle cerebral artery (MCA) PI and abnormal umbilical artery Doppler, which correlate with increased risks of fetal growth restriction, preterm birth, and neonatal morbidity [12]. Doppler-based assessment informs intervention strategies by enabling earlier identification of fetuses at risk, guiding closer monitoring, timing of delivery, and management of maternal glycemic control to reduce fetal morbidity and optimize perinatal outcomes [13]. This study aimed to compare Doppler blood flow indices in the third trimester between pregnant women with diabetes and those without diabetes.

Methods & Materials

This was a hospital-based comparative cross-sectional study conducted in the Department of Radiology and Imaging, BIRDEM General Hospital in Bangladesh. The study period extended from July, 2024 to June 2025. A total of 100 pregnant women in their third trimester (≥32 weeks of gestation) were enrolled and divided into two equal groups:

Group A (Diabetic group): 50 pregnant women with diabetes mellitus
Group B (Non-diabetic group): 50 pregnant women with normal glucose tolerance

Gestational age was determined based on the last menstrual period (LMP) and confirmed by first-trimester ultrasonography when available.

Inclusion Criteria:

- Pregnant women in the third trimester of pregnancy (≥32 weeks of gestation)
- Women diagnosed with diabetes mellitus (gestational or pregestational) for Group A
- Non-diabetic pregnant women with normal glucose tolerance for Group B
- Adequate visualization of fetal vessels on Doppler ultrasonography

Exclusion Criteria:

- Pregnancies complicated by hypertensive disorders.
- Known fetal congenital anomalies or chromosomal abnormalities
- Placental abnormalities.
- Intrauterine infections
- Maternal systemic illnesses other than diabetes
- Poor-quality Doppler waveforms or technically inadequate Doppler assessment

Ethical Considerations

The study protocol was approved by the Institutional Ethical Review Committee. Written informed consent was obtained from all participants prior to enrollment. Confidentiality of patient information was strictly maintained.

Doppler Ultrasonography

All participants underwent Doppler ultrasonography using a high-resolution ultrasound machine with color Doppler capability and a 3.5–5 MHz convex transducer. Doppler examinations were performed with the mother in a semi-recumbent position, during fetal quiescence, and in the absence of uterine contractions. At least three consecutive uniform waveforms were obtained, and the average value was recorded.

Data Collection

Baseline maternal characteristics, including maternal age, gestational age, body mass index (BMI), and parity, were recorded for all participants using a structured data collection sheet. Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m²). Doppler ultrasonography was performed to assess fetal and placental circulation. The umbilical artery was sampled from a free-floating loop of the umbilical cord, and systolic/diastolic (S/D) ratio, resistance index (RI), and pulsatility index (PI) were measured. The middle cerebral artery was identified in a transverse section of the fetal head at the level of the thalami, close to its origin from the internal carotid artery, and the same Doppler indices were recorded. The cerebroplacental ratio (CPR) was calculated as the ratio of middle cerebral artery pulsatility index to umbilical artery pulsatility index (MCA PI/UA PI). A CPR value of less than 1.1 was considered abnormal.

Definition of Abnormal Doppler

Abnormal Doppler findings were defined as:

- Umbilical artery PI above the 95th percentile for gestational age
- Middle cerebral artery PI below the 5th percentile for gestational age
- CPR < 1.1

Statistical Analysis

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Comparisons of continuous variables between the two study groups were performed using the independent sample *t*-test, and categorical variables were compared using the chi-square test. A *p*-value of less than 0.05 was considered statistically significant.

Result

The mean maternal age was significantly higher in Group A compared to Group B (29.6 ± 4.2 vs. 27.8 ± 3.9 years; $p = 0.03$). Mean BMI was also significantly higher in Group A (26.4 ± 3.1 kg/m²) than in Group B (24.1 ± 2.8 kg/m²; $p = 0.001$). However, there was no significant difference in mean gestational age between the two groups (33.9 ± 2.1 vs. 34.2 ± 2.0 weeks; $p = 0.42$). In the diabetic group, 22 women (44.0%) were primigravida and in the non-diabetic group, 25 women (50.0%) were primigravida. The difference in gravidity status between the groups was not statistically significant ($p = 0.54$) (*Table I*).

Table I
Baseline maternal characteristics of study population (*n* =100).

Variable	Group A, Mean ± SD	Group B, Mean ± SD	p-value
Maternal age (years)	29.6 ± 4.2	27.8 ± 3.9	0.03
Gestational age (weeks)	33.9 ± 2.1	34.2 ± 2.0	0.42
BMI (kg/m²)	26.4 ± 3.1	24.1 ± 2.8	0.001
Gravida, n (%)			
Primi	22 (44.00)	25 (50.00)	0.54
Multi	28 (56.00)	25 (50.00)	0.54

The mean systolic/diastolic (S/D) ratio was significantly increased in Group A (3.21 ± 0.52) compared with Group B (2.82 ± 0.41) ($p < 0.001$). Similarly, the resistance index (0.68 ± 0.07 vs 0.61 ± 0.06) and pulsatility index (1.12 ± 0.21 vs 0.95 ± 0.18) were significantly higher in the diabetic group, with all differences being statistically significant ($p < 0.001$) (*Table II*).

Table II
Umbilical artery Doppler indices in diabetic and non-diabetic pregnancies.

Doppler Index	Group A, Mean ± SD	Group B, Mean ± SD	p-value
Systolic/Diastolic ratio (S/D)	3.21 ± 0.52	2.82 ± 0.41	<0.001
Resistance Index (RI)	0.68 ± 0.07	0.61 ± 0.06	<0.001
Pulsatility Index (PI)	1.12 ± 0.21	0.95 ± 0.18	<0.001

The mean S/D ratio was significantly lower in the diabetic group compared to the non-diabetic group (3.78 ± 0.64 vs 4.12 ± 0.58; *p* = 0.01). Similarly, the resistance index and pulsatility index were significantly reduced in diabetic pregnancies (RI: 0.74 ± 0.06 vs 0.79 ± 0.05; PI: 1.28 ± 0.19 vs 1.45 ± 0.22), with both differences being highly statistically significant (*p* < 0.001) (*Table III*).

Table III
Middle cerebral artery (MCA) Doppler indices.

Doppler Index	Group A, Mean ± SD	Group B, Mean ± SD	p-value
S/D ratio	3.78 ± 0.64	4.12 ± 0.58	0.01
Resistance Index (RI)	0.74 ± 0.06	0.79 ± 0.05	<0.001
Pulsatility Index (PI)	1.28 ± 0.19	1.45 ± 0.22	<0.001

The mean cerebroplacental ratio was significantly lower in the diabetic group compared to the non-diabetic group (1.14 ± 0.26 vs 1.52 ± 0.31; *p* < 0.001). A CPR value < 1.1 was observed more frequently among diabetic pregnancies (36.0%) than non-diabetic pregnancies (12.0%), and this difference was statistically significant (*p* = 0.006) (*Table IV*).

Table IV
Cerebroplacental ratio (CPR) comparison among patients (*n* =100).

Parameter	Group A	Group B	p-value
CPR (mean ± SD)	1.14 ± 0.26	1.52 ± 0.31	<0.001
CPR < 1.1, n (%)	18 (36.00)	6 (12.00)	0.006

Regarding abnormal Doppler findings, diabetic pregnancies demonstrated a significantly higher proportion of abnormalities across all parameters. Abnormal umbilical artery pulsatility index was present in 40.0% of diabetic women and 16.0% in the non-diabetic group (*p* = 0.008). Abnormal MCA PI was observed in 34.0% versus 12.0% (*p* = 0.01), and abnormal CPR in 36.0% versus 12.0% of participants in Groups A and B, respectively (*p* = 0.006) (*Table V*).

Table V
Proportion of abnormal Doppler findings among study participants (*n* =100).

Doppler Abnormality	Group A, n (%)	Group B, n (%)	p-value
Abnormal UA PI	20 (40.00)	8 (16.00)	0.008
Abnormal MCA PI	17 (34.00)	6 (12.00)	0.01
Abnormal CPR	18 (36.00)	6 (12.00)	0.006

Discussion

Fetal Doppler indices in the third trimester provide important information on placental function and fetal well-being. Maternal diabetes can alter these indices, leading to changes in fetal circulation. This study aimed to compare umbilical artery, middle cerebral artery, and cerebroplacental ratio Doppler indices between diabetic and non-diabetic pregnancies. In this study, the diabetic group (Group A) had a higher mean maternal age (29.6 ± 4.2 years) than the non-diabetic group (27.8 ± 3.9 years) (p = 0.03), and BMI was significantly higher in Group A (26.4 ± 3.1 kg/m²) compared with Group B (24.1 ± 2.8 kg/m²) (p = 0.001). Gestational age and gravidity did not differ significantly. These trends align with several studies those reported that women with gestational diabetes or pre-existing diabetes are generally older and had higher BMI compared to non-diabetic pregnant women [14,15]. For example, in a large study of singleton pregnancies, women with gestational diabetes had a median age of 31.6 years versus 29.0 years in non-diabetic controls, and mean BMI was 30.8 kg/m² in the GDM group compared with 25.2 kg/m² in non-diabetic pregnancies (p < 0.01 for both comparisons) both showed older age and higher BMI in diabetic pregnancies [14]. Another case control baseline analysis in Bangladesh identified that diabetic pregnant women tended to have slightly higher mean age and BMI compared with non-diabetic counterparts, though differences were not statistically significant in that sample [15]. These results agree with previous studies showing that higher age and BMI increase the risk of diabetes in pregnancy. We found that diabetic pregnancies had significantly higher umbilical artery Doppler indices: S/D ratio 3.21 ± 0.52 vs. 2.82 ± 0.41, RI 0.68 ± 0.07 vs. 0.61 ± 0.06, and PI 1.12 ± 0.21 vs. 0.95 ± 0.18 (p < 0.001 for all). The systematic review by Perković-Kepeči et al. showed that umbilical artery resistance index (UA-RI) was significantly higher in diabetic compared with non-diabetic pregnancies, especially in third-trimester measurements, although pooled UA-PI and UA-S/D differences were not statistically significant [2]. This suggests that elevated UA resistance is a consistent hemodynamic change in diabetic pregnancies, particularly later in gestation [2]. For comparison with normative third-trimester values in low-risk pregnancies, reference data from a large normal study indicate that UA-PI normally decreases with gestational age and median values at 29–40 weeks are below those typical of pathological states for example, overall UA-PI in normal third trimester often averages below about 1.0 [16]. Here our finding higher UA PI and RI in the diabetic group indicate increased placental resistance and impaired placental blood flow. Our study examined that the diabetic group had lower MCA S/D ratio (3.78 ± 0.64 vs. 4.12 ± 0.58), MCA RI (0.74 ± 0.06 vs. 0.79 ± 0.05), and MCA PI (1.28 ± 0.19 vs. 1.45 ± 0.22) compared with non-diabetic pregnancies ($p \leq 0.01$). This pattern indicates relative cerebral vasodilation or redistribution of blood flow that has been described in some pathological states, suggesting compensatory fetal adaptation. By contrast, Perković-Kepeči et al. found no significant pooled differences in MCA-PI, MCA-RI, or MCA-S/D ratio between diabetic and non-diabetic pregnancies when averaged across multiple studies and different trimesters, suggesting that MCA changes may be less consistent than UA alterations overall [2]. For normative context, third-trimester reference ranges describe an MCA-PI peak around mid-third trimester (around 32–33 weeks) with gradual decline toward term in healthy pregnancies, where typical MCA-PI mean values are often around 1.3–1.4 in uncomplicated fetuses [16]. In our study, mean CPR was significantly lower in the diabetic group (1.14 ± 0.26 vs. 1.52 ± 0.31, $p < 0.001$), and the proportion with CPR < 1.1 was greater in diabetes (36.00% vs. 12.00%, $p = 0.006$). A CPR value below 1–1.1 was typically considered suggestive of fetal redistribution/hemodynamic compromise and is widely used as a clinical threshold to prompt closer monitoring [17]. Similarly, a study in low-risk populations describe normal CPR values in the third trimester that increase up to approximately 32–33 weeks and then decline toward term, usually maintaining mean values near or above 1.4–1.6 in healthy fetuses [16]. Compared with these normative patterns, the lower mean CPR in your diabetic group demonstrates a relative shift toward increased UA resistance and/or decreased MCA impedance consistent with hemodynamic adaptation to placental inefficiency or fetal stress. Furthermore, other study presented that there were mean CPR values slightly higher in diabetes compared with controls (1.77 ± 0.53 vs. 1.71 ± 0.43) but without statistical significance, evaluating variability across populations and clinical settings [18]. The significant CPR reduction in our study suggests a more pronounced hemodynamic shift in the diabetic study. Finally, this present study revealed that there were significantly higher proportions of abnormal Doppler patterns in the diabetic group: abnormal UA PI in 40.00% vs. 16.00%, abnormal MCA PI in 34.00% vs. 12.00%, and abnormal CPR in 36.00% vs. 12.00% (p values from 0.008 to 0.006). Although Perković-Kepeči et al. focused on mean values and showed that UA-RI is higher in diabetic pregnancies which matching our finding of more frequent UA abnormalities [2].

Limitations

- Gestational and pre-gestational diabetes were analyzed together, and the degree of glycemic control was not stratified, which may have influenced Doppler findings.
- Neonatal outcomes were not assessed, limiting the ability to correlate Doppler abnormalities with clinical outcomes.

Conclusion & Recommendations

This comparative study demonstrates that diabetic pregnancies in the third trimester exhibit significantly altered fetal Doppler indices compared with non-diabetic pregnancies. Increased umbilical artery resistance and reduced middle cerebral artery impedance, resulting in a lower cerebroplacental ratio, suggest compromised placental perfusion and adaptive fetal circulatory redistribution in diabetic mothers. These findings underscore the clinical value of Doppler ultrasonography as a non-invasive surveillance tool for identifying fetal compromise in diabetic pregnancies. Incorporation of routine Doppler assessment into antenatal care for diabetic women may facilitate early detection of high-risk fetuses, optimize monitoring strategies, and improve perinatal outcomes. Larger multicenter prospective studies incorporating neonatal outcome measures are recommended to further validate these observations.

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