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Doppler comparison of fetoplacental blood flow characteristics between pre-gestational diabetic and non-diabetic pregnant women during second and third trimester of pregnancy

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ABSTRACT

Objective. To compare the fetoplacental blood flow characteristics and placental thickness between diabetic *vs* non-diabetic pregnant women during second and third trimester.

Materials and Methods. It was case-control study. Sample size was 186. Pre-gestational diabetic and non-diabetic pregnant women between 20-35 years, with normal singleton, pregnancy at 20-42 weeks of gestational age were included. Females with maternal hypertension, intrauterine growth restriction, small /large for gestational age and any other foetal anomaly were excluded.

Results. Diabetic mothers had a peak systolic velocity of 37.05 ± 7.59 cm/s compared to 37.95 ± 7.03 cm/s in non-diabetics. However, end-diastolic velocity was significantly lower in diabetics 12.13 ± 3.85 cm/s than in non-diabetics 15.38 ± 3.63 cm/s, (P-value: 0.000). The systolic/diastolic ratio was higher in diabetics 3.11 ± 0.81 compared to non-diabetics 2.54 ± 0.40, also statistically significant. Additionally, diabetics had a higher resistive index of 1.15 ± 0.45 *versus* 0.90 ± 0.16 in non-diabetics (P-value: 0.000). The pulsatility index was 0.67 ± 0.09 in diabetics and 0.59 ± 0.06 in non-diabetics, showing a significant difference. Placental thickness was greater in diabetics 4.03 ± 0.40 mm compared to non-diabetics 3.51 ± 0.47 mm (P-value: 0.000).

Conclusions. Our study found that Doppler parameters were significantly changed in the diabetic pregnancy: the EDV is lower, and the S/D ratio is higher, while the RI and PI are increased. The findings reveal that PSV and EDV increase significantly from the second to the third trimester, indicating enhanced placental blood flow as pregnancy progresses.

INTRODUCTION

Diabetes is becoming more common in Asia at a startling rate. A new estimate from the International Diabetes Foundation suggests that by the year of 2030, almost 438 million people worldwide or more than 4.5% worlds estimated population may have diabetes [1]. South-East Asia has the greatest

prevalence of diabetes mellitus (24.2%), whereas Africa has the lowest prevalence (10.5%). Due to limited access to maternal healthcare within nations, nearly 90% of pregnancy-related occurrences of diabetes occurred in low- and middle-income countries [2]. The most prevalent illness during pregnancy is diabetes. Women who suffer from diabetes mellitus (GDM) or pre-gestational diabetes (type 1 and 2 diabetes). Diabetes affects 1 in 6 (16.8%) pregnancies, according to the International Diabetes Federation. Of these, 86.4 percent have gestational diabetes mellitus (GDM), while 13.6% have pre-gestational diabetes [3]. The fetus's normal growth mostly depends on the placenta's normal function, structure, and morphology. Placental dysfunction is caused by defects in placental development, such as decreased placental size or changed placental nutrient transport capacity [4].
South Asian women had the highest rate of prenatal placental vascular insufficiency, at roughly 10.6% [5]. In Pakistan, it varies between 2.2% and 7%, with a startlingly high perinatal death rate of 50.63% to 62.5% [6]. Vascular insufficiency is caused by a decrease in blood flow to the foetus across the umbilicus, and this condition may be attributable to elevated umbilical-placental vascular resistance. Reduced placental blood flow in pregnancy or aberrant villi insertion into the placental membrane, which is a perfusion defect between the placenta and umbilicus. Increased resistance results in abnormal Doppler flow of umbilical artery velocity waveforms [7]. Reduced umbilical artery diastolic flow and increased placental vascular resistance, indicated by a high pulsatility index, results from the destruction of small muscle arteries due to maternal or placental circumstances [25]. In response to a decline in foetal oxygenation and reduced blood flow through the umbilical cord, the foetal ductus venosus widens to redirect oxygenated blood away from the liver via the umbilical vein. This redirection ensures that the heart and brain receive an adequate supply of oxygen and nutrients [8].
Placental thickness is closely linked to foetal development and may play a significant role in the neonatal outcome. The placenta has a diameter of 15-25 cm and a thickness of about 3 cm at term. 2 cm of placental thickness and 18 cm of diameter at gestational age of 36 weeks indicates foetal low birth weight, is the "warning limit". Placentas larger than 4 cm in diameter at term have been reported in cases of foetal hydrops, diabetes mellitus, and perinatal infections [9].
Foetal hypoxemia causes a down regulation of foetal metabolic demands, which in turn prompts the preservation of resources that are already available and leads to intrauterine foetal growth restriction [10]. The placenta is usually described as round or oval, although it can also take on different forms like bilobate, irregular, or circumvallate [11]. An effective clinical method for antepartum foetal monitoring pregnancies at risk for placental vascular disease has been proposed: Doppler umbilical artery velocimetry. Pre-eclampsia and foetal growth retardation have been linked to abnormal umbilical artery waveforms. Pregnant women who have insulin-dependent diabetes mellitus are more susceptible to developing these disorders [12]. For this reason, UA Doppler is a helpful diagnostic test when early onset FGR identified by foetal biometry is present [5].
This study's rationale was to understand how diabetes might affect placental function and blood flow, potentially affecting foetal growth and development. By comparing Doppler ultrasound measurements in these two groups, we can gain insights into the potential role of diabetes in blood flow characteristics and its implications for pregnancy outcomes.

MATERIALS AND METHODS

It was a case-control study conducted at University Ultrasound Clinic, Green Town, Lahore for the duration of 12 months. Convenient sampling technique was used to collect the data. Sample size was calculated at 90% level of significance and 80% power of test. The mean ± SD Umbilical artery PI with and without DM are 0.93 ± 0.229 and 1.01 ± 0.209, respectively. Calculated sample size was 93 for cases and 93 for controls. Total sample size was 186.

Inclusion criteria

Pre-gestational diabetic and non-diabetic pregnant women between 20-35 years age, with normal singleton, pregnancy at 20-42 weeks of gestational age were included.

Exclusion criteria

Females with maternal hypertension, intrauterine growth restriction, small or large for gestational age, gestational diabetes and any other foetal anomaly.

Procedure

Data was collected after the approval from Research Ethical Committee, The University of Lahore Ref No # REC-UOL-519-09-2023. Prior to engaging with participants, consent forms were obtained. The patient couch was prepared with sheets for patient privacy, and the patient was positioned supine in accordance with scanning requirements. Ultrasound machine Toshiba (Xario Prime) with 2-5MHz frequency convex transducer was used and a generous amount of gel was applied. Scanning was conducted in both transverse and longitudinal planes as necessary. After participant selection based on inclusion and exclusion criteria, gestational age was recorded using the Last Menstrual Period (LMP). A standard obstetrical ultrasound examination for the 2nd and 3rd trimesters was performed to detect any abnormalities. Parameters were documented using Gray scale ultrasound in both longitudinal and transverse planes. Subsequently, Doppler ultrasound of the umbilical arteries was conducted in the sagittal plane to record the Umbilical Artery S/D ratio, PI, R1, PSV, and EDV. All scans were performed by a certified radiologist.

Data analysis procedure

Data was analysed using SPSS version 25.0. Quantitative variables were presented in mean ± SD. Qualitative variables were presented in frequency and percentages. Independent sample t-test and Analysis of variance (ANOVA) were applied. P-value less than 0.05 was considered significant.

RESULTS

In total 186 mothers, the average age was 27.76 ± 2.41 years. The mean gestational age was 31.30 ± 4.72 weeks. Among the participants, 50% (n = 93) had pre-gestational diabetes, and 50% (n = 93) were normal. 24.2% mothers (n = 45) were in their second trimester, while 75.8% (n= 141) were in their third trimester. When examining diabetes according to trimester, 14% (26 mothers) in the second trimester had pre-gestational diabetes, compared to 36% (n = 67) in the third trimester. Among those with normal diabetes, 8.6% (16 mothers) were in the second trimester, and 41.4% (n = 77) were in the third trimester. Placental thickness averaged 3.77 mm ± 0.50. Placental grading was distributed as follows: 47.3% (88) had a Grade 1 placenta, 45.7% (n = 85) had a Grade 2 placenta, and 7% (n = 13) had a Grade 3 placenta. For Doppler ultrasound measurements, the peak systolic velocity (PSV) averaged 37.50 ± 7.31 cm/s, the end-diastolic velocity (EDV) averaged 13.76 ± 4.07 cm/s, the systolic/diastolic (S/D) ratio averaged 2.83 ± 0.70, the pulsatility index (PI) averaged 0.63 ± 0.09, and the resistive index (RI) averaged 1.02 ± 0.36 (**Table 1**). Diabetic mothers had a peak systolic velocity (PSV) of 37.05 ± 7.59 cm/s compared to 37.95 ± 7.03 cm/s in non-diabetics, with no significant difference (P-value = 0.405). However, end-diastolic velocity (EDV) was significantly lower in diabetics (12.13 ± 3.85 cm/s) than in non-diabetics (15.38 ± 3.63 cm/s), with a P-value of 0.000. The systolic/diastolic (S/D) ratio was higher in diabetics (3.11 ± 0.81) compared to non-diabetics (2.54 ± 0.40), also statistically significant (P-value = 0.000). Additionally, diabetics had a higher resistive index (RI) of 1.15 ± 0.45 *versus* 0.90 ± 0.16 in non-diabetics (P-value = 0.000). The pulsatility index (PI) was 0.67 ± 0.09 in diabetics and 0.59 ± 0.06 in non-diabetics, showing a significant difference (P-value = 0.000). Lastly, placental thickness was greater in diabetics (4.03 ± 0.40 mm) compared to non-diabetics (3.51 ± 0.47 mm), with a P-value of 0.000. These findings highlight notable differences in vascular and placental parameters between diabetic and non-diabetic pregnant women (**Table 2**).

Table 1. *Demographic and descriptive statistics.*

Variables		Mean ± SD
Age		27.76 ± 2.41
Gestational Age		31.30 ± 4.72
Pre-Gestational Diabetes	Yes	93 (50%)
	No	93 (50%)
Trimester	2nd	45 (24.2%)
	3rd	141 (75.8%)
Diabetes according to trimester	Diabetics	2nd
		3rd
	Normal	2nd
		3rd
Placental thickness		3.77 ± 0.50
Placental Grading	Grade 1	88 (47.3%)
	Grade 2	85 (45.7%)
	Grade 3	13 (7%)
PSV		37.50 ± 7.31
EDV		13.76 ± 4.07
S/D Ratio		2.83 ± 0.70
PI		0.63 ± 0.09
RI		1.02 ± 0.36

Table 2. *Mean comparison of Doppler parameters between pre-gestational diabetic and non-diabetic.*

Pre-Gestational Diabetic and non-diabetic		n	Mean ± SD	Std. Error Mean	P-value
PSV	Diabetics	93	37.05 ± 7.59	0.78	0.405
	Non-Diabetic	93	37.95 ± 7.03	0.72	
EDV	Diabetics	93	12.13 ± 3.85	0.39	0.000
	Non-Diabetic	93	15.38 ± 3.63	0.37	
S/D Ratio	Diabetics	93	3.11 ± 0.81	0.08	0.000
	Non-Diabetic	93	2.54 ± 0.40	0.04	
RI	Diabetics	93	1.15 ± 0.45	0.04	0.000
	Non-Diabetic	93	0.90 ± 0.16	0.01	
PI	Diabetics	93	0.67 ± 0.09	0.01	0.000
	Non-Diabetic	93	0.59 ± 0.06	0.00	
Placental thickness	Diabetics	93	4.03 ± 0.40	0.04	0.000
	Non-Diabetic	93	3.51 ± 0.47	0.04	

Table 3. *Mean comparison of Doppler parameters between trimesters.*

	Trimester	n	Mean ± SD	Std. Error Mean	P-value
PSV	2nd	45	34.24 ± 7.37	109.893	0.001
	3rd	141	38.54 ± 7.00	.59026	
EDV	2nd	45	11.57 ± 4.00	.59759	0.000
	3rd	141	14.45 ± 3.85	.32495	
S/D Ratio	2nd	45	3.21 ± 0.82	.12322	0.000
	3rd	141	2.71 ± 0.61	.05154	
RI	2nd	45	1.20 ± 0.60	.09063	0.000
	3rd	141	0.97 ± 0.21	.01780	
PI	2ND	45	0.67 ± 0.11	.01726	0.001
	3rd	141	0.62 ± 0.07	.00659	
Placental thickness	2nd	45	3.77 ± 0.53	.07921	0.973
	3rd	141	3.77 ± 0.50	.04246	

The peak systolic velocity (PSV) was significantly lower in the second trimester (34.24 ± 7.37 cm/s) compared to the third trimester (38.54 ± 7.00 cm/s), with a P-Value of 0.001. End-diastolic velocity (EDV) was also significantly lower in the second trimester (11.57 ± 4.00 cm/s) than in the third trimester (14.45 ± 3.85 cm/s), with a P-value of 0.000. The systolic/diastolic (S/D) ratio was higher in the second trimester (3.21 ± 0.82) compared to the third trimester (2.71 ± 0.61), which was statistically significant (P-Value: 0.000). Additionally, the resistive index (RI) was higher in the second trimester (1.20 ± 0.60) than in the third trimester (0.97 ± 0.21), with a P-Value of 0.000. The pulsatility index (PI) showed a significant difference between trimesters, being higher in the second trimester (0.67 ± 0.11) compared to the third trimester (0.62 ± 0.07), with a P-Value of 0.001. However, placental thickness showed no significant difference between the second (3.77 ± 0.53 mm) and third trimesters (3.77 ± 0.50 mm), with a P-Value of 0.973. These findings indicate significant trimester-based differences in Doppler ultrasound parameters but not in placental thickness (**Table 3**). In the second trimester, diabetic participants had a lower peak systolic velocity (PSV) of 32.32 ± 6.16 cm/s compared to 35.52 ± 7.25 cm/s in non-diabetic participants, with a P-value of 0.000. End-diastolic velocity (EDV) was also lower in diabetic participants (9.58 ± 3.07 cm/s) than in non-diabetics (14.16 ± 4.07 cm/s), with a P-value of 0.000. The systolic/diastolic (S/D) ratio was higher in diabetics (3.57 ± 0.77) compared to non-diabetics (2.72 ± 0.52), which was statistically significant (P-value = 0.000). The resistive index (RI) was significantly higher in diabetics (1.37 ± 0.74) than in non-diabetics (0.98 ± 0.17), with a P-Value of 0.000. The pulsatility index (PI) was higher in diabetics (0.72 ± 0.12) compared to non-diabetics (0.61 ± 0.06), with a P-Value of 0.000. Placental thickness was also greater in diabetics (3.99 ± 0.39 mm) than in non-diabetics (3.32 ± 0.45 mm), with a P-value of 0.000. In the third trimester, the PSV was similar between diabetic (38.8 ± 7.33 cm/s) and non-diabetic participants (38.45 ± 6.93 cm/s), with a P-Value of 0.405. However, EDV was significantly lower in diabetics (13.13 ± 3.68 cm/s) compared to non-diabetics (15.6 ± 3.51 cm/s), with a P-Value of 0.000. The S/D ratio was higher in diabetics (2.94 ± 0.76) than in non-diabetics (2.50 ± 0.36), with a P-value of 0.000. The RI was higher in diabetics (1.06 ± 0.22) compared to non-diabetics (0.89 ± 0.16), with a P-Value of 0.000. The PI was also higher in diabetics (0.66 ± 0.07) compared to non-diabetics (0.59 ± 0.06), with a P-Value of 0.000. Finally, placental thickness was greater in diabetics (4.04 ± 0.41 mm) than in non-diabetics (3.55 ± 0.46 mm), with a P-Value of 0.000. These findings indicate that significant differences exist in Doppler characteristics and placental thickness between diabetic and non-diabetic participants, both in the second and third trimesters, with diabetic participants generally showing higher resistive and pulsatility indices, higher S/D ratios, and greater placental thickness (**Figures 1,2** and **Table 4**).

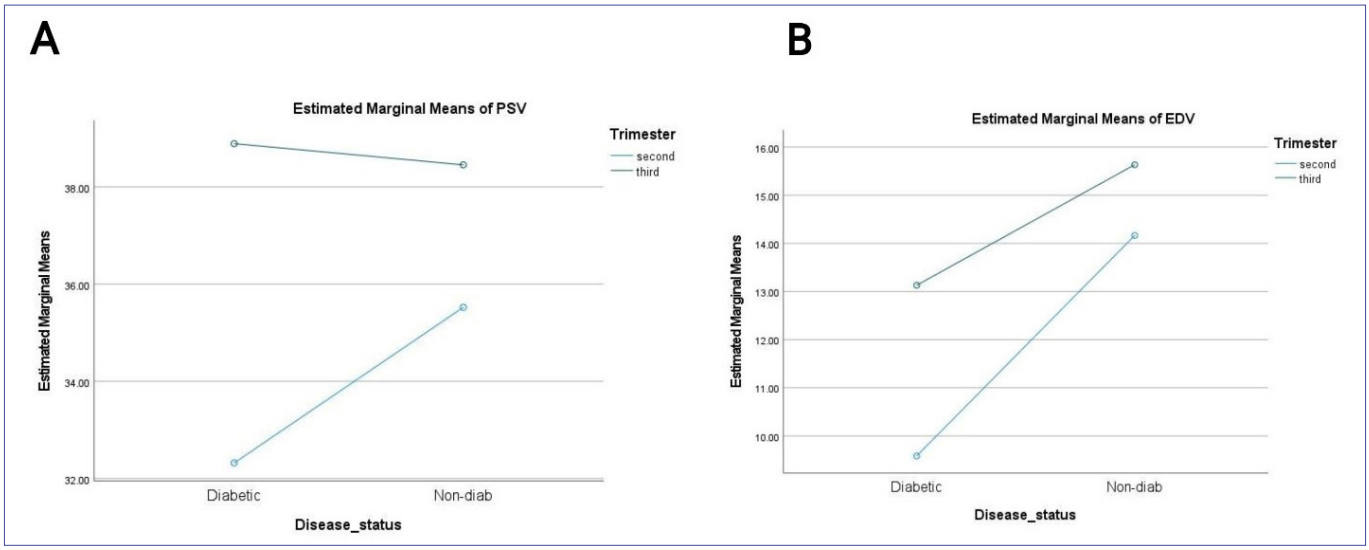

Figure 1. ***(A)*** *Line chart between estimated marginal means of PSV and disease status;* ***(B)*** *Line chart between estimated marginal mean of EDV and disease status.*

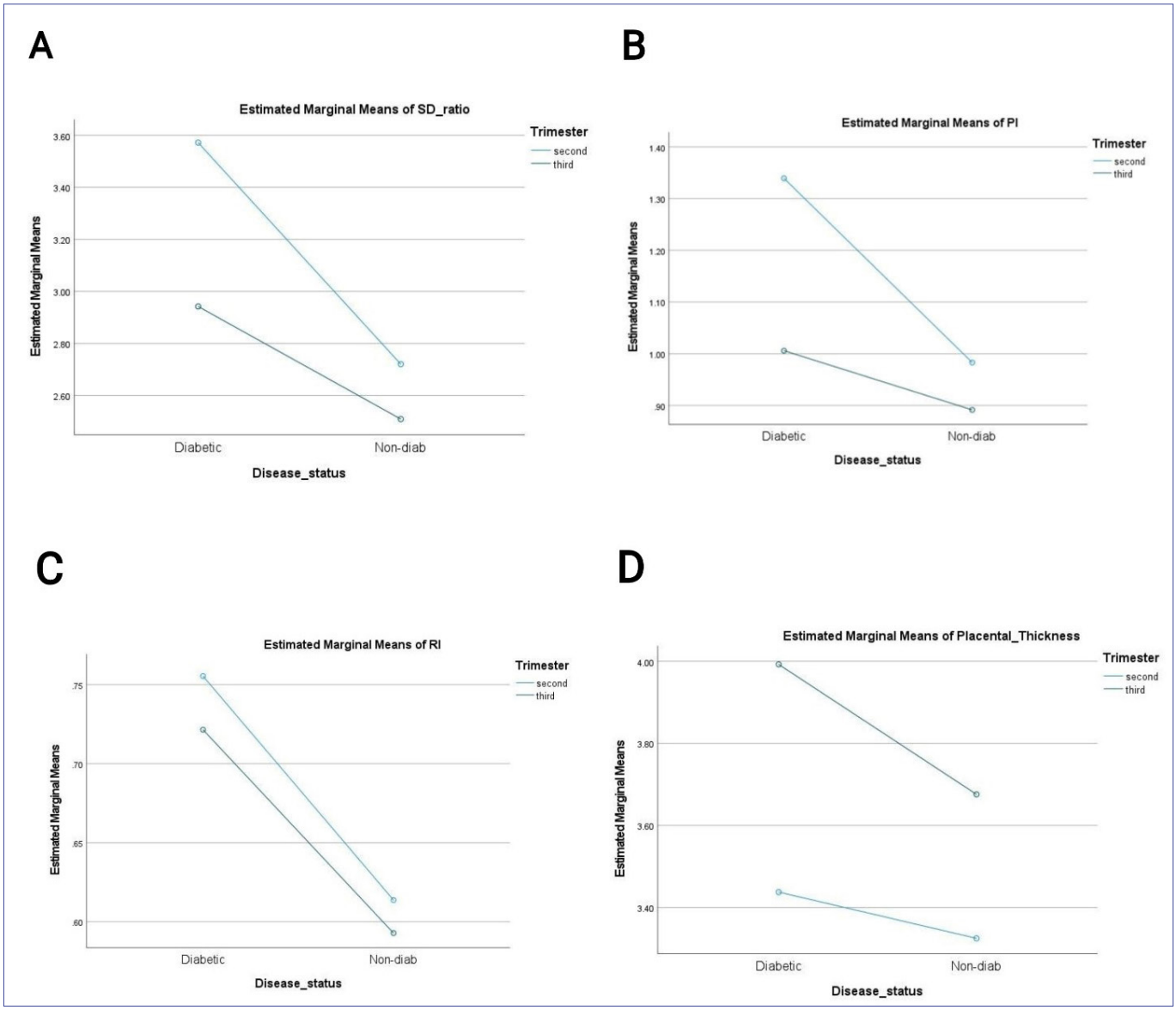

Figure 2. ***(A)*** *Line chart between estimated marginal mean of S/D ratio and disease status;* ***(B)*** *Line chart between estimated marginal mean of PI and disease status;* ***(C)*** *Line chart between estimated marginal mean of RI and disease status;* ***(D)*** *Line chart between estimated marginal mean of placental thickness and disease status.*

Table 4. *Mean comparison of Doppler characteristics according to trimesters and diabetes status.*

Doppler Characteristics	Diabetic n = 26 2nd Trimester Mean ± SD	Non-diabetic n = 16 2nd Trimester Mean ± SD	Diabetic n = 67 3rd Trimester Mean ± SD	Non-diabetic n = 77 3rd Trimester Mean ± SD
PSV	32.32 ± 6.16	35.52 ± 7.25	38.8 ± 7.33	38.45 ± 6.93
P-value	0.000		0.405	
EDV	9.58 ± 3.07	14.16 ± 4.07	13.13 ± 3.68	15.6 ± 3.51
P-value	0.000		0.000	
S/D Ratio	3.57 ± 0.77	2.72 ± 0.52	2.94 ± 0.76	2.50 ± 0.36
P-value	0.000		0.000	
RI	1.37 ± 0.74	0.98 ± 0.17	1.06 ± 0.22	0.89 ± 0.16
P-value	0.000		0.000	
PI	0.72 ± 0.12	0.61 ± 0.06	0.66 ± 0.07	0.59 ± 0.06
P-value	0.000		0.000	
Placental Thickness	3.99 ± 0.39	3.32 ± 0.45	4.04 ± 0.41	3.55 ± 0.46
P-value	0.000		0.000	

Table 5. *Mean comparison of Doppler parameters between placental grading.*

Placental Grading		Placental thickness	PSV	EDV	S/D Ratio	RI	PI
1 (n = 88)	Mean ± SD	3.69 ± 0.51	36.6 ± 7.10	13.83 ± 4.36	2.82 ± 0.68	1.01 ± 0.26	0.62 ± 0.08
2 (n = 85)	Mean ± SD	3.81 ± 0.51	37.87 ± 7.47	13.82 ± 3.69	2.86 ± 0.68	1.02 ± 0.44	0.64 ± 0.09
3 (n = 13)	Mean ± SD	4.05 ± 0.22	40.87 ± 7.00	12.83 ± 4.63	2.71± 0.90	1.14 ± 0.31	0.68 ± 0.10

For participants with a Grade 1 placenta (n = 88), the mean placental thickness was 3.69 ± 0.51 mm. The peak systolic velocity (PSV) was 36.6 ± 7.10 cm/s, end-diastolic velocity (EDV) was 13.83 ± 4.36 cm/s, systolic/diastolic (S/D) ratio was 2.82 ± 0.68, resistive index (RI) was 1.01 ± 0.26, and pulsatility index (PI) was 0.62 ± 0.08. For participants with a Grade 2 placenta (n = 85), the mean placental thickness was 3.81 ± 0.51 mm. The PSV was 37.87 ± 7.47 cm/s, EDV was 13.82 ± 3.69 cm/s, S/D ratio was 2.86 ± 0.68, RI was 1.02 ± 0.44, and PI was 0.64 ± 0.09. For participants with a Grade 3 placenta (n = 13), the mean placental thickness was 4.05 ± 0.22 mm. The PSV was 40.87 ± 7.00 cm/s, EDV was 12.83 ± 4.63 cm/s, S/D ratio was 2.71 ± 0.90, RI was 1.14 ± 0.31, and PI was 0.68 ± 0.10. These findings indicate that higher placental grades are associated with increased placental thickness and PSV. However, there is a slight decrease in EDV and S/D ratio with increasing placental grade. RI and PI also tend to increase with higher placental grades (**Table 5**).

DISCUSSION

This study reveals significant differences in Doppler characteristics and placental thickness between diabetic and non-diabetic pregnancies across the second and third trimesters. Diabetic participants consistently showed lower peak systolic and end-diastolic velocities, higher systolic/diastolic ratios, and elevated resistive and pulsatility indices compared to non-diabetic participants. Additionally, placental thickness was greater in diabetic pregnancies. These findings suggest that diabetes is associated with increased vascular resistance and impaired blood flow within the placenta, highlighting the potential impact of diabetes on placental function and foetal development.

In the second trimester, diabetic participants had a lower EDV (9.58 ± 3.07 cm/s) compared to non-diabetics (14.16 ± 4.07 cm/s). The increased S/D ratio (3.57 ± 0.77 in diabetics *vs* 2.72 ± 0.52 in non-diabetics) and higher RI (1.37 ± 0.74 in diabetics *vs* 0.98 ± 0.17 in non-diabetics) further underscore the elevated placental resistance in diabetic pregnancies. These changes are likely due to the vascular remodelling that occurs in response to hyperglycaemia, which can lead to endothelial dysfunction and impaired placental perfusion [13, 14]. In the third trimester, the pattern persisted, with diabetic participants showing a lower EDV (13.13 ± 3.68 cm/s) compared to non-diabetics (15.6 ± 3.51 cm/s), along with higher S/D ratio, RI, and PI. Placental thickness was also significantly greater in diabetic par-

ticipants (4.04 ± 0.41 mm in diabetics *vs* 3.55 ± 0.46 mm in non-diabetics in the third trimester), which might indicate compensatory mechanisms for maintaining adequate nutrient and oxygen supply to the foetus in the face of increased vascular resistance [15, 16]. These findings are consistent with existing literature that associates diabetes in pregnancy with alterations in placental structure and function, which can lead to adverse outcomes such as foetal growth restriction (FGR) and preeclampsia [17].

Trimester variations also showed significant effects on Doppler parameters and placental thickness. As pregnancy progresses from the second to the third trimester, there is an increase in peak systolic velocity (PSV) and end-diastolic velocity (EDV), reflecting enhanced placental blood flow and reduced vascular resistance as the placenta matures [18]. For instance, PSV increased from 34.24 ± 7.37 cm/s in the second trimester to 38.54 ± 7.00 cm/s in the third trimester. Similarly, EDV increased from 11.57 ± 4.00 cm/s to 14.45 ± 3.85 cm/s over the same period.

However, despite the increase in blood flow, the systolic/diastolic (S/D) ratio, resistive index (RI), and pulsatility index (PI) showed a decrease from the second to the third trimester. The S/D ratio decreased from 3.21 ± 0.82 in the second trimester to 2.71 ± 0.61 in the third trimester, indicating a reduction in placental vascular resistance as the pregnancy progresses. This decrease in resistive indices suggests that the placenta becomes more efficient at delivering blood to the foetus in later stages of pregnancy, which is crucial for supporting rapid foetal growth during the third trimester [19]. Placental thickness, however, did not show a significant difference between the second and third trimesters, with both trimesters recording a mean thickness of 3.77 mm. This lack of significant change suggests that placental thickness reaches a plateau during the second trimester and remains relatively stable afterward, while the placenta's vascular architecture continues to mature and adapt to the increasing demands of the growing foetus [20].

Placental grading, which reflects the maturity of the placenta, was also associated with significant differences in Doppler parameters and placental thickness. As placental grade increased from Grade 1 to Grade 3, there was a corresponding increase in placental thickness, PSV, and slight changes in EDV, S/D ratio, RI, and PI. For example, placental thickness increased from 3.69 ± 0.51 mm in Grade 1 to 4.05 ± 0.22 mm in Grade 3, suggesting that higher

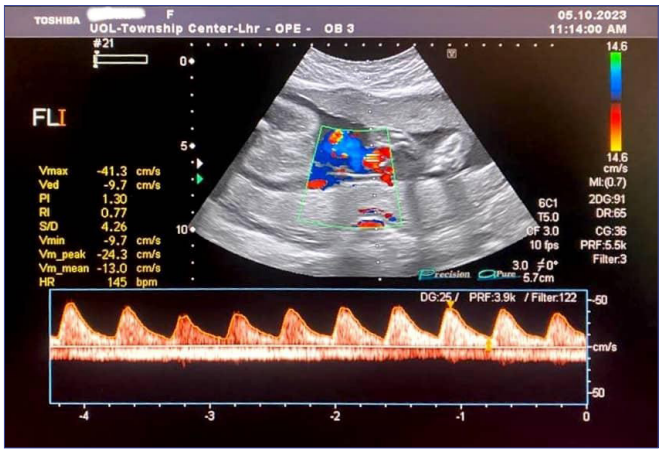

Figure 3. *Doppler indices of umbilical artery of diabetic pregnant woman with gestational age of 30 week 0 day.*

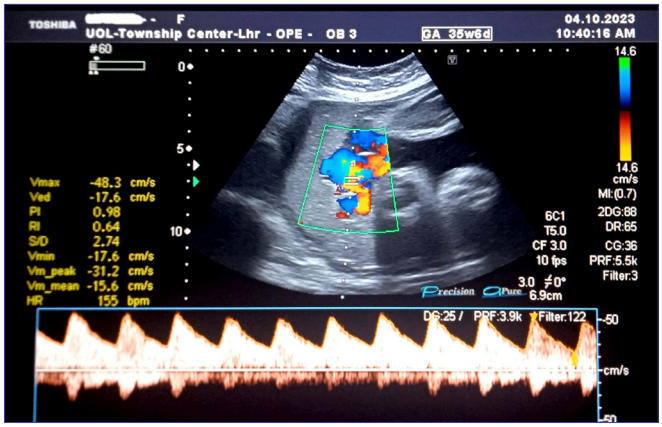

Figure 4. *Doppler indices of umbilical artery of diabetic pregnant woman with gestational age of 35 week 6 day.*

placental grades are associated with more advanced placental development and maturation [21].

The increase in PSV from 36.6 ± 7.10 cm/s in Grade 1 to 40.87 ± 7.00 cm/s in Grade 3 indicates enhanced placental blood flow as the placenta matures. However, the slight decrease in EDV in Grade 3 placentas might suggest that while the placenta becomes more capable of handling increased blood flow (as indicated by higher PSV), there may also be a slight increase in placental vascular resistance, as evidenced by the higher RI and PI values in Grade 3 [22].

These findings suggest that placental grading can serve as an important indicator of placental function and health, with higher grades reflecting more mature placentas that are capable of supporting the foetus through increased blood flow. However, the increased resistive indices in higher-grade placentas could indicate potential challenges in placental perfusion, particularly in pregnancies complicated by conditions such as diabetes, where placental function may already be compromised [23].

In addition, a study was conducted in Italy by Troìa *et al*., where they observed decreased in umbilical artery blood flow in diabetic mothers who were on insulin therapy [24].

A key limitation of this study is the lack of separate analysis based on diabetes type (Type 1 *vs* Type 2) and specific therapies (*e.g*., insulin, oral agents, and dietary management). Given the distinct physiological impacts and varied treatment responses, these factors likely affect fetoplacental blood flow differently. This limitation should be considered when interpreting the results, and future studies would benefit from examining these subgroups independently for more precise insights.

CONCLUSIONS

Our study found that Doppler parameters were significantly changed in the diabetic pregnancy: the EDV is lower, and the S/D ratio is higher, while the RI and PI are increased. Additionally, diabetic pregnancies showed increased placental thickness compared to non-diabetic pregnancies. The findings reveal that PSV and EDV increase significantly from the second to the third trimester, indicating enhanced placental blood flow as pregnancy progresses.

Study also highlights significant associations between placental grading and Doppler ultrasound parameters. Higher placental grades are associated with increased placental thickness and PSV, alongside changes in EDV, S/D ratio, RI, and PI. These findings suggest that careful monitoring of these parameters can provide critical insights into placental function and foetal health, enabling early detection of potential complications.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' contribution

F.R., S.G: Data curation. S.M.Y.F., M.F: Formal analysis, supervision, writing – original draft. S.A.G., H.S.A.G., A.U., M.M; Writing – review & editing.

Funding

None.

Study registration

N.A.

Disclosure of interests

The authors declare that they have no conflict of interests.

Ethical approval

The Research Ethical Committee of The University of Lahore approved this research (ethics code: Ref No # REC-UOL-519-09-2023).

Informed consent

All participants were provided with necessary explanations about the objectives and each enrolled patient gave informed consent to allow data collection and analysis for research purposes prior to the start of the study.

Data sharing

Data are available under reasonable request to the corresponding author.

REFERENCES

1. Li J, Chen YP, Dong YP, Yu CH, Lu YP, Xiao XM, et al. the impact of umbilical blood flow regulation on fetal development differs in diabetic and non-diabetic pregnancy. Kidney Blood Press Res. 2014;39(4):369-77. doi: 10.1159/000355815.
2. Plows JF, Stanley JL, Baker PN, Reynolds CM, Vickers MH. The Pathophysiology of Gestational Diabetes Mellitus. Int J Mol Sci. 2018;19(11):3342. doi: 10.3390/ijms19113342.
3. Egan AM, Dunne FP. Epidemiology of gestational and pregestational diabetes mellitus. Gest Diabet. 2020;28:1-10. doi: 10.1159/000480161.
4. Salavati N, Smies M, Ganzevoort W, Charles AK, Erwich JJ, Plösch T, et al. The Possible Role of Placental Morphometry in the Detection of Fetal Growth Restriction. Front Physiol. 2019;9:1884. doi: 10.3389/fphys.2018.01884.
5. Audette MC, Kingdom JC. Screening for fetal growth restriction and placental insufficiency. Semin Fetal Neonatal Med. 2018;23(2):119-25. doi: 10.1016/j.siny.2017.11.004.
6. Bibi S, Ghaffar S, Pir MA, Yousfani S. Risk factors and clinical outcome of placental abruption: a retrospective analysis. J Pak Med Assoc. 2009;59(10):672-4.
7. GRIT Study Group. A randomised trial of timed delivery for the compromised preterm fetus: short term outcomes and Bayesian interpretation. BJOG. 2003;110(1):27-32. doi: 10.1046/j.1471-0528.2003.02014.x.

8. Brown LD, Hay WW Jr. Impact of placental insufficiency on fetal skeletal muscle growth. Mol Cell Endocrinol. 2016;435:69-77. doi: 10.1016/j.mce.2016.03.017.
9. BaGhel P, Bahel V, Paramhans RA, Sachdev PO, Onkar SO. Correlation of placental thickness estimated by ultrasonography with gestational age and fetal outcome. Ind J Neonat Med Res. 2015;3(3):19-24. doi: IJNMR/2014/13676.2057.
10. Agarwal R, Tiwari A, Wadhwa N, Radhakrishnan G. Placental histopathological findings in preterm/term and early/late onset small for gestation age: Are they significant? Indian J Pathol Microbiol. 2017;60(2):232-235. doi: 10.4103/IJPM.IJPM_390_16.
11. Longtine MS, Nelson DM. Placental dysfunction and fetal programming: the importance of placental size, shape, histopathology, and molecular composition. Semin Reprod Med. 2011;29(3):187-96. doi: 10.1055/s-0031-1275515.
12. Landon MB, Gabbe SG, Bruner JP, Ludmir J. Doppler umbilical artery velocimetry in pregnancy complicated by insulin-dependent diabetes mellitus. Obstet Gynecol. 1989;73(6):961-5. doi: 10.1097/00006250-198906000-00011.
13. Jauniaux E, Burton GJ. Pathophysiology of histological changes in early pregnancy loss. Placenta. 2005;26(2-3):114-23. doi: 10.1016/j.placenta.2004.05.011.
14. Kornacki J, Gutaj P, Kalantarova A, Sibiak R, Jankowski M, Wender-Ozegowska E. Endothelial Dysfunction in Pregnancy Complications. Biomedicines. 2021;9(12):1756. doi: 10.3390/biomedicines9121756.
15. Negrato CA, Mattar R, Gomes MB. Adverse pregnancy outcomes in women with diabetes. Diabetol Metab Syndr. 2012;4(1):41. doi: 10.1186/1758-5996-4-41.
16. Alves JA, Silva BY, de Sousa PC, Maia SB, Costa Fda S. Reference range of uterine artery Doppler parameters between the 11th and 14th pregnancy weeks in a population sample from Northeast Brazil. Rev Bras Ginecol Obstet. 2013;35(8):357-62. doi: 10.1590/s0100-72032013000800004.
17. Kleinwechter H, Schäfer-Graf U, Bührer C, et al. Gestational diabetes mellitus (GDM) – diagnosis, treatment and follow-up. Guideline of the DDG and DGGG (S3-level, AWMF registry no. 057/008). Diabetol. 2016;11:107-16. doi: 10.1055/a-0659-2596.
18. Adekanmi AJ, Roberts A, Adeyinka AO, Umeh EO, Anor F, Odo JC, Fagbohun AO. Normal second and third trimester uterine and umbilical doppler indices among healthy singleton gestation Nigerian women. West African J Radiol. 2017;24(1):1-7. doi: 10.4103/1115-3474.198078.
19. Figueras F, Gratacós E. Update on the diagnosis and classification of fetal growth restriction and proposal of a stage-based management protocol. Fetal Diagn Ther. 2014;36(2):86-98. doi: 10.1159/000357592.
20. Kingdom JC, Kaufmann P. Oxygen and placental villous development: origins of fetal hypoxia. Placenta. 1997;18(8):613-21; discussion 623-6. doi: 10.1016/s0143-4004(97)90000-x.
21. Romero R, Espinoza J, Kusanovic JP, Gotsch F, Hassan S, Erez O, Chaiworapongsa T, Mazor M. The preterm parturition syndrome. BJOG. 2006;113 Suppl 3(Suppl 3):17-42. doi: 10.1111/j.1471-0528.2006.01120.x. Erratum in: BJOG. 2008;115(5):674-5.
22. Acharya G, Wilsgaard T, Berntsen GK, Maltau JM, Kiserud T. Reference ranges for serial measurements of umbilical artery Doppler indices in the second half of pregnancy. Am J Obstet Gynecol. 2005;192(3):937-44. doi: 10.1016/j.ajog.2004.09.019.
23. Baschat AA, Gembruch U, Reiss I, Gortner L, Weiner CP, Harman CR. Relationship between arterial and venous Doppler and perinatal outcome in fetal growth restriction. Ultrasound Obstet Gynecol. 2000;16(5):407-13. doi: 10.1046/j.1469-0705.2000.00284.x.
24. Troìa L, Ferrari S, Dotta A, Giacomini S, Mainolfi E, Spissu F, et al. Does Insulin Treatment Affect Umbilical Artery Doppler Indices in Pregnancies Complicated by Gestational Diabetes? Healthcare (Basel). 2024;12(19):1972. doi: 10.3390/healthcare12191972.
25. Lee S, Walker SP. The role of ultrasound in the diagnosis and management of the growth restricted fetus. Australas J Ultrasound Med. 2010;13(3):31-6. doi: 10.1002/j.2205-0140.2010.tb00161.x.