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Research Article

Doppler ultrasound of the ductus venosus in diabetic pregnancies

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ABSTRACT

Background: With the increasing number of pregnancies complicated by diabetes, it is essential to develop a straightforward and reliable method for monitoring the fetal cardiovascular system, which can be adversely affected by maternal hyperglycemia. This study aimed to investigate the potential role of ductus venosus Doppler velocities in pregnant women with diabetes.

Methods: The study involved 40 pregnant women with normal pregnancies as a control group, compared with 40 diabetic individuals in their third trimester. Each participant underwent a thorough medical history review, physical examination, laboratory analysis of HbA1c levels, and Doppler ultrasonography evaluation of their ductus venosus.

Results: The 5-minute Apgar scores were lower, infants were born with higher birth weights, and mothers with diabetes had higher BMIs. Regarding the Doppler evaluation of the ductus venosus (DV), all DV indicators, including the pulsatility index, preload index, and peak velocity index, were significantly higher in the diabetic cases than in the controls. Among the diabetic subjects, those with poor diabetes control had even higher DV indices. There was a strong correlation between the preload index and pulsatility index with pre-gestational diabetes. Neonates with low 5-minute Apgar scores had significantly higher pulsatility and preload indices compared to newborns with normal scores.

Conclusion: The ductus venosus Doppler values in pregnancies complicated by diabetes were significantly different from those in non-diabetic controls, which may have implications for fetal cardiac function.

Introduction

A group of metabolic disorders referred to as diabetes mellitus (DM) are marked by hyperglycemia caused by irregularities in the manufacturing of insulin, action, or both. It is one of the most prevalent noncommunicable illnesses and can be deleterious (1). There are three types of diabetes mellitus (DM): gestational diabetes mellitus (GDM), or diabetes first detected or diagnosed during pregnancy; type 2 diabetes, which is associated to inefficient insulin usage; and type 1 diabetes, which is correlated with pancreatic failure and insulin insufficiency (2).

Preterm births, congenital abnormalities, perinatal death, and large for gestational age (LGA) babies are among the prevalent unfavorable perinatal outcomes linked to diabetes during pregnancy (3). Heart-related abnormalities make up the largest percentage of fetal abnormalities and are the main cause of perinatal death (4). According to (5), the ductus venosus (DV), a blood channel exclusive to fetal circulation, emerges from the umbilical vein (UV) and enters the inferior vena cava at the right atrial's entrance. Fetal chromosomal disorders without cardiac malformations, congenital cardiac defects causing cardiac dysfunction, or fetal growth restriction can all result in aberrant DV waveforms (6). The pressure-volume variations in the heart are reflected in the DV waveform. Although the DV waveform has limited specificity, because of its strong link with cardiac forward function, it is crucial for determining the total severity of fetal cardiovascular pathology (7).

In complex pregnancies, such as those involving gestational diabetes, fetal cardiac function, and well-being have been assessed using the DV Doppler velocities, DV velocity ratios, and diastolic time intervals (8). Unusual DV hemodynamics in diabetic pregnancies may suggest altered fetal heart function (9). This study aimed to investigate the potential role of ductus venosus Doppler velocities in Diabetic pregnant ladies.

Methods

Between March 2020 and August 2022, the current case-control research was carried out at the Damietta Specialized Hospital's Obstetrics & Gynecology department. with the third trimester, 40 pregnant women with diabetes were enrolled as cases, while 40 women with a normal pregnancy were included as the control group. The research did not include fetuses with IUGR or suspected chromosomal abnormalities. Mothers with cardiovascular illnesses, including hypertension, collagen disorders, and renal ailments, were not included in the study. Follow-up: Every patient was monitored until birth, at which time the following information about the infants was collected: Apgar scores at one and five minutes, birth weight. Those whose birth weight exceeds the 90th percentile for their gestational age is classified as large for gestational age (LGA). Baby weights in the 10th to 90th percentile are considered appropriate for gestational age (AGA). The adverse perinatal outcome, as defined by Wong et al. (10), was an Apgar score of less than 4- or a 5-minute Apgar rating of less than 7. No obvious congenital abnormalities were seen in the babies undergoing routine examination. Sonography: A Voluson 730 Pro device (USA) was utilized to conduct an ultrasonography scan. The amniotic fluid index (AFI) was computed. An amniotic fluid index (AFI) of more than 24 cm or a vertical pocket of at least 8 cm was considered to be polyhydramnios; an AFI of less than 5 cm or a vertical pocket of less than 2 cm was considered oligohydramnios (11).

The fetal abdomen's midsagittal or oblique transverse slices were where the DV became apparent. The angle of insonation is determined using color Doppler, and pulsed Doppler measurements originated from the DV's isthmic section. The waveforms below were recorded at a maximum insonation angle of 30°: peak forward velocity during ventricular systole (S-wave), peak forward velocity during early diastole (D-wave), and minimum forward rate during atrial contraction in late diastole (a-wave). Each waveform's analysis was conducted using the average of three consecutive high-quality samples. In addition to the time-averaged maximum velocity (Tamx) computation, the subsequent DV proportions and indicators were discovered: The vein's peak velocity indicator (PVIV) was dynamically determined using the formula (S–A)/D. The Pulsatility Index associated with the Vein (PIV) was calculated using the formula (S–a)/Tamx. The preload index (PLI) can be determined by dividing (S–a)/S by D/

a, S/a, and S/D ratios (6). For analysis, only signals collected during fetal quiescence were considered. If the examination were to be repeated, the data would only consist of the most recent batch of prenatal recordings.

Ethical consent

Every patient received a thorough explanation about the purpose of the study. Written informed consent was acquired.

Statistical analysis

Using SPSS version 19 (SPSS Inc., Chicago, USA), an IBM-compatible computer was used to arrange, tabulate, and statistically analyse the acquired data. The means and standard deviations (SD) of quantitative data were reported. The relative frequency and percent distribution of the qualitative data were displayed. To compare two groups, the Mann-Whitney or independent samples (t) tests were employed. Use of Fisher's exact test or Chi square (X2) was made for comparing categorical groupings. Correlating various variables was done using the Pearson correlation coefficient (r-test). Significant tests were those with P values less than 0.05. P > 0.05 was deemed insignificant for all tests.

Results

Babies with low 5-min Apgar scores demonstrated significantly higher preload and pulsatility indices (P=0.027 and P=0.035) compared to those with normal 5-min Apgar scores. Age, the level of parity and gestational age did not substantially differ in general features amongst the patients and the control group. Mothers with diabetes mellitus had lower 5-minute Apgar ratings (p=0.039), higher birth weights (p=0.001), and higher BMIs (P=0.013). Pregnant women with diabetes accounted for 70% of cases, and 57% of cases had poorly managed diabetes (Table 1).

Regarding the Doppler assessment of the ductus venosus, there was no statistically significant distinction between the subjects and controllers (P=0.023) except for the a-wave. We noticed that, with respect to DV ratios, cases had significantly larger ratios (S/D) and (S/a) than controls (P=0.003 and 0.001, respectively). We found that all DV indicators, such as the peak velocity indices for the vein (P=<0.001), preloaded index (P=0.024), and pulsatility index (P=<0.001), were considerably more elevated in cases than in controls (Table 2)

Examining the relationship between the Doppler assessment of ductus venosus indices and various covariates showed that among the study's diabetic subjects, poor diabetes control was linked to higher DV indices overall. Moreover, pre-gestational diabetes mellitus was linked to noticeably higher preload and pulsatility indices (p=0.026 and 0.036, respectively); PVIV was also elevated, albeit not substantially different. In addition to having a substantially greater pulsatility index and preload index than newborns with a normal 5-min Apgar score, low-apgar newborns also exhibited elevated PVIV. A significant positive correlation was observed between the DV-PI and the Apgar score and the HbA1c. On the other hand, no statistically significant correlation was seen between DV-PI and the mother's age or birth weight (Tables 3 &4).

Discussion

Pregnancy is most commonly affected by diabetes, which is linked to higher rates of morbidity in both mothers and newborns (12). In women with diabetes mellitus, maternal hyperglycemia may have an impact on the development of the fetal heart (13). According to Chiu et al. (14), ductus venosus blood flow is crucial for hemodynamics and right ventricular preload. An important component of a prenatal fetal heart activity assessment is the ductus venosus assessment, which serves as a screening and initial diagnostic tool for a variety of fetal cardiovascular disorders (15).

Table (1). Features of the cases' demographics that were examined

Variables		Cases (n=40)	Control (n=40)	P
Maternal				
Age (years)		29.3±4.7	28.9±5.13	0.66
BMI (kg/m^2)		34.6±10.5	29.04±9.2	0.013*
Parity	Multiparous Primiparous	16 (40%) 24 (60%)	11 (27%) 29 (73%)	0.34
Gestational age (weeks)		29.4±2.7	30.3±3.07	0.17
Amniotic fluid index		19.31±6.25	14.43±4.7	<0.001*
Umbilical artery PI		1.24±0.32	1.18±0.24	0.45
Neonatal				
Birth weight (g)		3546±814	3117±398	0.005*
Birth weight	Appropriate for GA (AGA) Large for GA (LGA)	26 (65%) 14 (35%)	38 (95%) 2 (5%)	0.001*
5-min Apgar	< 7 ≥ 7	6 (12.5%) 34 (85%)	0 (0%) 40 (100%)	0.039*
Characters of diabetic pregnancies				
Type of DM	Pregestational Gestational	12 (30%) 28 (70%)		
HbA1c (%)	Good control (< 7%) Poor control (> 7%)	17 (42.5%) 23 (57.5%)		

*: significant

Table (2). Comparing the ductus venosus characteristics in pregnancies with and without diabetes

	Cases (n=40)	Control (n=40)	P
S-wave (cm/s)	70.2±12.6	65.4±11.3	0.1
D-wave (cm/s)	44.2±9.8	47.6±8.7	0.11
a-wave (cm/s)	28.6±7.7	32.4±6.9	0.023*
Tamx (cm/s)	52.1±10.3	53.9±12.4	0.48
D/a ratio	1.92±0.42	1.79±0.34	0.13
S/D ratio	1.42±0.19	1.28±0.14	0.003*
S/a ratio	2.43±0.49	2.09±0.42	0.001*
DV-PI	0.623±0.04	0.589±0.035	<0.001*
PLI	0.504±0.043	0.481±0.05	0.024*
DV-PVIV	0.348±0.054	0.312±0.042	<0.001*

DV: ductus venosus; PI: pulse index; **PVIV:** vein's peak velocity indicator; **PLI:** preload index.

Table (3). Comparing the ductus venosus doppler indices of diabetes patients with respect to several parameters

	DV-PI	P	PLI	P	DV-PVIV	P
HbA1c **≥ 7% (n=23)** **< 7% (n=17)**	 0.651±0.046 0.603±0.042	0.001*	 0.528±0.047 0.486±0.038	0.003*	 0.367±0.058 0.331±0.052	0.046*
Type of DM **Pre-gestational (12)** **Gestational (28)**	 0.647±0.04 0.615±0.04	0.026*	 0.527±0.042 0.496±0.041	0.036*	 0.361±0.044 0.342±0.05	0.26
5- min Apgar score **< 7 (n=6)** **≥ 7 (n=34)**	 0.646±0.04 0.617±0.04	0.035*	 0.528±0.034 0.502±0.041	0.027*	 0.369±0.042 0.334±0.053	0.13
Birth weight **LGA (n=14)** **AGA (n=26)**	 0.638±0.04 0.617±0.04	0.12	 0.509±0.043 0.498±0.043	0.44	 0.357±0.054 0.346±0.053	0.53

Evaluation of the ductus venosus Doppler ultrasonography characteristics and its impact on the neonate was the goal of this study conducted on pregnant diabetes women. In the current investigation, end-diastolic velocity (a-wave) was the only DV wave that differed significantly between diabetic pregnancies and controls. These findings are consistent with the recognized effects of maternal diabetes-induced reduced myocardial diastolic function on fetal cardiac health, even though most studies on diabetic pregnancies do not provide DV waves (16).

Avcı et al. (8) found that there were statistically significant differences in the a-wave ($p = 0.04$) and v-descent ($p = 0.03$) velocities between the groups. Still, there were non-significant differences in the S-wave ($p = 0.21$) and D-wave ($p = 0.07$) velocities between the fetuses with intracardiac echogenic focus and controls.

According to Braga et al. (17), no significant correlation was observed between the existence of an a-wave and other types of heart disease, although there was one between a-wave presence and heart-related outflow pathways and right heart disorders ($P = 0.01$). We found that the D/a ratio did not significantly change in terms of DV percentages, but the S/D and S/a ratios were significantly greater in cases compared to controls. These ratios allow waveform anomalies to be measured at each level, which facilitates the investigation of possible causes for an anomalous PIV (16). (8) report that no difference was identified in any of the studied DV ratios between the patients and controls.

All DV measures, including as the pulsatility index, preload index, and peak velocity indices for the vein, were found to be much higher in cases compared to controls in the study. The results of a retrospective investigation of PI-DV in 142 diabetes patients were compared with DV-PI reference values from a low-risk, non-diabetic population, according to Stuart et al. (9). It was observed that pregnancies complicated by gestational diabetes or pre-existing insulin-dependent diabetes had considerably higher values of DV-PI when compared to normal reference values.

When Turan et al. (16) investigated 63 cases of PGDM with controls during the first trimester, between 11 and 14 weeks of gestation, they found no noteworthy differences in UA-PI, DV-PIV, and individualised velocity proportions (S/v, S/D, S/a, v/D, v/a, and D/a). The underlying factor can be a change to the screening schedule. Dahlback et al. (5) added that ratios regulating flow rates during atrial contraction in ventricular diastole (DV-PIV) were assumed to be more common than fluctuations in DV blood flow velocities during ventricular systole (S/ES). Sanapo et al. (18) assert that the assessment of several indices provides a more comprehensive picture of heart health than semiquantitative DV Doppler indices like the PIV, which only display relative changes to v- and D-wave velocities. Our findings align with multiple studies that assessed the heart health of fetuses of diabetic mothers using fetal echocardiography; these studies found that there were notable variations in the first-trimester diastolic myocardial function between fetuses of poorly controlled diabetic mothers and non-diabetic controls (16). In a more investigation, both maternal DM and two-dimensional speckle-tracking echocardiography caused unfavorable alterations in the fetal myocardium (13).

An analysis of the relationship between DV Doppler indices and various covariates showed that low 5-min Apgar score, PGDM, and poorly controlled diabetes (as indicated by a high HbA1c) did not correlate with birth weight. According to Turan et al. (16), preload and afterload don't seem to have an impact on the decline in myocardial function, which is more pronounced as HbA1c rises. Furthermore, Stuart et al. (9) found a statistically significant relationship between mean HbA1c values in DM pregnancies during the final month prior to the most recent DV measurement and DV-PI SD-scores. Furthermore, it was observed that there was no statistically significant difference in absolute DV-PI between the PGDM and GDM groups. Conversely, Wong et al. (10) found no correlation between aberrant DV-PVIV and either the 5-min Apgar score or birth weight.

The lack of local reference values for the ductus venosus Doppler parameters limited the present study's ability to define aberrant blood flow; yet, the case control design of the study strengthened these findings.

Conclusions

When ductus venosus Doppler measurements were compared to non-diabetic controls, diabetes pregnancies showed a substantial difference, which could point to a fetal cardiac influence. DV Doppler indices showed a substantial difference compared to basic DV waves or ratios. In diabetic situations, poor glycemic control has been associated with elevated DV Doppler indices. Preload and pulsatility indices were noticeably greater in pre-gestational diabetes than in gestational diabetes mellitus. Low 5-min Apgar score was substantially correlated with elevated DV Doppler indices in the subjects under study. The DV-pulsatility index and HbA1c showed a strong positive connection.

Prenatal care of pregnancies complicated by diabetes mellitus may benefit from the inclusion of DV-Doppler indices as a straightforward screening technique. It is advised that diabetic pregnancies be properly managed antenatally, with a focus on tight control of hyperglycemia and frequent monitoring with the HbA1c test. Given its early effects on fetal development, PGDM deserves greater attention. To validate these findings, larger-scale research is advised, with a particular emphasis on the variable elements of diabetic complications, such as intrauterine growth restriction and congenital abnormalities.

Author contribution

In the study, all authors contributed equally.

Declaration of Competing Interests

Regarding this study's implementation, authorship, or publishing, the authors state that they have no potential conflicts of interest.

Data sharing plans

Data will be available upon request.

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