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Beyond Glycemic Status: Unveiling Hidden Maternal Cardiac Dysfunction in Gestational Diabetes Mellitus versus Normoglycemic Pregnancy Using 2D Echocardiography

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Abstract

Background: Gestational Diabetes Mellitus (GDM) is a common pregnancy complication that not only affects glucose metabolism during pregnancy but also increases the long-term risk of cardiovascular diseases, highlighting the need for early cardiovascular monitoring and intervention.

Objective: This study aimed to assess the cardiac dysfunction in pregnant women with Gestational Diabetes Mellitus (GDM) compared to normoglycemic controls using two-dimensional echocardiography.

Methods: A hospital-based, observational, cross-sectional study was conducted at the Department of Obstetrics and Gynaecology, SMS Medical College, Jaipur. The study included 60 pregnant women (30 in the GDM group and 30 in the control group) with a gestational age of >34 weeks. Echocardiographic parameters, including left ventricular end-diastolic volume (LVEDV), stroke volume, cardiac output, aortic root diameter, left ventricular mass (LVM), and diastolic filling velocities, were evaluated. Statistical analysis was performed using SPSS, with p-values < 0.05 considered statistically significant.

Results: The GDM group exhibited significant differences in echocardiographic parameters compared to the control group. The GDM group had significantly lower LVEDV ($p = 0.01$), stroke volume ($p < 0.01$), and cardiac output ($p = 0.02$), while showing higher aortic root diameter ($p < 0.01$) and LVM ($p < 0.01$). Diastolic filling velocities (E-wave, $p < 0.01$) were also higher in the GDM group. Univariate logistic regression revealed significant associations between BMI, stroke volume, and cardiovascular alterations in GDM ($p < 0.001$). Multivariate analysis identified BMI, stroke volume, and aortic root diameter as independent predictors of GDM ($p < 0.001$).

Conclusion: Our findings suggest that GDM is associated with early cardiovascular alterations, including changes in cardiac structure and function, even in the absence of overt cardiovascular disease. These subclinical changes highlight the need for early cardiovascular screening in women with GDM to reduce long-term cardiovascular risks.

Keywords: Gestational Diabetes Mellitus, Cardiovascular Disease, Echocardiography, Cardiac Dysfunction, Left Ventricular Function, Stroke Volume, Aortic Root Diameter, Diastolic Dysfunction, Maternal Health, Metabolic Dysfunction.

Introduction

Gestational Diabetes Mellitus (GDM) is a condition of glucose intolerance that arises during pregnancy due to insulin resistance caused by placental hormones, leading to maternal hyperglycaemia. [1] In India, the prevalence of GDM ranges between 10% and 14.3%, with urban areas showing the highest rates. GDM significantly increases the long-term risk of cardiovascular diseases (CVD), with women who have had GDM having nearly double the risk of cardiovascular events in the first 10 years postpartum.[2] GDM is a marker of persistent metabolic and vascular dysfunction, contributing to conditions like hypertension, coronary artery disease, and stroke. [3] The physiological cardiovascular changes during pregnancy may be altered in women with GDM, leading to persistent endothelial dysfunction, oxidative stress, and dyslipidemia, which further increases cardiovascular risk.[4]

Even in women who don’t develop overt diabetes, GDM is linked to subclinical atherosclerosis and endothelial dysfunction. Postpartum, the condition often resolves but still signals increased future cardiometabolic risks.[5] The postpartum period is a crucial time for cardiovascular risk assessment and lifestyle interventions, such as diet and exercise, to reduce long-term cardiovascular events. This study aims to evaluate left and right ventricular function in women with GDM to detect early cardiac dysfunction and identify women at higher risk for future CVD. Early screening, lifestyle modifications, and long-term follow-up can significantly improve outcomes for this vulnerable population.

Materials and methods

This was a hospital-based, observational, cross-sectional, and comparative analytical study conducted at the Department of Obstetrics and Gynaecology at SMS Medical College and Attached Hospitals, Jaipur. The study aimed to evaluate maternal cardiac structure and function using two-dimensional echocardiography in pregnant women with gestational diabetes mellitus (GDM) compared to normoglycemic controls. The study was carried out over one year after obtaining approval from the Institutional Research Review Board and the Ethics Committee. Participants were singleton pregnant women with a gestational age of >34 weeks who met the eligibility criteria.

Inclusion criteria included pregnant women with a singleton live pregnancy of >34 weeks gestational age, diagnosed with GDM according to the DIPSI criteria, and normoglycemic women. Exclusion criteria ruled out pregnancies complicated by chronic illnesses such as hypertension, diabetes, hypothyroidism, ischemic heart disease, and other conditions affecting glucose metabolism. The sample size was calculated based on a previous study, estimating 30 women in each group for adequate power and significance.

Data collection included clinical evaluations and routine antenatal investigations. GDM was diagnosed using the DIPSI test, and echocardiographic assessments were performed on all participants. The systolic and diastolic function of the left ventricle was evaluated according to the American Society of Echocardiography guidelines. Statistical analysis was performed using SPSS software, with continuous variables analysed using t-tests and categorical variables analysed using chi-square or Fisher's exact tests. A p-value <0.05 was considered statistically significant.

Results

In our study, a total of 60 participants were included, with 30 women in each group. Group A consisted of pregnant women diagnosed with Gestational Diabetes Mellitus (GDM), while Group B included pregnant women with normoglycemia as the control group.

In this study Table I provides a comprehensive comparison of various demographic, clinical, and echocardiographic parameters between the control group (normoglycemic pregnant women) and the GDM group (pregnant women with gestational diabetes mellitus). There were no significant differences in the age distribution between the two groups, with a similar mean age of 29 ± 9.16 years in the control group and 30 ± 10.50 years in the GDM group. However, the GDM group had significantly higher BMI values (27.82 ± 2.71) compared to the control group (24.95 ± 2.11), indicating that elevated BMI is more common in women with GDM (p = 0.01). The heart rate was slightly higher in the GDM group (78.61 ± 9.10 bpm) compared to the control group (75.10 ± 7.31 bpm), though this difference was not statistically significant (p = 0.071). Additionally, systolic blood pressure (SBP) was significantly higher in the GDM group (123.39 ± 8.17 mmHg) compared to the control group (116.70 ± 6.35 mmHg), with a p-value of 0.01, while diastolic blood pressure (DBP) showed a trend toward being higher in the GDM group but did not reach statistical significance (p = 0.06). The DIPSI test confirmed significantly higher glucose levels in the GDM group (173.07 ± 15.55 mg/dL) compared to the control group (124.03 ± 12.47 mg/dL, p = 0.01), confirming the diagnosis of GDM.

In terms of echocardiographic parameters, significant differences were observed between the two groups. The GDM group had lower left ventricular end-diastolic volume (LVEDV) (133.54 ± 18.84 ml) compared to the control group (144.07 ± 13.63 ml, p = 0.01), and also had lower stroke volume (79.38 ± 9.57 ml vs 84.52 ± 3.93 ml, p < 0.01) and cardiac output (5501.34 ± 1301.64 ml/min vs 4891.16 ± 502.24 ml/min, p = 0.02). These changes suggest altered cardiac function in women with GDM. In contrast, the GDM group showed a significantly larger aortic root diameter (2.85 ± 0.44 cm) and left ventricular mass (128.79 ± 25.29 g) compared to the control group (2.13 ± 0.38 cm and 118.69 ± 8.96 g, p < 0.01), indicating structural changes in the heart associated with GDM. Additionally, the GDM group exhibited higher early diastolic filling velocity (E-wave) (0.52 ± 0.09 m/s vs 0.46 ± 0.08 m/s, p < 0.01), but the E/A ratio was similar between both groups (p = 0.85).

Table II presents the results of a univariate logistic regression analysis, identifying various clinical and echocardiographic parameters associated with GDM. BMI was strongly associated with GDM (OR = 1.36, p < 0.001), indicating that higher BMI is a significant risk factor for GDM. Stroke volume was also found to be significantly associated with GDM (OR = 1.33, p = 0.04), further suggesting that lower stroke volume may be a predictor of the condition. Other parameters such as systolic blood pressure (SBP), left ventricular end-diastolic volume (LVEDV), and aortic root diameter (ARD) were also significantly associated with GDM, highlighting the cardiovascular alterations in women with GDM. Notably, the diastolic parameter of the A-wave was significantly associated with GDM (OR = 0.749, p = 0.003), suggesting that diastolic dysfunction may also play a role in the pathophysiology of GDM.

Table III presents the results of a multivariate logistic regression analysis, which adjusts for potential confounders and identifies independent risk factors associated with GDM. In this analysis, BMI (OR = 0.566, p < 0.001), stroke volume (OR = 0.72, p < 0.001), and aortic root diameter (OR = 1.19, p < 0.001) were found to be significant predictors of GDM. This suggests that alterations in cardiac function and structure, such as changes in stroke volume and aortic root diameter, are independently associated with the presence of GDM. These findings underline the importance of these parameters in the early identification and management of women at risk for GDM and associated cardiovascular complications.

Overall, the data from these tables highlight the significant cardiovascular alterations in women with GDM, including increased BMI, changes in cardiac function and structure, and the persistence of these alterations even after adjusting for other potential risk factors. These findings emphasize the need for early screening and intervention for cardiovascular risk in women with GDM to prevent long-term health complications.

Discussion

Gestational diabetes mellitus (GDM) is a common pregnancy complication that has been increasingly linked to long-term cardiovascular risk in women. In this study, we examined the cardiovascular parameters in pregnant women with GDM compared to normoglycemic controls to assess the impact of GDM on maternal cardiac function and structure. The results presented in the preceding sections underscore significant alterations in cardiac structure and function in women with GDM, which may have implications for their future cardiovascular health.

Age Distribution and Demographics

In our study, we found that the age distribution between the control and GDM groups was comparable, with no significant difference in mean age between the two groups. Most participants in both groups were within the 26–30 years age range, and the overall mean age for the study population was 29.39 ± 9.83 years. These findings are consistent with those of Li et al. (2022)[5] and Buddeberg et al.[6] (2020), both of whom reported no significant age-related difference between GDM and control groups. However, some studies, like Oliveira et al.[7] (2015), suggest that advanced maternal age may be a risk factor for developing GDM, as they observed a significantly higher mean age in the GDM group. In our study, age did not emerge as a significant factor, suggesting that other risk factors, such as BMI, may have had a more pronounced influence on the development of GDM.

Cardiac Remodelling in GDM

Our study also demonstrated significant alterations in echocardiographic parameters in women with GDM, particularly in terms of left ventricular (LV) function. The Left Ventricular End-Diastolic Volume (LVEDV) was significantly lower in the GDM group, indicating a reduction in the volume of blood in the left ventricle during diastole. This reduction in LVEDV may reflect subclinical diastolic dysfunction or reduced myocardial compliance, possibly due to metabolic and vascular changes associated with GDM, such as hyperglycaemia induced myocardial remodelling, low-grade inflammation, and endothelial dysfunction. These findings are in line with studies by Aguilera et al.[8] (2020) and Buddeberg et al. [6] (2020), who reported altered cardiac filling and reduced global longitudinal strain

(GLS) in women with GDM, suggesting early cardiac dysfunction despite the absence of overt cardiovascular disease.

However, despite the significant reduction in LVEDV, the Left Ventricular End-Systolic Volume (LVESV) did not show a significant difference between the two groups. This result suggests that GDM does not appear to affect left ventricular systolic volume at end-systole, a finding consistent with the preserved systolic function observed in most pregnant women, even those with GDM. Our findings are supported by previous research, which has generally shown that systolic function remains within normal ranges in mild to moderate GDM cases.

Stroke Volume and Cardiac Output

Stroke volume was significantly lower in the GDM group compared to controls. This reduction in stroke volume may be indicative of early subclinical alterations in cardiac function due to increased myocardial stiffness, impaired relaxation, or subtle myocardial remodeling. GDM is associated with systemic inflammation, oxidative stress, and insulin resistance, all of which can negatively impact myocardial performance. Additionally, increased afterload from elevated blood pressure and altered vascular tone may further impair ventricular ejection.

Despite the lower stroke volume, cardiac output (CO) was significantly higher in the GDM group, which could be a compensatory mechanism to maintain adequate perfusion and oxygen delivery to maternal and fetal tissues. This finding is consistent with the hyperdynamic circulatory state observed in pregnancy, where CO naturally increases, but it appears amplified in women with GDM. The increase in CO, driven by a higher heart rate, may reflect early vascular stiffness or impaired vasodilation, conditions commonly observed in GDM.

Aortic Root Diameter and Left Ventricular Outflow Tract

The aortic root diameter (ARD) was significantly larger in women with GDM, suggesting a structural change possibly related to early vascular remodelling and increased vascular wall stress. Gestational diabetes is known to induce endothelial dysfunction, systemic inflammation, and increased oxidative stress, which can affect vascular compliance and promote remodelling of large arteries, including the aorta. This result aligns with previous findings by Osman et al. [9] (2018) and McKenzie et al.[10] (2018), who observed that GDM was associated with increased arterial stiffness and long-term cardiovascular risk. Similarly, we found that the Left Ventricular Outflow Tract (LVOT) diameter was significantly smaller in the GDM group, which may reflect abnormal cardiac remodelling secondary to metabolic and hemodynamic disturbances in GDM. This reduction in LVOT diameter could lead to altered hemodynamics during systole, suggesting early signs of maladaptation to the metabolic burden of GDM.

Diastolic Function Changes

In terms of diastolic function, several significant findings emerged. The early diastolic filling velocity (E) and the late diastolic filling velocity (A) were both significantly higher in the GDM group compared to controls, indicating altered diastolic filling patterns. An increase in E velocity may reflect a compensatory mechanism for impaired myocardial relaxation, a common feature in GDM due to myocardial stiffness and increased left atrial pressure. Similarly, the increased A velocity suggests a greater reliance on atrial contraction for ventricular filling, a hallmark of diastolic dysfunction. These changes in diastolic function were further supported by the significantly shorter deceleration time (DT) and prolonged isovolumetric relaxation time (IVRT) in the

GDM group, both of which are indicative of impaired ventricular relaxation and early diastolic dysfunction.

Logistic Regression Analysis

Univariate logistic regression analysis identified several clinical and echocardiographic parameters significantly associated with GDM, including BMI, LVEDV, stroke volume, and aortic root diameter. Notably, BMI showed a strong positive association with GDM, further emphasizing the importance of weight management in preventing GDM. In the multivariate logistic regression analysis, BMI, stroke volume, aortic root diameter, and LVOT were independently associated with GDM, highlighting the complex relationship between cardiovascular changes and the development of GDM.

Conclusion

The results of this study demonstrate that GDM is associated with significant alterations in both cardiac structure and function, including reduced LVEDV, lower stroke volume, increased cardiac output, and structural changes in the aorta and left ventricle. These findings suggest that even in the absence of overt cardiovascular disease, GDM can lead to subclinical cardiovascular changes, which may predispose women to future cardiovascular complications. Early detection of these changes through routine cardiac assessment is crucial for preventing long-term cardiovascular morbidity in women with GDM. Further studies are needed to explore the long-term implications of these cardiovascular alterations and to develop targeted interventions to reduce the future cardiovascular risk in this population.

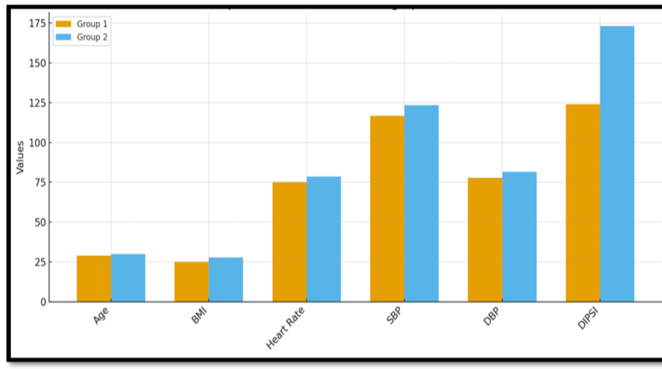

Figure 1: Comparison of Demographic Parameters

Table 1: Comparison of Demographic, Clinical, and Echocardiographic Parameters Between Control Group and GDM Cases

Parameter	Control Group Mean ± SD (n=30)	GDM Case Mean ± SD (n=30)	p-value
Systolic Parameters			
LVEDV (ml)	144.07 ± 13.63	133.54 ± 18.84	0.01
LVESV (ml)	60.84 ± 6.25	62.91 ± 8.85	0.30
Stroke Volume (ml)	84.52 ± 3.93	79.38 ± 9.57	<0.01
Aortic Root Diameter (ARD) (cm)	2.13 ± 0.38	2.85 ± 0.44	<0.01
LVOT (cm)	2.11 ± 0.12	1.78 ± 0.16	<0.01
Diastolic Parameters			
Early Diastolic Filling Velocity (E) (m/s)	0.46 ± 0.08	0.52 ± 0.09	<0.01
A Wave (m/s)	0.41 ± 0.09	0.47 ± 0.11	0.02
E/A Ratio (%)	1.18 ± 0.34	1.2 ± 0.44	0.85
Deceleration Time (DT) (ms)	218.32 ± 34.38	196.68 ± 25.73	<0.01
Isovolumetric Relaxation Time (IVRT) (ms)	68.88 ± 15.12	75.92 ± 12.28	0.05

Table 2: Univariate Logistic Regression Analysis of GDM Associated Parameters

Variable	OR (95% CI)	p-value
Age (years)	1.021 (0.91–1.01)	0.81
Gestation week	1.081 (0.982–1.192	0.32
BMI (kg/m²)	1.36 (1.7–1.88)	< 0.001**
SBP (mmHg)	1.77 (1.10–2.108)	0.33
DBP (mmHg)	1.76 (1.12–1.24)	0.09
HR (bpm)	1.022 (0.96–1.11)	0.31
LVEDV (ml)	3.003 (1.329–6.787)	0.008
LVESV (ml)	0.954 (0.78–0.99)	0.54
Stroke Volume (ml)	1.33 (0.893–1.71)	0.04**
CO (ml/min)	0.952 (0.901–1.007)	0.084
Aortic Root Diameter (ARD)	0.968 (0.907–1.033)	0.02**
LVOT (Left Ventricular Outflow Tract)	0.966 (0.962–1.034)	0.04**
LVM (g)	0.234 (0.28–0.98)	0.214
E (m/s)	1.011 (0.563–1.815)	0.971
A (m/s)	0.749 (0.620–0.904)	0.003
E/A (%)	0.978 (0.993–1.21)	0.71
Isovolumetric Relaxation time	0.92(0.87-1.02)	0.32
DT	0.81(0.76-1.1)	0.07

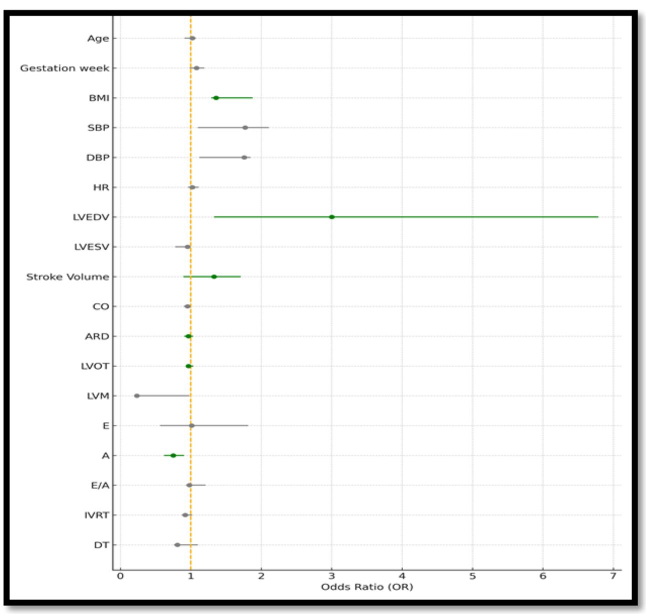

Figure 2: The forest plot illustrates the odds ratios (ORs) with 95% confidence intervals (CIs) for all clinical and echocardiographic variables included in the regression analysis. A vertical reference line at OR = 1.0 represents the point

of no association. Variables with statistically significant associations (p < 0.05) are highlighted in green, whereas non-significant variables appear in grey.

Table 3: Multivariate Logistic Regression Analysis of GDM Associated Parameters

Variable	OR (95% CI)	p-value
BMI (kg/m²)	0.566 (0.421 – 0.67)	< 0.001
Stroke Volume (ml)	0.72 (0.59 – 0.812)	< 0.001
Aortic Root Diameter (ARD)	1.19 (1.011 – 1.43	< 0.001
LVOT (Left Ventricular Outflow Tract)	1.99 (1.023 – 2.01)	< 0.001

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