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Correlation of Left Ventricular Diastolic Dysfunction with Glycemic Parameters in Type 2 Diabetes Mellitus

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ABSTRACT

Type 2 Diabetes Mellitus (T2DM) is a progressive metabolic condition that contributes significantly to systemic complications, particularly those affecting the cardiovascular system. Diastolic dysfunction, an early manifestation of diabetic heart disease, often develops even in the absence of hypertension or coronary artery disease. This study investigates the frequency of left ventricular diastolic dysfunction (LVDD) in patients with T2DM and explores its association with various glycaemic markers. A hospital-based observational study was conducted over a 12-month period at a tertiary care center in Puducherry. A total of 100 adults with T2DM, who were normotensive and free from pre-existing cardiac conditions, were enrolled. Clinical details, glycaemic indices (FBS, PPBS, HbA1C), and echocardiographic measurements (via tissue Doppler imaging) were obtained and analyzed. LVDD was diagnosed based on established Doppler parameters. LVDD was identified in 91% of participants, with Grade I dysfunction being the most prevalent. Poor glycaemic control, longer disease duration, and elevated systolic/diastolic pressures were significantly associated with more advanced grades of dysfunction ($p < 0.05$). Diastolic dysfunction is highly prevalent in individuals with T2DM and shows a strong link with poor metabolic control. Routine cardiac evaluation in diabetic patients may facilitate early detection and timely intervention to reduce cardiac complications.

INTRODUCTION

The global burden of Type 2 Diabetes Mellitus (T2DM) is rising at an alarming rate, with the International Diabetes Federation estimating a prevalence of 9.3% in 2019, expected to rise to 10.2% by 2030 and further to 700 million cases by 2045 (1- 5). This rapid increase is especially concerning in low- and middle-income countries like India, where lifestyle transitions and urbanization have accelerated disease onset (6-8). T2DM is associated with a spectrum of complications that range from microvascular (retinopathy, nephropathy, neuropathy) to macrovascular (coronary artery disease, stroke, peripheral arterial disease) disorders (9,10). Among these, cardiovascular disease is the leading cause of death, accounting for the majority of diabetes-related morbidity and mortality (11-13). Re1cent attention has shifted toward diabetic cardiomyopathy, a specific form of heart muscle dysfunction that occurs independently of hypertension or ischemic heart disease and is marked by impaired diastolic function (12,14,15,16).Diastolic dysfunction refers to the heart's reduced ability to relax and accommodate blood during diastole. It often precedes systolic dysfunction and clinical symptoms of heart failure, making it a valuable early marker in diabetic heart disease (17-19). The pathophysiology of LVDD in diabetes includes myocardial fibrosis, endothelial dysfunction, oxidative stress, and chronic inflammation—all of which are potentiated by persistent hyperglycaemia (14-16,19).

Despite the recognition of LVDD as a key cardiovascular complication, routine cardiac assessment in diabetic patients is not universally practiced, particularly in resource-constrained settings. This study aims to determine the prevalence of LVDD in a cohort of T2DM patients and explore its association with glycaemic control indicators. Understanding this relationship could inform early intervention strategies and contribute to improved long-term cardiac outcomes in diabetic populations.

MATERIALS AND METHODS

Study Design and Setting

This was a cross-sectional, observational study conducted over 12 months (October 2022 to September 2023) in the Departments of General Medicine, Cardiology, and Diabetology in a tertiary care centre at Puducherry.

Study Population

The study enrolled 100 patients aged 18 years and above, diagnosed with T2DM based on American Diabetes Association (ADA) criteria. All participants were normotensive and free from pre-existing cardiac disease, as verified through history and clinical records.

Inclusion and Exclusion Criteria

Patients with confirmed diagnosis of Type 2 Diabetes Mellitus and normotensive individuals not on antihypertensive therapy were included for the study. Those with history of hypertension or use of antihypertensive medications, pre-existing cardiac conditions (e.g., ischemic heart disease, cardiomyopathies, arrhythmias), chronic systemic illnesses (e.g., CKD, malignancy, connective tissue disorders), use of cardiotoxic drugs (e.g., daunorubicin, bleomycin, adriamycin), thyroid disorders, and stroke, or peripheral vascular disease were excluded from the study.

Ethical Considerations

The study was approved by the Institutional Ethics Committee (IEC No: 06/SVMCH/IEC-Cert/Aug22). Written informed consent was obtained from all participants.

Data Collection

Data were collected using a pretested semi-structured proforma, covering demographic details, diabetes duration, treatment adherence, and presence of complications. Physical examination included height, weight (for BMI calculation), pulse, and blood pressure.

Biochemical tests included

- Fasting Blood Sugar (FBS)
- Postprandial Blood Sugar (PPBS)
- Glycosylated Hemoglobin (HbA1C)

FBS and PPBS were measured using the hexokinase method, and HbA1C was estimated using turbidometric immunoassay.

STATISTICAL ANALYSIS

Data were entered in Microsoft Excel 2019 and analyzed using SPSS version 26. Quantitative variables were summarized as mean ± SD, and qualitative variables as frequencies and percentages. Chi-square test was used for categorical comparisons, while ANOVA with post hoc Scheffé test was applied for comparing means across diastolic dysfunction grades. A p-value < 0.05 was considered statistically significant. Results were illustrated using pie charts and bar diagrams.

RESULTS

Table 1: Association of Demographics, Diabetic factors, BMI, and Diastolic dysfunction

S. No.	Variables	Categories	Diastolic dysfunction								X^2	p value
			0		I		II		III			
			N	%	N	%	N	%	N	%		
i.	Age group (in years)	35-40	4	44.4	4	9.8	7	18.4	0	0	13.82	0.129
		41-50	3	33.3	12	29.3	7	18.4	2	16.7		
		51-60	2	22.2	15	36.6	14	36.8	5	41.7		
		61-70	0	0	10	24.4	10	26.3	5	41.7		
ii.	Sex	Male	2	22.2	17	41.5	28	73.7	9	75	14.26	0.003
		Female	7	77.9	24	58.5	10	26.3	3	25		
iii.	Duration of diabetes mellitus (in years)	≤ 5	7	77.8	13	31.7	11	28.9	1	8.3	24.38	0.018
		6-10	2	22.2	17	41.5	14	36.8	4	33.3		
		11-15	0	0	4	9.8	6	15.8	5	41.7		
		16-20	0	0	3	7.3	6	15.8	0	0		
		21-25	0	0	4	9.8	1	2.6	2	16.7		
iv.	Regularity of treatment	Regular	6	66.7	35	85.4	29	76.3	4	33.3	13.42	0.004
		Irregular	3	33.3	6	14.6	9	23.7	8	66.7		
v.	Complications	Present	0	0	11	26.8	12	31.6	7	58.3	8.68	0.034
		Absent	9	100	30	73.2	26	68.4	5	41.7		
vi.	BMI categories	Normal	2	22.2	12	29.3	12	31.6	4	33.3	3.25	0.777
		Over weight	4	44.4	24	58.5	19	50	5	41.7		
		Obesity	3	33.3	5	12.2	7	18.4	3	25		

From table 1; among the participants with diastolic dysfunction of grade 0, 44.4% were of age 35 to 40 years followed by 33.3% were of age 41 to 50 years. Among those with diastolic dysfunction of grade I, 36.6% were of age 51 to 60 years followed by 29.3% of age 41 to 50 years. Among those with grade II diastolic dysfunction, 36.8% were of age 51 to 60 years followed by 26.3% of age 61 to 70 years. Among those with grade III diastolic dysfunction, 41.7% were of age 51 to 60 years and 61 to 70 years, respectively. The distribution of age groups was similar across various categories of diastolic dysfunction with p value of more than 0.05.

Among the participants with diastolic dysfunction of grade 0, 22.2% were males. Among those with diastolic dysfunction of grade I, 41.5% were males. Among those with grade II diastolic dysfunction, 73.7% were males. Among those with grade III diastolic dysfunction, 75% were males. As the grades increased so did the proportion of males. Males were more prone to diastolic dysfunction than females with p value of less than 0.05.

Among the participants with grade 0 dysfunction. None had duration of diabetes above 10 years. Among those with grade I dysfunction, 26.9% had duration of more than 10 years. Among those with grade II dysfunction, 34.2% had duration of more than 10 years. Among those with grade III dysfunction, 58.4% had duration of more than 10 years. AS the grade of diastolic dysfunction increased so did the proportion of participants with increased duration of diabetes with p value of less than 0.05.

Among the participants with diastolic dysfunction of grade 0, 66.7% had regular treatment. Among those with diastolic dysfunction of grade I, 85.4% had regular treatment. Among those with grade II diastolic dysfunction, 76.3% had regular treatment. Among those with grade III diastolic dysfunction, the proportion was 33.3%. The proportion of irregular treatment was more among those with grade III dysfunction than the rest of the grades. The difference was statistically significant with p value of less than 0.05.

Among the participants with diastolic dysfunction of grade 0, none had complications. Among those with diastolic dysfunction of grade I, 26.8% had complications. Among those with grade II diastolic dysfunction, 31.6% had complications. Among those with grade III diastolic dysfunction, the proportion was 58.3%. The proportion of participants with complications increased with each category of diastolic dysfunction. The difference was statistically significant with p value of less than 0.05.

Among the participants with diastolic dysfunction of grade 0, 44.4% were overweight and 33.3% were obese. Among those with diastolic dysfunction of grade I, 58.5% were overweight and 12.2% were obese. Among those with grade II diastolic dysfunction, 50% were overweight and 18.4% were obese. Among those with grade III diastolic dysfunction, 41.7% were overweight and 25% were obese. The distribution of BMI categories was similar across different categories of diastolic dysfunction with p value of more than 0.05.

Table 2: Mean Blood pressure, Blood Sugar, and HbA1C across Diastolic Dysfunction Categories

	Diastolic dysfunction	F value	p value	Remark

		0	I	II	III			
Systolic blood pressure (in mmHg)	Mean	120	119.02*	116.58*	127.50*	5.43	0.002	*III > I, III > II – Significant p value (<0.05)
	SD	7.07	8.31	9.08	4.52			
Diastolic blood pressure (in mmHg)	Mean	76.67	73.90*	73.16*	80.83*	3.79	0.013	*III > I, III > II – Significant p value (<0.05)
	SD	7.07	6.66	8.08	6.68			
Fasting blood sugar (mg/dl)	Mean	104.44*	134.83*	144.79*	225.50*	9.69	0.001	*III>0, III > I, III > II – Significant p value (<0.05)
	SD	13.21	55.42	46.81	101.37			
Post prandial blood sugar (mg/dl)	Mean	150.22*	226.35*	238.71*	372.42*	12.32	0.001	*III>0, III > I, III > II – Significant p value (<0.05)
	SD	24.56	87.31	78.95	139.34			
HbA1C (%)	Mean	6.06*	7.32*	7.35*	10.05*	13.79	0.001	*III>0, III > I, III > II – Significant p value (<0.05)
	SD	0.44	1.68	1.27	2.2			

From table 2; the mean systolic blood pressure for those with grade 0 dysfunction was 120 ± 7.07 mmHg, for grade I dysfunction the mean systolic BP was 119.02 ± 8.31 mmHg, for grade II dysfunction it was 116.58 ± 9.08 mmHg and for grade III diastolic dysfunction, the systolic blood pressure was 127.50 ± 4.52 mmHg. The post hoc test showed that the mean systolic blood pressure of those with grade III dysfunction was significantly more than those with grade I dysfunction and grade II dysfunction, respectively (p value < 0.05).

The mean diastolic blood pressure for those with grade 0 dysfunction was 76.367 ± 7.07 mmHg, for grade I dysfunction the mean diastolic BP was 73.90 ± 6.66 mmHg, for grade II dysfunction it was 73.16 ± 8.08 mmHg and for grade III diastolic dysfunction, the diastolic blood pressure was 80.83 ± 6.68 mmHg. The post hoc test showed that the mean diastolic blood pressure of those with grade III dysfunction was significantly more than those with grade I dysfunction and grade II dysfunction respectively (p value < 0.05).

The mean fasting blood sugar for those with grade 0 dysfunction was 104.44 ± 13.21 mg/dl, for grade I dysfunction the mean fasting blood sugar was 134.83 ± 55.42 mg/dl, for grade II dysfunction it was 144.79 ± 46.81 mg/dl and for grade III diastolic dysfunction, the fasting blood sugar was 225.50 ± 101.37 mg/dl. The mean fasting blood sugar was higher for participants with grade III dysfunction than those with grade II, grade I and grade 0 dysfunctions, respectively (p value < 0.05).

The mean post prandial blood sugar for those with grade 0 dysfunction was 150.22 ± 24.56 mg/dl, for grade I dysfunction the mean post prandial blood sugar was 226.35 ± 87.31 mg/dl, for grade II dysfunction it was 238.71 ± 78.95 mg/dl and for grade III diastolic dysfunction, the post prandial blood sugar was 372.42 ± 139.34 mg/dl. The mean post prandial blood sugar was higher for participants with grade III dysfunction than those with grade II, grade I and grade 0 dysfunctions, respectively (p value < 0.05).

The mean HbA1C for those with grade 0 dysfunction was 6.06 ± 0.44 %, for grade I dysfunction the mean HbA1C was 7.32 ± 1.68 %, for grade II dysfunction it was 7.35 ± 1.27 % and for grade III diastolic dysfunction, the HbA1C was 10.05 ± 2.20%.

The mean HbA1C was higher for participants with grade III dysfunction than those with grade II, grade I and grade 0 dysfunctions, respectively (p value < 0.05).

DISCUSSION

Diabetes mellitus is a chronic metabolic disorder marked by persistent hyperglycaemia, resulting either from insufficient insulin secretion or from impaired cellular response to insulin (2,3). With the global increase in diabetes prevalence, the number of individuals experiencing associated complications is also rising (9,10). Among these, cardiovascular diseases (CVDs) are the most prominent causes of morbidity and mortality, with myocardial infarction and heart failure being the most frequent manifestations (12).

Evidence suggests that, in addition to hyperglycaemia, factors such as insulin resistance, hypertension, dyslipidaemia, systemic inflammation, and thrombosis significantly contribute to the development of cardiovascular complications in diabetic patients (14,15). These vascular complications affect several organs, including the myocardium, arteries, central nervous system (e.g., stroke), and renal glomeruli (11). A less commonly recognized, yet increasingly important, complication in diabetics is diabetic cardiomyopathy, which is characterized by ventricular dysfunction independent of coronary artery disease or hypertension (12).

The hallmark of diabetic cardiomyopathy is diastolic dysfunction, defined as the heart's inability to relax and fill adequately during diastole (17). When diastolic dysfunction occurs without elevated blood pressure or ischemic heart disease, it is categorized as diabetic cardiomyopathy (18). The pathogenesis of diastolic dysfunction involves either stiffening of the ventricular chamber or impaired myocardial relaxation, largely due to changes in the extracellular matrix, calcium handling, and altered myocardial metabolism (19, 20).

In our study, 91% of the participants exhibited diastolic dysfunction, with Grade I dysfunction observed in 41%, Grade II in 38%, and Grade III in 12%. These findings are consistent with those of Ahsan S et al. (2024), who reported diastolic dysfunction in more than half of the T2DM patients studied and Lumori BAE et al. (2022), who found a prevalence of 86%.(21, 20) A systematic review by Palanisamy S and Kumaresan S et al. (2024) involving 55 studies confirmed that T2DM is a major contributor to the development of diastolic dysfunction (22). The presence of diabetes alone predisposes patients to subclinical myocardial changes, making LVDD a common but underdiagnosed complication.

In our study, male patients were found to have a higher prevalence of diastolic dysfunction compared to females. Although limited research has examined sex-based differences in LVDD prevalence among diabetics, our findings suggest the need for further investigation into gender-specific cardiovascular risk profiles.

The duration of diabetes was significantly associated with the presence of LVDD. This trend was also reported by Ahsan S et al. (2024), Lin N et al. (2023), and Rajput R et al., who noted an increased probability of diastolic dysfunction in patients with longer disease duration (21, 23, 24). Ashour K et al. (2018) further emphasized that prolonged exposure to hyperglycaemia and inflammatory mediators increases vascular stress and contributes to the development of myocardial fibrosis and dysfunction.(25)

Another key observation was the higher prevalence of LVDD in patients who were non-adherent to treatment. Similarly, the presence of other diabetic complications (neuropathy, retinopathy, nephropathy) was significantly associated with LVDD ($p < 0.05$). Furthermore, glycaemic parameters such as fasting blood sugar, postprandial blood sugar, and HbA1C levels were all significantly elevated in patients with more severe grades of diastolic dysfunction. For instance, mean HbA1C was highest among patients with Grade III dysfunction, confirming the link between poor glycaemic control and LVDD severity. These results align with findings from Ahsan S et al. (2024), Li N et al. (2023), and Ashour K et al. (2018), all of whom identified elevated HbA1C as a predictor of LVDD.

Blood pressure was another influential factor.(21, 23, 25) The mean systolic and diastolic blood pressures were significantly higher in patients with Grade III dysfunction compared to those with milder or no dysfunction ($p < 0.05$). Uncontrolled hypertension, even in borderline cases, has been implicated in the progression of diastolic dysfunction in diabetic patients, as noted by Ahsan S et al. (2024) (21). In addition, Kidawara Y et al. (2024) reported that absence of nocturnal blood pressure dipping was associated with a higher risk of LVDD, while Sagara R et al. (2022) demonstrated that increased systolic blood pressure correlated with the severity of diastolic dysfunction in T2DM (26, 27).

Overall, the findings of this study affirm that LVDD is highly prevalent in T2DM, and its severity correlates with poor glycaemic control, longer disease duration, higher blood pressure, and presence of diabetic complications. These results support the growing consensus that early detection of subclinical cardiac involvement through echocardiographic screening and maintaining optimal glycaemic and blood pressure control are essential in preventing the progression to heart failure in diabetic patients.

CONCLUSION

This study highlights the high prevalence of left ventricular diastolic dysfunction (LVDD) among patients with Type 2 Diabetes Mellitus (T2DM), even in the absence of hypertension or overt cardiac disease. A significant association was found between diastolic dysfunction and poor glycaemic control, with higher fasting blood sugar, postprandial blood sugar, and HbA1C levels correlating with increasing severity of LVDD. Duration of diabetes and inadequate treatment adherence further contributed to the worsening of cardiac function. These findings underscore the importance of early screening for cardiac dysfunction in diabetic patients using echocardiography, particularly tissue Doppler imaging. Regular monitoring of glycaemic parameters and maintaining optimal blood sugar levels may help in preventing or delaying the onset of diabetic cardiomyopathy. Integrating cardiovascular assessment into routine diabetic care is essential for improving long-term outcomes and reducing diabetes-related morbidity and mortality.

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