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Left Ventricular Diastolic Dysfunction in Asymptomatic Type 2 Diabetes Mellitus

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ABSTRACT

Background: Type 2 diabetes mellitus is a global public health issue. Left ventricular diastolic dysfunction is the earliest diabetic cardiovascular complication. This study aims to determine the incidence of left ventricular diastolic dysfunction in asymptomatic type 2 diabetes mellitus.

Methods: A case control study was conducted in Azadi Teaching Hospital, Kirkuk, Iraq, over one year from February 1, 2023, to January 31, 2024. The study involved 102 patients with type 2 diabetes, which was compared to 102 age and sex matched controls. Type 2 diabetes mellitus was diagnosed according to the American Diabetes Association criteria. Left ventricular diastolic dysfunction was identified following the guidelines of the American Society of Echocardiography and the European Association of Cardiovascular Imaging.

Results: The incidence of diastolic dysfunction in type 2 diabetic patients was (58.8%) distributed as follows: grade I diastolic dysfunction in (90%) and grade II (10%), and none of the patients had grade III. There was a significant association between diastolic dysfunction and type 2 diabetic patients ($p<0.001$); 58.8% of type 2 diabetic patients had diastolic dysfunction compared to 9.8% of controls. The risk factors for left ventricular diastolic dysfunction in asymptomatic type 2 diabetic patients were increased age, obesity, long duration of disease, insulin treatment, retinopathy, albumin in urine, high HbA1c level, high blood urea, and low ejection fraction.

Conclusion: The incidence of left ventricular diastolic dysfunction among asymptomatic type 2 diabetic patients is high.

Key words: Left ventricular Diastolic Dysfunction; Type 2 Diabetes Mellitus; Echocardiography.

INTRODUCTION

Diabetes mellitus (DM) is a long-term disease that can be caused by several genes and/or environmental causes [1]. Undoubtedly, over the last twenty years, Type 2 Diabetes Mellitus (T2DM) has developed as a novel and highly significant health issue, affecting even youngsters. The investigations conducted on children have shown the simultaneous presence of obesity, insulin resistance, and β-cell dysfunction, similar to what is found in older individuals with T2DM [2].

Type 2 diabetes mellitus typically presents with the following symptoms: frequent urination, excessive thirst and hunger, weight loss, fatigue, difficulty concentrating, vomiting, stomach pain, blurred vision, recurring infections such as candidiasis, balanitis in men and vulvovaginitis in women, delayed wound healing, and tingling in the extremities. It is important to note that some individuals may not experience any symptoms [3].

The majority of health issues associated with type 2 diabetes mellitus are directly linked to cardiovascular disorders, specifically coronary artery disease, congestive heart failure, and arterial hypertension. Type 2 diabetes mellitus has been identified as being similar to coronary artery disease since many individuals with established coronary artery disease also have diabetes mellitus or its precursor forms. Approximately 20-30% of individuals diagnosed with acute coronary syndromes also have type 2 diabetes mellitus, whereas over 40% of these patients have impaired glucose tolerance [4].

Research indicates that those with diabetes have a mortality rate that is twice as high as those without diabetes following an acute myocardial infarction. As a result, people with type 2 diabetes mellitus have a 2 to 8 times higher risk of dying from cardiovascular causes. Additionally, 75% of fatalities in these patients can be attributed to the underlying coronary artery disease. Compelling data indicates that, apart from coronary artery disease, type 2 diabetes mellitus plays a significant role as a risk factor for arrhythmias and sudden death [5].

Left ventricular diastolic dysfunction is the initial phase of diabetic cardiomyopathy that occurs before any alterations in systolic function. Emphasizing the significance of early assessment of ventricular function in individuals with diabetes. Diastolic abnormalities are found in diabetic patients who do not have cardiovascular complications associated with diabetes [6]. This is the earliest functional abnormality in diabetic cardiomyopathy and can affect patients who do not have macrovascular complications, have recently been diagnosed with diabetes, or have had the disease for less than one year.

The 2016 recommendations from the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) presented a straightforward approach to identify and assess the degree of left ventricular diastolic dysfunction (LVDD). The diagnosis of left ventricular diastolic dysfunction (LVDD) in cases when the left ventricular ejection fraction (LVEF) is normal was made using echocardiographic markers such as left atrium volume index, tricuspid regurgitation velocity, E/e', and septal or lateral e' velocity [7].

Various imaging modalities can be employed to diagnose DCM by analyzing its morphological features and evaluating heart function, Echocardiography is the predominant imaging technique used to evaluate the structure and function of the heart, including its shape and how it contracts and relaxes. This is mainly because it is widely accessible and very inexpensive. Diastolic function is evaluated by employing pulse wave doppler to examine transmitral and pulmonary venous flow, tissue doppler imaging (TDI) to quantify myocardial tissue velocities throughout the cardiac cycle, and evaluating the volume of the left atrium. It allows for the assessment of both diastolic function and the monitoring of illness development, ranging from moderate diastolic dysfunction (impaired relaxation) to more advanced stages (pseudo normalization or limitation) [8].

Cardiac magnetic resonance imaging (CMRI) is a valuable imaging technique that may be used to diagnose several structural and functional abnormalities of the heart muscle, such as diastolic dysfunction and myocardial steatosis. CMRI and positron emission tomography (PET) can be useful in diagnosing DCM because they can identify anomalies in myocardial metabolism [9].

Echocardiography is an efficient and economical technique that offers precise and consistent diagnostic and prognostic data for patients with DM [10]. Utilizing two-dimensional, doppler, and speckle tracking echocardiography allows for a comprehensive assessment of heart function in individuals with diabetes. Additionally, stress echocardiography and examination of coronary flow reserve offer additional predictive value. Echocardiographic abnormalities are observed in individuals with diabetes, even in the absence of symptoms or clinical indications that necessitate echocardiographic evaluation.

There is a substantial amount of data indicating that nonpharmacological therapies, together with lifestyle modifications such as maintaining a healthy weight, quitting smoking, and engaging in aerobic exercise, are linked to positive changes in the structure and function of the heart, as well as a reduced

risk of heart failure in patients aged 40 and above with diabetes mellitus [11]. Aside from promoting a healthy lifestyle, the professional public is mostly concerned with finding pharmaceutical remedies to prevent and treat diastolic dysfunction. The number of drugs that are efficacious in the treatment of systolic heart failure and enhance the quality of life in affected individuals is steadily growing. However, it is important to note that there is now no singular medicine available specifically for the treatment of diastolic heart failure. Researchers conducted experiments to evaluate the efficacy of commonly prescribed drugs, including aldosterone receptor antagonists, angiotensin II receptor antagonists, angiotensin convertase inhibitors, beta-blockers, calcium channel antagonists, statins, or their combinations, in treating diastolic dysfunction in animal models [12]. It is widely recognized that maintaining adequate control of blood sugar levels is crucial in order to prevent cardiovascular problems in those with DM [13].

This study aimed to identify the occurrence of left ventricular diastolic dysfunction in individuals with asymptomatic type 2 diabetes mellitus and compare it to that of healthy individuals.

MATERIAL AND METHODS

A case-control study was conducted at a consultancy clinic (internal medicine, diabetic clinic) and echocardiography unit of Azadi Teaching Hospital in Kirkuk City, Iraq, over one year, from February 1, 2023, to January 31, 2024. All patients with type 2 diabetes mellitus presenting at the consultancy clinic were evaluated according to the American Diabetes Association (ADA) diagnostic criteria for diabetes mellitus (DM), which include any of the following four methods. Type 2 diabetes mellitus was diagnosed based on the criteria established by the American Diabetes Association.

A diagnosis of diabetes can be made if any one of these criteria is met:

i. Fasting Plasma Glucose (FPG) $\geq$ 126 mg/dL (7.0 mmol/L)

- Fasting is defined as no caloric intake for at least 8 hours.

ii. 2-hour Plasma Glucose $\geq$ 200 mg/dL (11.1 mmol/L) during an Oral Glucose Tolerance Test (OGTT)

- The test uses a glucose load containing 75 g of anhydrous glucose dissolved in water.

iii. Hemoglobin A1c (HbA1c) $\geq$ 6.5

iv. Random Plasma Glucose $\geq$ 200 mg/dL (11.1 mmol/L) in a patient with classic symptoms of hyperglycemia (such as polyuria, polydipsia, and unexplained weight loss) or hyperglycemic crisis. (internal medicine clinic, diabetic clinic) and echocardiography unit of Azadi Teaching Hospital were the study population.

The study involves adult participants aged 30 to 65 years who have a confirmed diagnosis of type 2 diabetes mellitus. Eligible participants must be free of clinically evident cardiovascular disease, including the absence of chest pain or exertional dyspnea. Additionally, all included individuals should be normotensive, with a blood pressure of less than 130/80 mmHg, and must have a normal resting electrocardiogram (ECG).

Exclusion criteria include individuals younger than 30 years or older than 65 years. Patients with significant valvular heart disease, coronary artery disease diagnosed by symptoms, ECG findings, or evidence of regional wall motion abnormalities on echocardiography or coronary angiography are not eligible. Other exclusion criteria include hypertensive heart disease, congestive heart failure, and cardiomyopathies such as dilated or hypertrophic cardiomyopathy.

Participants with atrial fibrillation or other arrhythmias, thyroid dysfunction, severe anemia, or hemoglobinopathies are also excluded. Pregnancy and chronic renal failure are additional exclusion factors. Furthermore, the sample does not include individuals with abnormal ECG findings or those with a poor transthoracic echocardiographic window.

A convenience sample included 102 type 2 diabetic patients and 102 healthy individuals who were screened for diabetes mellitus and found normal, referring to the echocardiography unit without any medical conditions, considered as controls. Both diabetic and control groups were examined for their pulse rate, while blood pressure was measured using manual sphygmomanometers. Body mass index (BMI) was calculated by measuring weight in kilograms (Kg) and dividing it by height in meters (m) squared.

A standard 12-lead ECG was performed on participants. Blood samples were taken from both groups and sent to the laboratory to measure blood urea and serum creatinine. The diabetic group was further investigated for their HbA1C, and about 3 to 5 ml of urine was collected from them for albumin detection using a dipstick test. The diabetic group was also referred to an ophthalmologist for retinopathy detection using slit lamp examination. An echocardiologist conducted echocardiography for both groups. Both groups were asked about their demographic characteristics (age and gender), general characteristics (smoking status, body mass index, blood pressure, and pulse rate), diabetes mellitus disease characteristics

(duration of type 2 diabetes mellitus, treatment, HbA1c level, blood urea, serum creatinine, presence of retinopathy, and urine for albumin), and left ventricular diastolic dysfunction with its grading.

The statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS), version 22, for data entry and analysis. Continuous variables were presented as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Multiple contingency tables were created, and appropriate statistical tests were performed, including Chi-square and Fisher's exact tests for categorical variables. Continuous variables were analyzed using an independent sample t-test. A p-value of ≤ 0.05 was considered significant.

RESULTS

The mean age was 52.3±8.1 years; the highest proportion was within 50-59 years, followed by 40-49 years, and the least was among those younger than 40 years. Females were more than males (56.9% vs. 43.1%). Current smoking was shown in 45.1% of type 2 diabetic patients and ex-smoking history in 9.8% of them. The mean body mass index of type 2 diabetic patients was 29.22 Kg/m2; 39.2% of them were overweight, and 45.1% of them were obese. The mean blood pressure of type 2 diabetic patients was (113.9/71.5mmHg), and their mean pulse rate was (80.4±7.4 b/m)..

The mean duration of DM disease was 5.2 years. The common DM treatment used by type 2 diabetic patients was oral antidiabetic drugs (72.5%), while insulin was the least used treatment (1.96%). The mean HbA1c of type 2 diabetic patients was 9%. Moreover, the mean blood urea of type 2 diabetic patients was 32.6 mg/dl. The mean serum creatinine of type 2 diabetic patients was 0.81 mg/dl. Retinopathy was shown in 54.9% of type 2 diabetic patients, and albumin in urine was demonstrated in 54.9% of type 2 diabetic patients.

The prevalence of diastolic dysfunction in type 2 diabetic patients was 58.8%; grade I in 90%, grade II in 10%, and no patients had grade III **(Table 1)**.

There are no significant differences between type 2 diabetic patients and controls regarding age, gender, smoking status, and body mass index. Furthermore, there were also no significant differences between type 2 diabetic patients and controls concerning blood pressure, pulse rate, blood urea, serum creatinine, LA volume, and LA size. The means of E and E/A were significantly lower among type 2 diabetic patients compared to controls ($p<0.001$). Mean A was significantly higher in type 2 diabetic patients with diastolic dysfunction compared to those without ($p<0.001$).

The means of lateral e and septal e were significantly lower among type 2 diabetic patients compared to controls ($p<0.001$). Mean E/e was significantly higher in type 2 diabetic patients with diastolic dysfunction compared to those without ($p<0.001$). Mean peaked TRV was significantly higher in type 2 diabetic patients with diastolic dysfunction compared to those without ($p<0.001$).

The mean ejection fraction was significantly lower among type 2 diabetic patients compared to controls ($p<0.001$). There was a highly significant association between diastolic dysfunction and type 2 diabetic patients ($p<0.001$), with 58.8% of type 2 diabetic patients exhibiting diastolic dysfunction, whereas only 9.8% of controls did. Although there was no significant difference in the grades of diastolic dysfunction between the two study groups, 10% of type 2 diabetic patients with diastolic dysfunction presented with grade II dysfunction, while all the controls with diastolic dysfunction exhibited grade I dysfunction **(Table 2)**.

There was a highly significant association between the increased age of type 2 diabetic patients and diastolic dysfunction ($p<0.001$). No significant differences were observed between type 2 diabetic patients with diastolic dysfunction and type 2 diabetic patients without diastolic dysfunction regarding gender, No significant differences were observed between type 2 diabetic patients with diastolic dysfunction and type 2 diabetic patients without diastolic dysfunction regarding smoking status ($p=0.211$). There was a highly significant association between the increased BMI of type 2 diabetic patients and diastolic dysfunction ($p<0.001$).

A highly significant association was observed between increased DM duration and diastolic dysfunction ($p<0.001$). There was a significant association between insulin treatment of type 2 diabetic patients and diastolic dysfunction ($p=0.031$). Both retinopathy and albumin in the urine of type 2 diabetic patients were significantly related to diastolic dysfunction ($p<0.001$).

The mean pulse rate, HbA1c, blood urea level, Mean A, and Mean peaked TRV of type 2 diabetic patients were significantly higher among patients with diastolic dysfunction. Means of E and E/A were significantly lower among type 2 diabetic patients with diastolic dysfunction ($p<0.001$). Means of lateral e and septal e were significantly lower among type 2 diabetic patients with diastolic dysfunction ($p<0.001$). Mean E/e was significantly lower among type 2 diabetic patients with diastolic dysfunction ($p<0.001$). The mean ejection fraction was significantly lower among type 2 diabetic patients with diastolic dysfunction ($p=0.007$) **(Table 3)**.

Table 1. Demographic, General, and Disease Characteristics of Type 2 Diabetic Patients

Variable	No.	%
Demographic Characteristics		
Age (Mean ± SD: 52.3 ± 8.1 years)		
<40 years	6	5.9
40-49 years	30	29.4
50-59 years	40	39.2
60-65 years	26	25.5
Gender		
Male	44	43.1
Female	58	56.9
General Characteristics		
Smoking Status		
Current smoker	46	45.1
Ex-smoker	10	9.8
Non-smoker	46	45.1
Body Mass Index (Mean ± SD: 29.11 ± 3.85 Kg/m²)		
Normal	16	15.7
Overweight	40	39.2
Obese	46	45.1
Blood Pressure (Mean ± SD: 113.9/71.5 ± 7.3/7 mmHg)		
Normal	102	100.0
Pulse Rate (Mean ± SD: 80.4 ± 7.4 b/m)		
Normal	102	100.0
Diabetes Mellitus Disease Characteristics		
DM Duration (Mean ± SD: 5.2 ± 2.9 years)		
5 years	54	52.9
>5 years	48	47.1
DM Treatment		
Oral ADD	74	72.5
Both HD & Insulin	26	25.5
Insulin	2	1.96
HbA1c (Mean ± SD: 9 ± 2.1 %)		
6.5%	102	100.0
Blood Urea (Mean ± SD: 32.6 ± 8.3 mg/dl)		
Normal	102	100.0
Serum Creatinine (Mean ± SD: 0.81 ± 0.15 mg/dl)		
Normal	102	100.0
Retinopathy		
Yes	56	54.9
No	46	45.1
Albumin in Urine		
Yes	56	54.9
No	46	45.1
Diastolic Dysfunction		
Diastolic Dysfunction		
Yes	60	58.8
No	42	41.2
Grades of Diastolic Dysfunction		
Grade I	54	90.0
Grade II	6	10.0
Grade III	0	-

Abbreviations: DM = Diabetes Mellitus, ADD = Antidiabetic Drugs, HD = Hemodialysis.

Table 2. Distribution of demographic, general, and echocardiographic characteristics according to study groups

Variables	Diabetic Cases		Control		*P*-value
	No.	%	No.	%	
Demographic Characteristics					
Age Group					0.222*
<40 years	6	5.9	8	7.8	
40-49 years	30	29.4	29	28.5	
50-59 years	40	39.2	50	49.0	
60-65 years	26	25.5	15	14.7	
Gender					0.391*
Male	44	43.1	50	49.0	
Female	58	56.9	52	51.0	
General Characteristics					
Smoking Status					0.172*
Current smoker	46	45.1	36	35.3	
Ex-smoker	10	9.8	18	17.6	
Non-smoker	46	45.1	48	47.1	
Body Mass Index					0.221*
Normal	16	15.7	20	19.6	
Overweight	40	39.2	48	47.1	
Obese	46	45.1	34	33.3	
Echocardiographic Measures (Mean ± SD)					
Blood Pressure (mmHg)	113.9/71.5 ± 7.3/7		113.7/71 ± 9/7		0.932†
Pulse Rate (b/m)	80.4 ± 7.4		79.5 ± 7.7		0.423†
Blood Urea (mg/dl)	32.6 ± 8.3		31.8 ± 7.7		0.471†
Serum Creatinine (mg/dl)	0.81 ± 0.15		0.82 ± 0.11		0.630†
E (m/s)	0.67 ± 0.15		0.73 ± 0.1		**<0.001**†
A (m/s)	0.7 ± 0.15		0.56 ± 0.11		**<0.001**†
E/A Ratio	1.02 ± 0.37		1.3 ± 0.26		**<0.001**†
Lateral e (m/s)	0.08 ± 0.04		0.1 ± 0.01		**<0.001**†
Septal e (m/s)	0.07 ± 0.04		0.1 ± 0.01		**<0.001**†
E/e Ratio	11.24 ± 4.23		6.8 ± 0.9		**<0.001**†
LA Volume (ml/m²)	28.67 ± 1.93		28.9 ± 1.6		0.22†
Peaked TRV	2.45 ± 0.24		2.25 ± 0.26		**<0.001**†
LA Size (mm)	38 ± 4.3		37.2 ± 5.4		0.310†
Ejection Fraction (%)	63.71 ± 1.68		64.8 ± 2.2		**<0.001**†
Diastolic Dysfunction					
Diastolic Dysfunction					**<0.001***
Yes	60	58.8	10	9.8	
No	42	41.2	92	90.2	
Grades of Diastolic Dysfunction					0.290**
Grade I	54	90.0	10	100.0	
Grade II	6	10.0	0	-	

*Chi-square test, **Fisher's exact test, †Independent sample t-test.

Abbreviations: E = Early diastolic mitral inflow velocity, A = Late diastolic mitral inflow velocity, E/A Ratio = Ratio of early to late diastolic mitral inflow velocity, e = Early diastolic tissue Doppler velocity, E/e Ratio = Ratio of early diastolic mitral inflow velocity to early diastolic tissue Doppler velocity, LA = Left atrium, TRV = Tricuspid regurgitation velocity.

Table 3. Distribution of Demographic, General, and Echocardiographic Characteristics According to Diastolic Dysfunction Prevalence

Variables	Diastolic Dysfunction		P-value
	Yes	No	
	No. (%)	No. (%)	
Demographic Characteristics			
Age			**<0.001***
<40 years	0 (0.0)	6 (14.3)	
40-49 years	12 (20.0)	18 (42.9)	
50-59 years	26 (43.3)	14 (33.3)	
60-65 years	22 (36.7)	4 (9.5)	
Gender			0.960**
Male	26 (43.3)	18 (42.9)	
Female	34 (56.7)	24 (57.1)	
General and Diabetes Mellitus Characteristics			
Smoking Status			0.211**
Current smoker	28 (46.7)	18 (42.9)	
Ex-smoker	8 (13.3)	2 (4.8)	
Non-smoker	24 (40.0)	22 (52.4)	
Body Mass Index			**<0.001****
Normal	8 (13.3)	8 (13.3)	
Overweight	14 (23.3)	26 (61.9)	
Obese	38 (63.3)	8 (19.0)	
DM Duration			**<0.001****
5 years	20 (33.3)	34 (81.0)	
>5 years	40 (66.7)	8 (19.0)	
DM Treatment			**0.031***
Oral ADD	38 (63.3)	36 (85.7)	
Insulin & Oral ADD	20 (33.3)	6 (14.3)	
Insulin	2 (3.3)	0 (0.0)	
Retinopathy			**<0.001****
Yes	54 (90.0)	2 (4.8)	
No	6 (10.0)	40 (95.2)	
Albumin in Urine			**<0.001****
Yes	54 (90.0)	2 (4.8)	
No	6 (10.0)	40 (95.2)	
Echocardiographic Measures (Mean ± SD)			
Blood Pressure (mmHg)	112.8/72 ± 7.2/7.9	115/70 ± 7/6.3	0.070†
Pulse Rate (b/m)	81.6 ± 6	78.5 ± 8.8	**0.030**†
HbA1c (%)	9.8 ± 2.3	7.8 ± 0.67	**<0.001**†
Blood Urea (mg/dl)	34.3 ± 8.7	30 ± 7.1	**0.011**†
Serum Creatinine (mg/dl)	0.83 ± 0.15	0.78 ± 0.13	0.312†
E (m/s)	0.58 ± 0.13	0.78 ± 0.07	**<0.001**†
A (m/s)	0.78 ± 0.13	0.56 ± 0.05	**<0.001**†
E/A Ratio	0.76 ± 0.24	1.3 ± 0.15	**<0.001**†
Lateral e (m/s)	0.04 ± 0.01	0.12 ± 0.01	**<0.001**†
Septal e (m/s)	0.03 ± 0.01	0.11 ± 0.01	**<0.001**†
E/e Ratio	14.38 ± 2.3	6.7 ± 0.7	**<0.001**†
LA Volume (ml/m²)	28.4 ± 4	29 ± 1.6	0.140†
Peaked TRV	2.5 ± 0.18	2.2 ± 0.19	**<0.001**†
LA Size (mm)	37.8 ± 3.9	38.4 ± 4.8	0.491†
Ejection Fraction (%)	62.8 ± 1.27	65 ± 1.3	**<0.001**†

*Fisher's exact test, **Chi-square test, †Independent sample t-test.
Abbreviations: DM = Diabetes Mellitus, ADD = Antidiabetic Drugs, TRV = Tricuspid Regurgitation Velocity, LA = Left Atrium.

DISCUSSION

Type 2 diabetes mellitus is a common risk factor for cardiovascular co-morbidities [14]. Additionally, type 2 DM is accompanied by poor prognosis and higher cardiovascular death rates in both reduced and preserved ejection fraction heart failure [15]. Therefore, assessing diastolic dysfunction among type diabetic patients is essential in early detection and management [16].

The current study indicates that the occurrence rate of left ventricular diastolic dysfunction in individuals with type 2 diabetes is 58.8%, which aligns with the research conducted by Ashour K. in Iraq involving 86 type 2 diabetes patients [17], who revealed that 62.3% of type 2 diabetic patients exhibited left ventricular diastolic dysfunction.

Patil et al. [18] conducted a study in India including 127 patients with type 2 diabetes mellitus that revealed 54.33% of these patients had left ventricular diastolic dysfunction that were comparable to the current study.

The results of our investigation revealed that the left ventricular diastolic dysfunction was categorized as grade I diastolic dysfunction in 90%, grade II diastolic dysfunction in 10%, while none of the patients exhibited grade III diastolic dysfunction. This finding aligns with the results of the Chee et al. study in Malaysia [19].

Myocardial hypertrophy and diastolic dysfunction are the primary features of diabetic cardiomyopathy. However, systolic dysfunction becomes increasingly common in the latter stages of the illness. In individuals with type 2 diabetes mellitus, the dysfunction of the cardiomyocyte cytoskeleton leads to an elevation in both cellular and extracellular matrix stiffness. Consequently, this causes an increase in myocardial stiffness. Additional factors contributing to diastolic failure in individuals with type 2 diabetes include compromised myocardial nitric oxide pathway, coronary microvascular dysfunction, heightened inflammation and oxidative stress, and the impact of myocardial sodium glucose cotransporter-2 [20].

The echocardiography study of type 2 diabetic patients revealed lower average values for E and E/A compared to the control group. However, the mean value for A was significantly higher in the diabetic patients compared to the controls. Additionally, the mean values for lateral e and septal e were significantly lower in the diabetic patients compared to the controls. The mean value for E/e was significantly higher in the diabetic patients compared to the controls, and the mean value for peaked TRV was significantly higher in the diabetic patients compared to the controls. These findings align with the results of several studies [21, 22]. Our study revealed a statistically significant decrease in the average ejection percent among patients with type 2 diabetes compared to the control group. This finding aligns with the study of Liao et al. [23].

The current study revealed a statistically significant correlation between left ventricular diastolic dysfunction and patients with type 2 diabetes; this aligns with the results of the study by Hassan AE et al., conducted in Iraq [24].

The present study demonstrated a statistically significant correlation between advancing age in patients with type 2 diabetes and the occurrence of diastolic dysfunction. Similarly, a study by Yadava et al. in Nepal found that as the age of patients with type 2 diabetes increased, the prevalence of diastolic dysfunction also rose [25].

The current study revealed that there is a statistically significant correlation between higher body mass index (BMI) in patients with type 2 diabetes and the presence of diastolic dysfunction. This finding aligns with the study of Lumori et al. [26] conducted in Uganda, which demonstrated that obesity in individuals with type 2 diabetes contributes to the heightened risk of diastolic dysfunction.

Our study found a strong correlation between longer duration of diabetes mellitus (DM) and diastolic dysfunction, which aligns with the results of a comprehensive review research conducted by Kim et al. [27] in South Korea.

The present study found a significant correlation between the administration of insulin to patients with type 2 diabetes and the occurrence of diastolic dysfunction. This might be attributed to the fact that we have just two patients who require insulin, and both of them have diastolic dysfunction. Fontes-Carvalho et al. [28] conducted a population-based study in Portugal, which consistently found that type 2 diabetes patients who were on insulin therapy had a high level of insulin resistance. Moreover, this insulin resistance was found to be related to a greater incidence of diastolic dysfunction.

This study indicates a substantial association between retinopathy, albumin in urine, and diastolic dysfunction in patients with type 2 diabetes, which is in agreement with the findings of two previous studies [29, 30]

The current study revealed that the average pulse rate of patients with type 2 diabetes was significantly higher in those exhibiting diastolic dysfunction. This finding is consistent with the results of a systematic review and meta-analysis conducted by Bouthoorn et al. in the Netherlands. [31].

Our study revealed a statistically significant association between diastolic dysfunction and higher mean HbA1c levels in type 2 diabetes patients. Guria et al. conducted a cross-sectional study in India and consistently showed that the level

of HbA1c was considerably higher in type 2 diabetes patients with diastolic dysfunction compared to diabetic individuals without diastolic dysfunction [32].

The average blood urea level in patients with type 2 diabetes was significantly higher in those with diastolic dysfunction, according to our study. This finding is consistent with research conducted by Singh P et al. [33].

In our study, we found that type 2 diabetic patients with diastolic dysfunction had lower average values of E and E/A compared to type 2 diabetic patients without diastolic dysfunction. Additionally, the average value of A was significantly higher, and the average values of lateral e and septal e were significantly lower among type 2 diabetic patients with diastolic dysfunction. Furthermore, the average value of E/e was significantly higher, and the average value of peaked TRV was significantly higher among type 2 diabetic patients with diastolic dysfunction. These findings align with the results of the Poulsen et al. study [34].

The current study found that the average ejection fraction was notably lower in type 2 diabetic patients with diastolic dysfunction. This aligns with the findings of the Dodiyi-Manuel et al. study conducted in Nigeria [35].

CONCLUSION

Left ventricular diastolic dysfunction is significantly more prevalent among asymptomatic patients with type 2 diabetes mellitus, with Grade I diastolic dysfunction being the most prevalent form. Furthermore, type 2 diabetes mellitus is strongly associated with diastolic dysfunction and a lower ejection fraction compared to healthy individuals.

ETHICAL DECLARATIONS

- **Ethics Approval and Consent to Participate**

  The study was approved by the Iraqi Board for Medical Specializations, the Scientific Council of Medicine.

- **Consent for Publication**

  Non.

- **Availability of Data and Material**

  The datasets are available from the corresponding author upon reasonable request.

- **Competing Interests**

  The authors declare that there is no conflict of interest.

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- **Authors' Contributions**

  All authors contributed significantly, directly, and intellectually to the work and consented to its publication.

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