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ORIGINAL ARTICLE

Evaluation of Right Ventricular Function and Epicardial Adipose Tissue in Type 2 Diabetes Mellitus Patients Using Two-Dimensional Speckle Tracking Echocardiography

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ABSTRACT

Background: Two-dimensional speckle tracking echocardiography can be used to measure the effects of type 2 diabetes, which include increased epicardial adipose tissue and impaired right ventricular performance. This study aimed to evaluate the impact of type 2 diabetes mellitus (T2DM) on right ventricular function and its relationship with epicardial adipose tissue (EAT) thickness.

Methods: This case-control study included 92 patients categorized into two groups: group I included 29 non-T2DM patients enrolled as a control group, and group II included 63 T2DM patients. All T2DM patients were divided into two groups according to their epicardial adipose tissue (EAT) thickness: group II-A included 33 T2DM patients with EAT thickness <5 mm, and group II-B included 30 T2DM patients with EAT thickness >5 mm. Right ventricular function and EAT thickness were measured using two-dimensional speckle tracking echocardiography (2DSTE).

Results: Epicardial fat thickness was significantly lower in the control group than in both the EAT < 5 mm group and the EAT > 5 mm group. Also, the EAT < 5 mm group had a lower EAT thickness when compared to the EAT > 5 mm group. The RV LS and RV LSR-E and TAPSE were significantly higher in the control group than in the EAT >5mm group. Also, the RV LS, RV LSR-E, and TAPSE were significantly higher in EAT <5mm when compared to the EAT >5mm group.

Conclusions: This study highlighted the significant relationship between increased epicardial adipose tissue thickness and impaired right ventricular function in patients with type 2 diabetes mellitus.

Keywords: Type 2 diabetes mellitus; Epicardial Adipose Tissue; Echocardiography

INTRODUCTION

One of the most prevalent chronic metabolic illnesses, type 2 diabetes mellitus (T2DM), is now extensively acknowledged as a significant cardiovascular disease risk factor [1]. Recent years have seen a steady rise in the prevalence of diabetes mellitus, which presents a serious threat to public health [2].

The subtypes of diabetes mellitus include gestational diabetes mellitus (GDM), type 1 diabetes mellitus (T1DM), T2DM, and various kinds of diabetes. Unusual visceral fat buildup increases the risk of insulin resistance, which can hasten the onset of diabetes and cardiovascular diseases, decrease insulin sensitivity, and increase proinflammatory cytokine expression and secretion in adipose tissue [3]. Epicardial fat tissue is a kind of visceral fat that envelops the pericardium and heart. It is among the body's visceral fat deposits. Prior research has

indicated that EFT measures can be used in place of visceral fat [4,5].

The ability of EFT to release and absorb free fatty acids affects poor glucose utilization, which is directly associated with coronary artery disease and the metabolic syndrome [6].

Both type 2 and type 1 diabetes were shown to have elevated EFT levels, and more recent studies have shown that in T2DM patients, EFT is linked to adiponectin, insulin resistance, obesity, and fasting blood glucose levels [7]. EFT can be measured using computed tomography (CT) and cardiac magnetic resonance imaging [8].

It is well known that diabetic cardiomyopathy first presents as diminished diastolic function, elevated heart stiffness, and ventricular hypertrophy. This disease may cause cardiac failure with a reduced ejection fraction and considerable cardiovascular-related mortality [9].

When the left ventricle fails, the pericardium or septal wall mechanically interacts to limit the function of the right ventricle [10]. Research indicates that there may be a connection between right ventricular dysfunction and a poor prognosis for chronic cardiovascular disease [11].

Using speckle tracking echocardiography in two dimensions, EFT and ventricular function can be assessed. The myocardium can now be assessed using a new angle-independent, semiautomated method called a two-dimensional speckle tracking echocardiogram (2DSTE) [12].

It tracks blocks of spikes from frame to frame using normal B-mode pictures, and it calculates lengthening and shortening in comparison to the baseline Lagrangian technique. Local myocardial information is provided by 2DSTE, from which displacement, velocity, strain (ε), and strain rate can be obtained, making it possible to evaluate the longitudinal, radial, and circumferential cardiac mechanics accurately [13].

The aim of this study was to evaluate the impact of type 2 diabetes mellitus (T2DM) on right ventricular function and its relationship with epicardial adipose tissue (EAT) thickness.

METHODS

Ninety-two patients total were used in this case-control study. They were split into two groups: group I consisted of 29 non-T2DM patients who were enrolled as a control group, and group II consisted of 63 T2DM patients. Based on the thickness of their epicardial adipose tissue (EAT), all T2DM patients were split into two groups: group II-A consisted of 33 patients with EAT thickness less than 5 mm, and group II-B comprised 30 patients with EAT thickness greater than 5 mm. Using two-dimensional speckle tracking echocardiography (2DSTE), right ventricular function and EAT thickness were assessed in patients admitted to Zagazig University Hospital's cardiology department between April and September of 2024. Every patient provided written informed permission, and Zagazig University IRB #11375-13-12-2023 approved the study. The World Medical Association's (Declaration of Helsinki) rule of ethics for human subject's research was followed in the conduct of the study.

Inclusion criteria Patients ranged in age from 23 to 75 years old, and both sexes were included. In accordance with the guidelines set forth by the American Diabetes Association (2010), a patient is diagnosed with type 2 diabetes if their FPG is ≥ 126 mg/dL (7.0 mmol/L) after abstaining from food for at least 8 hours and if their 2-hour plasma glucose during an oral glucose tolerance test (OGTT) is ≥ 200 mg/dL (11.1 mmol/L). A random plasma glucose level of ≥ 200 mg/dL (11.1 mmol/L) can also be diagnostic for patients exhibiting the characteristic signs of hyperglycemia or hyperglycemic crises. Severe arrhythmia, cardiomyopathy, valvular heart disease, congenital heart disease, type 1 diabetes mellitus, gestational diabetes, coronary heart disease, left ventricular ejection fraction (LVEF) <50%, acute complications from diabetes, cerebrovascular disease, and kidney disease were among the conditions that disqualified the participants.

Conventional measurement of RV:

An expert cardiologist performed transthoracic echocardiography examinations on all T2DM patients using the GE Vivid E9 echocardiography machine. From the four chambers at the apex, routine RV echocardiography values were measured. RV's middle and basal diameters were measured at the end of the diastolic phase.

The ratio of the end-diastolic area to the difference between the end-systolic and end-diastolic areas was divided to calculate RV fractional area change (RV-FAC), which was then expressed as a percentage. Measurements were taken of the RV's end-diastolic and end-systolic zones. A measurement made in M-mode is called the tricuspid annular plane systolic excursion (TAPSE), which is the difference between the end-diastolic and end-systolic excursions of the tricuspid annulus.

The left ventricular ejection fraction (LVEF) was calculated using the bi-plane Simpson's rule [14]. Wave-pulse the trans-tricuspid input velocities, early (E) and late (A), were measured using Doppler. The

tricuspid annulus's peak systolic, early diastolic, and late diastolic velocities were measured using tissue Doppler imaging (TDI S, TDI E, and TDI A).

Echocardiographic measurement of EAT thickness:

Every patient was positioned in the left lateral decubitus position. The echogenic gap between the myocardium's outer wall and the echogenic space (EAT), which was measured on the free wall of the right ventricle from the parasternal long-axis views, was used to delineate the visceral layer of the pericardium. At the end of each of the three cardiac cycles, its thickness was measured at the mid-chordal and tip of the papillary muscle levels in the parasternal short axis view perpendicular to the ventricular septum and in the parasternal long axis view perpendicular to the aortic annulus **(Figure 1).**

Two-dimensional speckle-tracking echocardiography analysis:

During an end-expiratory breath-hold, three successive cardiac cycle pictures of the RV's apical four chamber were obtained, and they were then imported into the Echo PAC program for offline STE analysis. When the endocardial border was most clearly defined during the cardiac cycle, in the end-systolic frame, the RV's endocardial border was manually drawn. The program would then automatically define a region of interest and make the necessary modifications to include the myocardium. The case was disregarded if it was impractical to follow one or more segments [15].

The basal, mid, and apical areas of the RV free wall were easily identifiable. RV peak systolic longitudinal strain (RV LS) and strain rate (RV LSR-S), RV peak early diastolic longitudinal strain rate (RV LSR-E), and RV peak longitudinal strain mean (RV LSR-A) were all calculated, and RV peak late diastolic longitudinal strain rate (RV LSR-L) **(Figure 2).** Because RV LS's absolute value is negative, it was selected for a simpler interpretation.

Reproducibility test:

Twenty randomly selected subjects underwent two administrations of the EAT, RV LS, and RV LSR-E measures to assess the variability between and among observers, both by the same doctor (inter-observer variability) and by a separate doctor (intra-observer variability).

Statistical analysis:

The collected data were coded, entered, and analyzed by computer using a database software program, IBM SPSS 23.0 for Windows (IBM Corp., Armonk, NY, USA). The relationship between two or more categorical variables is analyzed using the Chi-Square [X2] analysis of variance (ANOVA) test. Used to analyze the difference between means of independent variables of more than two groups. (n) Number of each observation and (%) percentage of the observation to all categories or orders were used. Median was used for summarization of skewed data. Standard deviation (SD) used as a measure of dispersion and square root of the variance. Interquartile range (IQR) used a range of values that resided in the middle of the scores. The P-value of less than 0.05 was deemed statistically significant.

RESULTS

This included 92 patients, split into two groups: 29 non-T2DM patients were enrolled in Group I as a control group. With a mean ± SD of 46.6 ± 11.72 years, their ages ranged from 23 to 75 years. There were 41.4% females and 58.6% males. Their BMI was 23.4 ± 1.33 kg/m2, with a range of 21.1 to 25.5 kg/m2. There were 63 T2DM patients in group II. In accordance with the thickness of their epicardial adipose tissue (EAT), all T2DM patients were split into two groups: Group II-A included 33 T2DM patients with EAT thickness < 5 mm. Their ages ranged from 30 to 70 years with a mean ± SD of 52.9 ± 9.87. (72.7%) were males and (27.3%) were females. Their BMI ranged from 20.9 to 26.5 kg/m2, with a mean ± SD of 23.6 ± 1.68. Group II-B included 30 T2DM patients with EAT thickness > 5 mm. Their ages ranged from 31 to 73 years with a mean ± SD of 50.4 ± 11.22. (73.3%) were males and (26.7%) were females. Their BMI ranged from 21.5 to 26.1 kg/m2, with a mean ± SD of 23.8±1.46.

Table 1 showed that there was no statistically significant difference between the studied groups as regards demographic data (P > 0.05). The control group's mean systolic blood pressure (SBP) was statistically significantly lower than that of the EAT <5mm group (P = 0.02) and the EAT > 5mm group (P = 0.001) when the three study groups' SBPs were compared. However, there was no significant difference in mean SBP between the two groups.

Table 2 showed that there was no statistically significant difference between the studied groups as regards associated comorbidities (P > 0.05).

When the mean Eat thickness of the three groups under study was compared, the control group's EAT thickness was found to be considerably lower than that of the EAT < 5 mm group (P = 0.001) and the EAT > 5 mm group (P < 0.001). Additionally, as table 3 illustrates, the EAT <5 mm group had a lower EAT thickness than the EAT > 5 mm group (P<0.001).

After analyzing the right ventricular longitudinal strain (RV LS) of the three groups under study, there was no significant difference in RV LS between the EAT < 5 mm group and the EAT > 5 mm group (P = 0.14); however, the control group had a considerably greater RV LS compared to both the EAT < 5 mm group (P<0.001) and the EAT > 5 mm group (P<0.001). Regarding the right ventricular early diastole longitudinal strain rate (RV LSR-E), the EAT > 5 mm group was shown to have a considerably lower RV LSR-E (P = 0.01) than the control group. Table 4 further indicates that there was no significant difference in RV LSR-E between the control group and the EAT < 5 mm group (P = 0.92); however, the EAT < 5 mm group had a higher RV LSR-E than the EAT > 5 mm group (P = 0.02).

Figure (3) demonstrates a strong positive relationship between SBP and the thickness of the epicardial adipose tissue (EAT). (r=0.298, P=0.004), FBG (r=0.599, P<0.001), HbA1C (r=0.737, P<0.001), TG (r=0.437, P<0.001), and LDL-C (r=0.260, P=0.01). While there was a significant negative correlation between EAT thickness and TAPSE (r = -0.216, P = 0.04), RV LS (r = -0.441, P<0.001), and RV LSR-E (r = -0.302, P = 0.004).

Table 5: To identify factors that independently affected RV LS, multiple linear regression analysis was performed using age, SBP, FBG, HbA1C, lipid profile, EAT thickness, and echocardiographic findings as independent variables and RV LS as a dependent variable. RV LS was negatively associated with HbA1C (β =-0.629, P<0.001) and EAT thickness (β =-0.721, P<0.001).

Table 6: To identify factors that independently affected RV LSR-E, multiple linear regression analysis was performed using age, SBP, FBG, HbA1C, lipid profile, EAT thickness, and echocardiographic findings as independent variables and RV LSR-E as a dependent variable. RV LSR-E was negatively associated with SBP (β = -0.008, P=0.02), FBG (β = -0.0319, P=0.005), HbA1C (β = -0.031, P=0.004), EAT thickness (β = -0.067, P=0.004), and LVEF (β = -0.019, P=0.04).

Table (1): Demographic data among the studied groups

Variables		**Control group (n=29)**	**EAT < 5 mm (n=33)**	**EAT > 5 mm (n=30)**	**P Value**	
Age *(years)*	*Mean ± SD*	46.6 ± 11.72	52.9 ± 9.87	50.4 ± 11.22	0.09[1]	
	Range	(23 – 75)	(30 – 70)	(31 – 73)		
Sex *(n. %)*	Male	17 (58.6%)	24 (72.7%)	22 (73.3%)	0.39[2]	
	Female	12 (41.4%)	9 (27.3%)	8 (26.7%)		
BMI *(kg/m²)*	*Mean ± SD*	23.4 ± 1.33	23.6 ± 1.68	23.8 ± 1.46	0.61[1]	
	Range	(21.1 – 25.5)	(20.9 – 26.5)	(21.5 – 26.1)		
Clinical		**Control group (n=29)**	**EAT < 5 mm (n=33)**	**EAT > 5 mm (n=30)**	**P Value**	**Post-Hoc**
SBP *(mmHg)*	*Mean ± SD*	120.2 ± 7.62	127 ± 10	129.5 ± 10.9	**<0.001[1]**	P1=**0.02** P2=**0.001** P3=0.55
	Range	(110 – 130)	(110 – 145)	(110 – 145)		
DBP *(mmHg)*	*Mean ± SD*	23.4 ± 1.33	23.6 ± 1.68	23.8 ± 1.46	0.58[1]	-
	Range	(21.1 – 25.5)	(20.9 – 26.5)	(21.5 – 26.1)		

**[1]One way ANOVA test, [2]Chi-square test, Non-significant: P >0.05, Significant: P ≤0.05*

**P=Comparison between the three groups, P1=Comparison between control group & EAT < 5 mm group, P2=Comparison between control group & EAT > 5 mm group, P3=Comparison between EAT < 5 mm group & EAT < 5 mm group*

** **EAT**=Epicardial adipose tissue, **SBP**=Systolic blood pressure, **DBP**=Diastolic blood pressure, BMI=Body mass index*

Table (2): Associated comorbidities among the studied groups

Variables		Control group (n=29)	EAT < 5 mm (n=33)	EAT > 5 mm (n=30)	P Value
Hypertension *(n. %)*	Absent	15 (51.7%)	16 (48.5%)	13 (43.3%)	0.81
	Present	14 (48.3%)	17 (51.5%)	17 (56.7%)	
Dyslipidemia *(n. %)*	Absent	14 (48.3%)	16 (48.5%)	12 (40%)	0.65
	Present	15 (51.7%)	17 (51.5%)	18 (60%)	

**Chi-square test, Non-significant: P >0.05, Significant: P ≤0.05*
** **EAT**=Epicardial adipose tissue*

Table (3): Epicardial adipose tissue thickness among the studied groups

Variables		Control group (n=29)	EAT < 5 mm (n=33)	EAT > 5 mm (n=30)	P Value	Post-Hoc
EAT thickness *(mm)*	*Mean ± SD*	3.25 ± 0.65	3.93 ± 0.55	6.67 ± 0.94	**<0.001**	P1=**0.001** P2<**0.001** P3<**0.001**
	Range	(1.87 – 4.32)	(2.95 – 5.03)	(4.94 – 8.88)		

**One way ANOVA test, Non-significant: P >0.05, Significant: P ≤0.05*
**P=Comparison between the three groups, P1=Comparison between control group & EAT < 5 mm group, P2=Comparison between control group & EAT > 5 mm group, P3=Comparison between EAT < 5 mm group & EAT < 5 mm group*
** **EAT**=Epicardial adipose tissue*

Table (4): Conventional echocardiographic characteristics and right ventricular functional

Variables		Control group (n=29)	EAT < 5 mm (n=33)	EAT > 5 mm (n=30)	P Value	Post-Hoc
LVEF *(%)*	*Mean ± SD*	61.6 ± 4.06	63.1 ± 3.55	63.7 ± 3.35	0.11	-
	Range	(53.2 – 68.8)	(56.7 – 69.4)	(55.8 – 69.4)		
RVD-base *(mm)*	*Mean ± SD*	29.3 ± 1.9	30.6 ± 2.28	30.4 ± 2.22	0.06	-
	Range	(24.6 – 32.6)	(25.5 – 36)	(26.8 – 34.5)		
RVD-mid *(mm)*	*Mean ± SD*	25.5 ± 1.84	26.3 ± 1.93	25.1 ± 2.17	0.09	-
	Range	(21.3 – 30.5)	(21.9 – 29.9)	(20.4 – 30.7)		
RVA-D *(cm^2)*	*Mean ± SD*	13.21 ± 2.92	13.28 ± 2.52	12.96 ± 2.38	0.87	-
	Range	(6.76 – 20.75)	(8.03 – 17.78)	(8.28 – 18.15)		
RVA-S *(cm^2)*	*Mean±SD*	6.22 ± 1.39	6.33 ± 1.34	5.88 ± 1.24	0.37	-
	Range	(3.51 – 9.64)	(3.14 – 8.7)	(3.41 – 7.57)		
RV-FAC *(%)*	*Mean ±SD*	51.7 ± 7.4	51.97 ± 6.18	51.33 ± 6.97	0.93	-
	Range	(39.9 – 69.02)	(36.55 – 66.9)	(33.62–63.18)		
TAPSE	*Mean ±SD*	22.5 ± 1.95	22.5 ± 2.37	21.8 ± 1.59	0.24	-
	Range	(18.7 – 26.6)	(16 – 26.6)	(18.7 – 26.2)		
E *(m/s)*	*Mean ±SD*	59 ± 2.6	59 ± 8.57	60.4 ± 6.36	0.54	-
	Range	(52.9 – 63.7)	(41.1 – 76.2)	(41.4 – 70.9)		

Variables	Control group (n=29)	EAT < 5 mm (n=33)	EAT > 5 mm (n=30)	P Value	Post-Hoc	Variables
A *(m/s)*	*Mean ±SD*	37.7 ± 4.78	36.4 ± 5.7	37.8 ± 5.04	0.55	-
	Range	(26.3 – 44.9)	(23.3 – 47.5)	(25.2 – 46.1)		
E/A	*Mean ±SD*	1.64 ± 0.21	1.59 ± 0.12	1.59 ± 0.09	0.51	-
	Range	(1.15 – 2)	(1.37 – 1.8)	(1.35 – 1.77)		
TDI S *(m/s)*	*Mean ±SD*	12.55 ± 2.29	12.51 ± 2.74	11.93 ± 2.52	0.56	-
	Range	(8.68 – 20.33)	(7.09 – 17.61)	(5.94 – 16.53)		
TDI E *(m/s)*	*Mean ±SD*	13.65 ± 2.35	13.27 ± 1.82	12.95 ± 1.96	0.47	-
	Range	(9.44 – 17.09)	(9.96 – 17.45)	(8.13 – 16.09)		
TDI A *(m/s)*	*Mean ±SD*	11.85 ± 1.97	12.27 ± 2.19	12.1 ± 2.34	0.73	-
	Range	(8.31 – 15.87)	(8.06 – 17.79)	(6.94 – 16.75)		
E/TDI E	*Mean ±SD*	4.33 ± 0.77	4.49 ± 0.75	4.53 ± 0.74	0.56	-
	Range	(2.93 – 5.69)	(2.97 – 6.09)	(3.22 – 6.02)		
RV LS *(%)*	*Mean ±SD*	28.23 ± 2.21	25.28 ± 2.32	24.14 ± 2.46	**<0.001**	P1**<0.001** P2**<0.001** P3=0.14
	Range	(24.4 – 31.84)	(17.97–28.22)	(19.22–29.22)		
RV LSR-S *(I/s)*	*Mean ±SD*	-1.84 ± 0.36	-1.8 ± 0.27	-1.83 ± 0.31	0.86	-
	Range	(-2.78 – -1.07)	(-2.58 – -1.21)	(-2.39 – -1.25)		
RV LSR-E *(I/s)*	*Mean ±SD*	1.98 ± 0.29	1.94 ± 0.39	1.7 ± 0.34	**0.004**	P1=0.92 P2=**0.01** P3=**0.02**
	Range	(1.28 – 2.45)	(1.09 – 2.61)	(0.93 – 2.56)		
RV LSR-A *(I/s)*	*Mean ±SD*	1.44 ± 0.33	1.52 ± 0.34	1.42 ± 0.37	0.49	-
	Range	(0.68 – 2.15)	(0.62 – 2.09)	(0.81 – 2.12)		

**One way ANOVA test, Non-significant: P >0.05, Significant: P ≤0.05*

**P=Comparison between the three groups, P1=Comparison between control group & EAT < 5 mm group, P2=Comparison between control group & EAT > 5 mm group, P3=Comparison between EAT < 5 mm group & EAT < 5 mm group.*

***EAT=Epicardial adipose tissue, **LVEF**=Left ventricular ejection fraction, **RVD-base**=Right ventricular basal diameter, **RVD-mid**=Right ventricular middle diameter, **RVA-D**=Right ventricular area at end-diastolic, **RVA-S**=Right ventricular area at end systolic, **RV-FAC**= Right ventricular fractional area change, **TAPSE**=Tricuspid annular plane systolic excursion, **E**=Peak early diastolic flow velocity of tricuspid valve, **A**=Peak late diastolic flow velocity of tricuspid valve, **TDI S**=Tricuspid annular peak systolic velocity, **TDI E**=Tricuspid annular early diastolic velocity, **TDI A**=Tricuspid annular late diastolic velocity, **RV LS**=Right ventricular longitudinal strain, **RV LSR-S**=Right ventricular systole longitudinal strain rate, **RV LSR-E**=Right ventricular early diastole longitudinal strain rate, **RV LSR-A**=Right ventricular late diastole longitudinal strain rate*

Table (5): Multiple linear regression analysis for predictors of right ventricular longitudinal strain

Model fit measures	R=0.610	R^2=0.372	P Value
Model coefficients	**Estimate**	**t**	
Age	-0.044	-1.66	0.11
SBP	0.003	0.111	0.91
FBG	-0.247	-1.779	0.08
HbA1C	-0.629	-6.33	**<0.001**
TG	-1.1	-1.33	0.19

Model fit measures	R=0.610	R^2=0.372	P Value
Model coefficients	**Estimate**	**t**	
LDL-C	-1.33	-1.82	0.07
HDL-C	-1.943	-1.381	0.17
EAT thickness	-0.721	-4.28	**<0.001**
LVEF	-0.079	-0.98	0.33
RVD-base	-0.128	-0.94	0.35
RVD-mid	0.074	0.496	0.62
RVA-D	-0.163	-1.41	0.16
RVA-S	-0.408	-1.82	0.07
RV-FAC	0.042	0.952	0.34
TAPSE	0.065	0.436	0.66
E	-8.22	-0.018	0.99
A	0.052	0.899	0.37
E/A	2.209	1.271	0.21
TDI S	3.12	0.003	0.99
TDI E	0.077	0.522	0.61
TDI A	0.085	0.606	0.55
E/TDI E	-0.014	-0.035	0.97
RV LSR-S	0.985	1.02	0.31
RV LSR-E	0.477	0.653	0.52
RV LSR-A	-1.53	-1.78	0.08

Table (6): Multiple linear regression analysis for predictors of RV LSR-E

Model fit measures	R=0.514	R^2=0.264	P Value
Model coefficients	**Estimate**	**T**	
Age	-5.43	-0.157	0.88
SBP	-0.0084	-2.31	**0.02**
FBG	-0.0319	-2.91	**0.005**
HbA1C	-0.031	-2.99	**0.004**
TG	-0.048	-0.33	0.12

Model fit measures	R=0.514	R^2=0.264	P
Model coefficients	**Estimate**	**T**	**Value**
LDL-C	-0.035	-0.369	0.71
HDL-C	-0.150	-0.718	0.48
EAT thickness	-0.067	-2.97	**0.004**
LVEF	-0.019	-2.07	**0.04**
RVD-base	0.006	0.372	0.71
RVD-mid	-0.004	-0.223	0.82
RVA-D	-0.024	-1.63	0.11
RVA-S	-0.025	-0.88	0.38
RV-FAC	0.635	0.112	0.91
TAPSE	0.008	0.403	0.69
E	-0.002	-0.376	0.71
A	-0.005	-0.665	0.51
E/A	0.388	1.53	0.13
TDI S	0.013	0.861	0.39
TDI E	0.002	0.097	0.92
TDI A	-0.008	-0.474	0.64
E/TDI E	0.069	1.36	0.18
RV LS	0.024	1.58	0.12
RV LSR-S	0.170	1.40	0.17
RV LSR-A	0.006	0.056	0.96

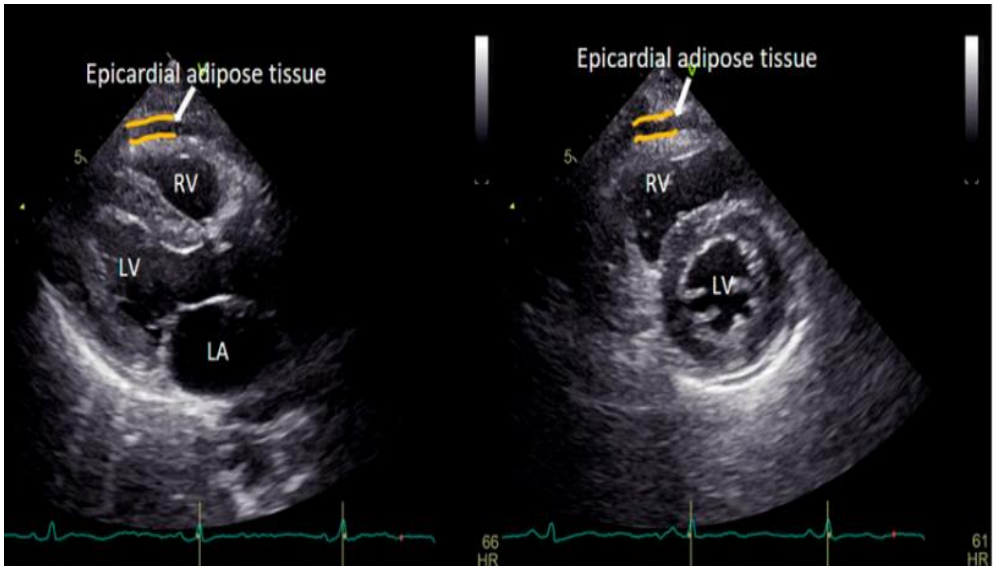


Figure 1: Echocardiographic measurement of EAT thickness in the parasternal long-axis and short-axis views of left ventricle at end systole. LA: left atrium; LV: left ventricle; RV: right ventricle.

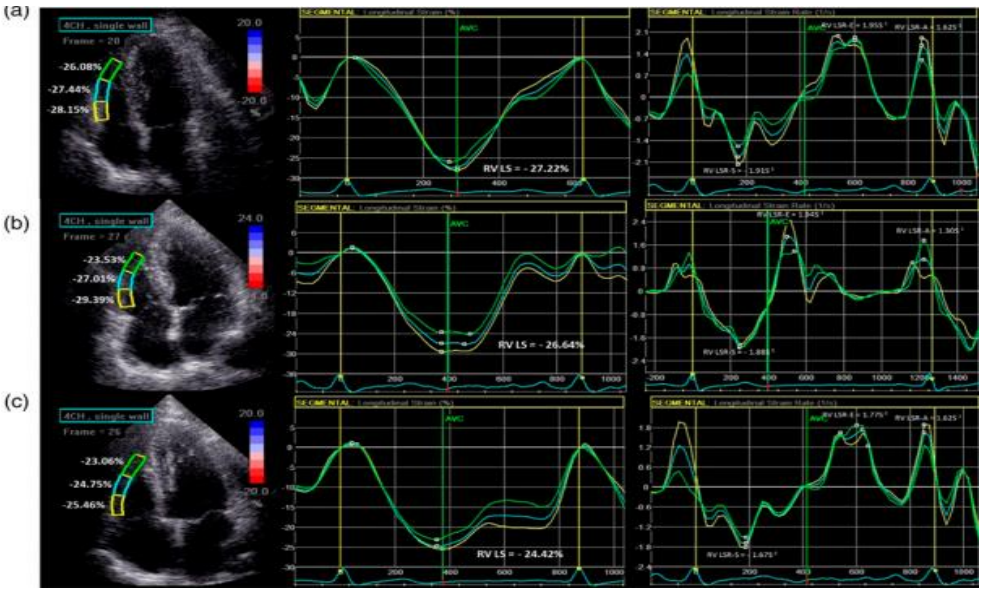
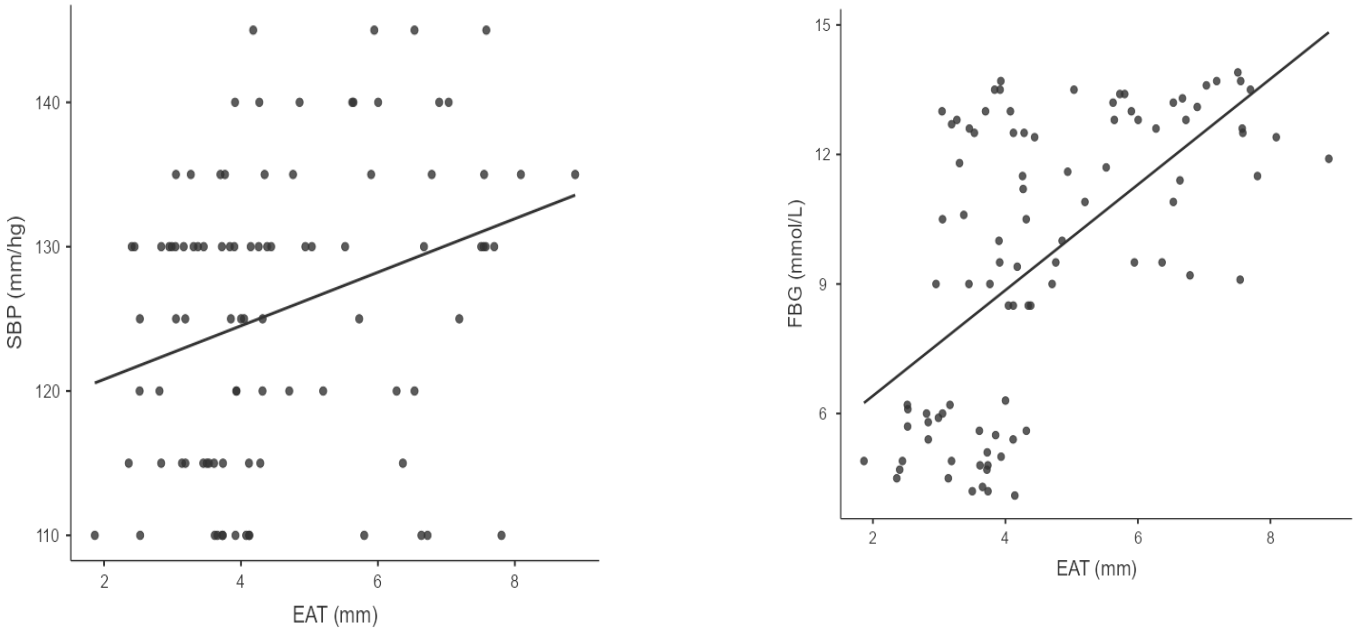


Figure 2: The representative images of RV longitudinal strain and longitudinal strain rate in controls (a) T2DM with EAT <5 mm (b) and T2DM with EAT ≥5 mm (c).



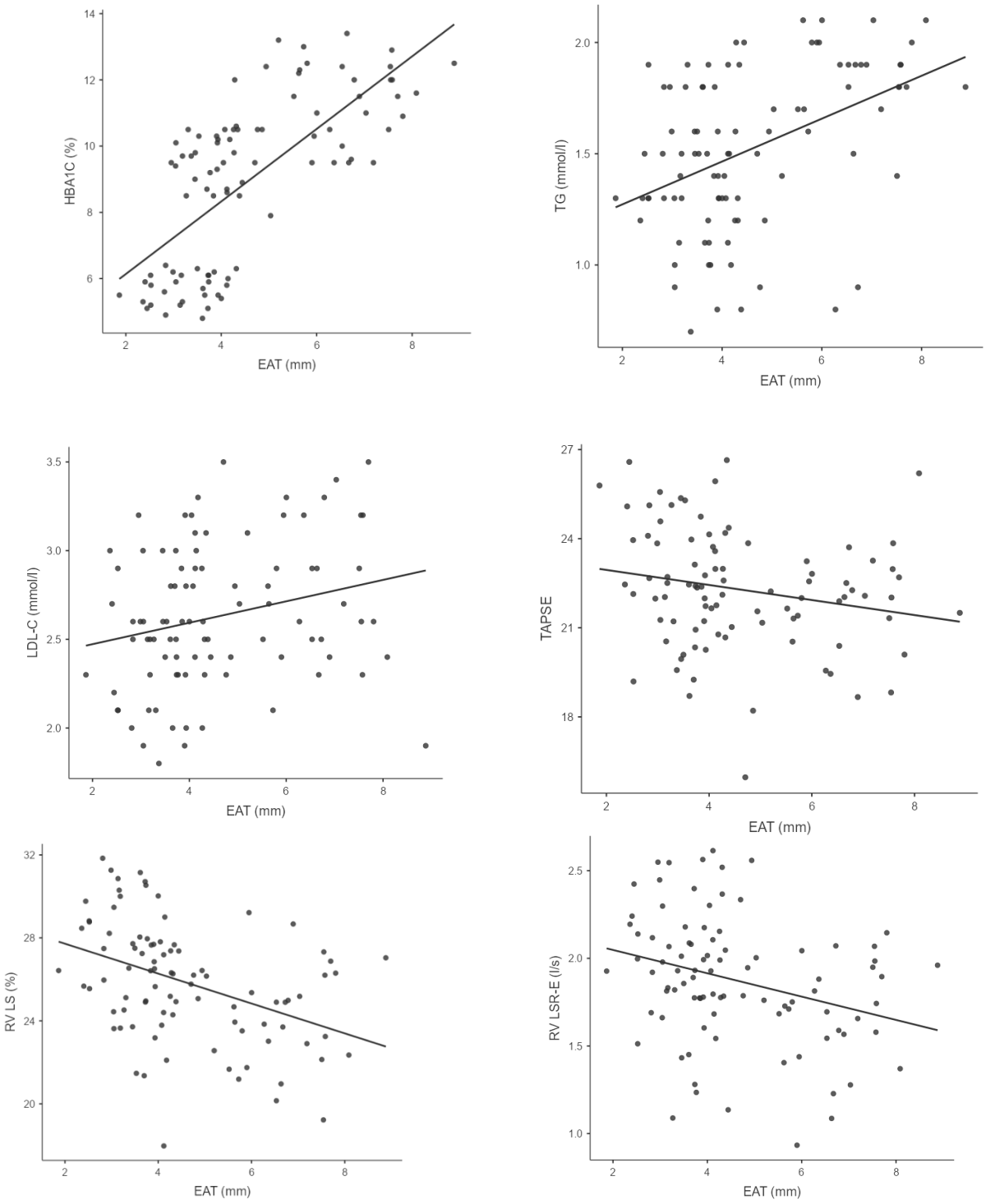


Figure 3: Scatter plot showing the correlation of EAT thickness with different parameters among the studied patients

DISCUSSION

In our work, we evaluated right ventricular function in individuals with type 2 diabetes using 2DSTE, hypothesizing that increased EAT thickness would correlate with impaired right ventricular function. This investigation builds on previous findings but uniquely focuses on right ventricular mechanics, which are often overlooked in the context of T2DM **[7].**

The non-diabetic control group and the two T2DM groups did not significantly differ in terms of age, gender distribution, or BMI, according to our research (with different EAT thicknesses). BMI across groups suggests that while general obesity may not differ, visceral fat accumulation (as measured by EAT) might play a more specific role in cardiovascular dysfunction in T2DM patients.

The metabolic profile of our T2DM patients, including elevated FBG, HbA1c, and lipid disturbances (higher triglycerides and LDL-C), further emphasizes the importance of metabolic control in managing cardiovascular risk. Several studies have confirmed the relationship between poor glycemic control and increased EAT, which contributes to cardiovascular dysfunction [11].

In our study, the significant correlation between higher HbA1c and thicker EAT suggests that poor glycemic control in particular is a key driver of EAT accumulation and subsequent right ventricular dysfunction. This is consistent with the mounting evidence that suggests glucose control is essential for lowering the chance of heart disease in people with type 2 diabetes. Evidence from numerous research endeavors points to these facts.

Our study found a significant increase in systolic blood pressure (SBP) among T2DM patients, especially in the group with higher EAT thickness ($P < 0.001$). According to this research, EAT may be a major factor in T2DM patients' high blood pressure. Previous studies have linked increased EAT to systemic inflammation and vascular dysfunction, which can elevate blood pressure [16].

Research has demonstrated that visceral adiposity, especially around the heart, contributes to elevated SBP due to its influence on systemic inflammation and arterial stiffening [8].

Our study revealed significantly higher fasting blood glucose (FBG) and HbA1c levels in T2DM patients, particularly in those with increased epicardial adipose tissue (EAT) thickness. Findings from diverse research efforts supported our study. These findings align with existing research suggesting that poor glycemic control contributes to the accumulation of visceral fat, including EAT, which exacerbates cardiovascular risk [9].

The significant elevation in FBG and HbA1c observed in our study supports the hypothesis that poor glycemic control accelerates EAT accumulation and negatively impacts heart function [11].

A study supports our findings, reporting a strong correlation between higher HbA1c levels and increased EAT in T2DM patients. These studies, including ours, highlight the importance of achieving better glycemic control to manage EAT accumulation and mitigate cardiovascular risks in diabetic patients [17].

Our research revealed that T2DM patients with greater EAT thickness also had significantly higher levels of low-density lipoprotein cholesterol (LDL-C) and triglycerides (TG) in addition to hyperglycemia. These lipid disturbances further contribute to the risk of cardiovascular events by promoting atherosclerosis, plaque formation, and arterial stiffening [8].

In our findings on EAT thickness, we identified significant correlations between EAT and clinical/metabolic parameters such as fasting blood glucose (FBG), HbA1c, and systolic blood pressure (SBP). These correlations suggest that poor metabolic control drives EAT accumulation, which, in turn, aggravates cardiovascular risk factors. Similar associations have been reported in previous studies, where elevated FBG and HbA1c were closely linked to increased visceral fat depots like EAT [17].

Interestingly, our investigation also showed a strong negative connection between right ventricular longitudinal strain and EAT thickness, two important echocardiographic markers (RV LS) and right ventricular early diastolic longitudinal strain rate (RV LSR-E), suggesting that EAT directly contributes to both systolic and diastolic dysfunction. This finding is supported by research showing that increased EAT impairs myocardial mechanics, leading to right ventricular dysfunction [11].

Our study demonstrated that right ventricular longitudinal strain (RV LS) was significantly lower in T2DM patients, particularly those with increased epicardial adipose tissue (EAT) thickness, indicating reduced right ventricular systolic function. RV LS is a sensitive marker of right ventricular systolic performance, and its decline reflects early changes in myocardial contractility. Previous research has linked increased EAT with impaired right ventricular function due to the direct mechanical effects of fat deposition and the proinflammatory cytokines released by EAT, which impair myocardial contractility [11].

These findings highlight the role of EAT not only as a marker of metabolic dysfunction but also as a contributor to right ventricular impairment.

In addition to systolic dysfunction, our study also revealed that in patients with type 2 diabetes, the right ventricular early diastolic longitudinal strain rate (RV LSR-E) was considerably lower. with high

EAT thickness, reflecting diastolic dysfunction. Diastolic dysfunction in the right ventricle has been attributed to both increased myocardial stiffness and reduced ventricular compliance, exacerbated by the inflammatory environment created by visceral fat [5].

The lowest RV LSR-E values were observed in patients with EAT thickness greater than 5 mm, suggesting that the degree of visceral fat accumulation directly influences right ventricular diastolic performance. This result aligns with previous studies, which showed that increased EAT is associated with impaired diastolic function due to its effects on myocardial relaxation [18].

Our findings on RV LS and RV LSR-E emphasize the importance of evaluating both systolic and diastolic function in T2DM patients, as these measures provide a comprehensive view of right ventricular health. The decline in both parameters with increasing EAT suggests that T2DM patients with high visceral fat deposition are at higher risk for heart failure, particularly right-sided heart failure, which is often underdiagnosed in this population. The pathophysiology behind this association likely involves both the mechanical compression of the heart by excess EAT and the systemic inflammation driven by the adipose tissue, which affects both systolic and diastolic functions [9].

The clinical implications of these findings are significant. In T2DM patients, measuring both RV LS and RV LSR-E may offer valuable insights into the risk of heart failure, especially in those with high EAT thickness. Reducing EAT through metabolic and lifestyle interventions, including glycemic control, weight management, and anti-inflammatory therapies, may help preserve right ventricular function in these patients.

While our study provides valuable insights into the relationship between epicardial adipose tissue (EAT) and right ventricular function in T2DM patients, there remain several avenues for further exploration. The intricate interplay between metabolic control, visceral fat deposition, and cardiac performance highlights the complexity of managing cardiovascular risk in this population. Future studies should focus on understanding the longitudinal impact of reducing EAT through targeted interventions, such as pharmacological agents and lifestyle modifications, on both systolic and diastolic heart function. Additionally, expanding research to include larger, more diverse cohorts could provide more comprehensive data on the variability of EAT's effects across different patient groups. Ultimately, addressing these knowledge gaps may lead to more tailored treatment approaches that mitigate cardiovascular risks in T2DM patients.

The limitations of the study:

Study limitations: Because this was a single site, bias may have been introduced, limiting the findings' application to other groups or contexts. The findings may not be as broadly applicable to the larger population of patients with T2DM. As a cross-sectional study, causality between EAT thickness and right ventricular dysfunction cannot be firmly established. The absence of long-term follow-up prevents conclusions about the progression of right ventricular impairment over time in relation to EAT accumulation. While efforts were made to control for confounding variables, other factors such as lifestyle, medications, or undiagnosed comorbidities may have influenced the results.

Conclusion:

This study highlighted the significant relationship between increased epicardial adipose tissue (EAT) thickness and impaired right ventricular function in patients with type 2 diabetes mellitus (T2DM). Our findings demonstrated that both systolic and diastolic dysfunctions, as measured by right ventricular longitudinal strain (RV LS) and early diastolic strain rate (RV LSR-E), were closely linked to EAT accumulation, emphasizing the role of visceral adiposity in cardiovascular risk. Furthermore, the independent associations of EAT and glycemic control with right ventricular impairment underscored the importance of addressing both metabolic disturbances and fat deposition in managing cardiovascular complications in T2DM patients. These results suggested that targeted interventions aimed at reducing EAT and improving metabolic control could provide important therapeutic benefits for preserving cardiac function in this population.

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