



Evaluation of the Systolic and Diastolic Right Ventricular Function: A Comparison Between Diabetes, Prediabetes and Normal Patients Without Coronary Artery Disease

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Abstract: Diabetes mellitus is a well-known dangerous factor for cardiovascular disease with high rate of comorbidities. Patients suffering from this disease have represented more heart failures which is entangled with Ischemic heart disease or high blood pressure. Thus, depending on the recent scientific facts, diabetes mellitus as a separate factor which is independent from CAD, Arterial blood pressure or other factors, is claimed to culminate in advance heart failure. Previous studies have concentrated on the impacts of diabetes and prediabetes on the performance of the left ventricular which leaves right ventricular uncovered. Consequently, the aim of this article is to analyze and compare the systolic and diastolic function of the right ventricular in normal patients and the ones with diabetes and prediabetes without any coronary artery disease. (Curr Probl Cardiol 2021;46:100817.)

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Introduction

Diabetes increases the risk of developing heart failure in the absence of coronary artery disease, hypertension, or other comorbidities, and can increase the rate of mortality 2-4 times in heart failure patients.^{1,2} Diabetes first impairs myocardial function as a latent clinical condition that, if not controlled, can lead to cardiomyopathy triggered by diabetes.¹ In diabetic patients, glucose oxidation in the myocardium is reduced. Fatty acid metabolism is increased, and by altering intracellular signals, excitation-contraction coupling is disrupted and energy deficiency is increased.³ Prediabetes is also a common condition for cardiovascular changes. About 33% of people pertaining to the developed and developing countries are prediabetic.³ Prediabetes is associated with unpleasant heart damages such as left ventricular hypertrophy (LVH), increased intima-media thickness ratio of carotid arteries and decreased coronary artery reserve flow. Pre-diabetes is associated with insulin resistance, and left ventricular dysfunction is associated with insulin resistance. The hypothesis that exacerbation of glycemic status can lead to the right ventricular myocardial infarction (RVMI) bestows more importance upon this study. Right ventricular function is the primary determinant of prognosis in many patients.^{4,5}

Right ventricular dysfunction may affect the functioning of the left ventricular not only by restricting left ventricular preload but also with systolic and diastolic interference with the ventricular septum and pericardium.⁶ Table 1 comprising some of the most important studies is presented so as to have a more simple while comprehensive review of previous studies.⁷⁻¹²

According to the evaluations, RV function has more impact on myocardial contraction,¹ in spite of the previous heart failure reports pertaining to the cases with DM which straightly condemned the LV as the major cause.² Also there is not enough data about cases with prediabetes. RV is a passive cavity that is not considered in clinical trials because of the obliviousness of its essential role in heart and lung diseases.¹² Thus, the aim of the study is to compare the systolic and diastolic function of the RV in cases with prediabetes, diabetes and normal patients, without any coronary artery disease.

Methodology

In this case study, from the patients that are admitted for angiography in cardiac clinic of Bu Ali Sina Hospital in Qazvin, Iran, the ones with normal coronary or mild coronary angiography without any clinical signs

Table 1. Some of the most important studies

Results	cases	Goals	Researchers	Sources
Type 2 diabetes can affect the function of the right ventricle in the absence of coronary artery disease, diastolic dysfunction, and high pulmonary blood pressure	22	Investigation of right ventricular disorders in patients with DM2	Parsaee et al.	1
Ventricular diastolic disorders in diabetic patients should be considered when prescribing medication to prevent right ventricular dysfunction	96	Evaluating the ventricular systolic and diastolic function via conventional and Doppler echocardiography in diabetic patients with and without high blood pressure with no coronary artery disease	Kosmala et al.	2
Novel echocardiogram techniques, including TDI, strain rate imaging, RT3DE (Real Time Three Dimensional Echo), and echocardiographic contrast, can increase the precision in measuring RV performance	-	Evaluation of the echocardiography and complementary technologies roles in right ventricular function	Bleeker et al.	6
Myocardial dysfunction in cases with diabetes was significantly higher than healthy ones. There was no clear relationship between MPI and blood sugar levels and the duration of DM.	60	Evaluation of right ventricular function versus myocardial function index in diabetic patients	Abdelaziz and	
Daoud	12			
DM is independently correlated with RV systolic dysfunction (or 2.84 (1.09-7.40) $p = 0.03$) and RV diastolic dysfunction (or 4.33 (1.25-15.07) $P = 0.02$) after age, sex and pulmonary pressure adjustments.	91	DM with left myocardial reconstruction in heart failure	Gorter et al.	7

(continued)

Table 1. (continued)

Results	cases	Goals	Researchers	Sources
Global longitudinal broadenings of the right ventricular specific layer (endomid and epicardial) are less common in patients with high blood pressure and normal rather than control patients.	129	Evaluation of right ventricular specific layer deformation in cases with normal blood pressure and high blood pressure with DM2	Tadic et al.	8
In cases with DM1 without any cardiovascular disease, lesser mass of the LV and smaller LV and RV volumes were observed compared to the cases without diabetes	71	Evaluation of the DM1 and its effect on increasing cardiovascular side effects	Hjortkjær et al.	9
Among diabetics, those with HbA1C greater than 7% are more likely to develop RVD than those with HbA1C less than 7%.	106	Determining the role of diabetes mellitus as an independent indicator in RVDs	Roifman et al.	10
LV IVA had better diagnostic accuracy compared to RV IVA for predicting premature contractile dysfunction in people with DM.	53	Evaluating the role of the Tissue Doppler imaging (TDI) and global LV and RV functions in cases with DM	Suran et al.	11

diagnosing systolic and diastolic heart failure would enter the study on their own will. It should be noted that patients would not be financially charged, also a total number of 90 cases will be examined. Afterwards they are divided into 3 groups of diabetes, pre-diabetes, and normal based on their hemoglobin A1C (HbA1C) or FBS levels (30 people in each group). The type of diabetes (one or two) does not affect the procedure of choosing diabetic patients. The classification of the groups is as follows: A1C hemoglobin levels ≥ 6.5 refers to diabetics, between 5.7 and 6.4 refers to prediabetics and ≤ 5.7 refers to the normal cases.¹³ Conditions that cause patients to be excluded from the study are: congenital or valvular heart disease, left ventricular ejection fraction less than 50%, abnormal heart rhythms, documented pulmonary disease with increased pulmonary arterial pressure, patients with severe valvular disease and Cardiomyopathies, having a history of radiotherapy or chemotherapy and ischemic heart disease (myocardial infarction, heart surgery, or stent

placing), also they should comprise none of the complications of diabetes such as advanced diabetic retinopathy, neuropathy, and nephropathy. Only diabetics who are on a diet and are treated with oral hypoglycemic and insulin medications will be selected. Between the normal and prediabetic patients only the ones with a normal diet will be selected. First, the checklist including age, sex, weight, height, systolic, and diastolic blood pressure is completed for participants in the study, then echocardiography tests will be performed by a cardiologist (echo fellowship) in all 3 groups. Transthoracic echo is performed for all patients with left-sided lying position. The variables that will be measured are as follows:

Standard echocardiography

The LV volumes in the apical 2 and 4 chamber views at the end of the systole and diastole are measured. The left ventricular EF is measured using the Simpson method. RV diameters at the end of the diastole and in the middle of the right ventricle, the area of the RV at the end of the systole and diastole are evaluated through apical 4 chamber view. RVFAC, as an index for right ventricular systolic function, will be obtained from the following formula:

$$RVFAC = \frac{\text{the area of RV at the end of the diastole} - \text{the area of RV at the end of the systole}}{\text{the area of RV at the end of the diastole}} \times 100$$

By tracing the right ventricular endocardium in the systole and diastole from the tricuspid valve annulus in the direction of the apex along the free wall of the right ventricle and then toward the annulus from the apex along the interventricular septum is calculated (with the apical 4 chamber view). TAPSE is measured by placing an M-Mode marker line in an apical 4 chamber view in the tricuspid valve lateral annulus and shows the peak longitudinal movement of the systolic annulus which is an index for systolic RV functioning. SPAP is estimated using TR Velocity at exhaling. To evaluate the RV function the earliest peak (E) and the latest peak (A) of the diastolic velocity along with their E/A ratios and velocity diminution time (DT) are recorded which are placed in a parallel position with the RV inflow in an apical 4 chamber view and then the sample size would be positioned at the tip of the tricuspid valve leaflets. Evaluations are undertaken at the end of the exhalation and as a final result last 3 exhalation cycles will be averaged out. [Figure 1](#) indicates the trans-tricuspid flow delineated with pulse wave Doppler presenting E and A waves.

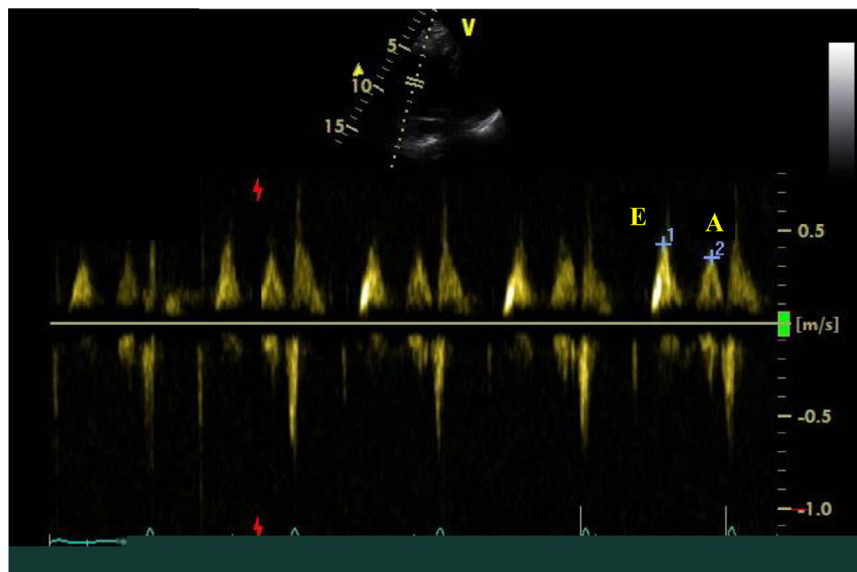


FIG 1. Trans-tricuspid flow delineated with pulse wave Doppler presenting E and A waves.

Tissue Doppler echocardiography

Tricuspid annulus lateral velocities are measured in an apical 4 chamber view using pulse-wave tissue Doppler echocardiography only when there is the maximum parallelism with the RV wall. Colorful TDI is used in addition to 2D images with depth and angle adjustment to achieve adequate frame rates. The sample size (2-4 mm) would be placed at the junction between tricuspid valve lateral leaflet and the RV wall. Furthermore, the measurements are carried out at the end of the exhalation and the decision criterion would be the average of 3 cycles. One positive systolic wave (s'), a premature negative diastolic wave (e') and a late negative diastolic wave (a') will be formed which then will be used to calculate the velocities of s' , e' , and a' waves. The velocity scale will be set to ± 20 (m/s) and the recording speed is 100-50 mm/s. [Figure 2](#) displays tricuspid annulus lateral velocity using pulse wave tissue Doppler in apical 4 chamber view.

The flowchart of the research steps is presented in [Figure 3](#)¹³:

Data collection and analysis method

After collecting the data through experiments, version 24 of the SPSS statistical software for Windows (SPSS Inc., Chicago, IL) is used for statistical analysis and the descriptive results are expressed as average (standard deviation) and percentage. Variance analysis is used to analyze the

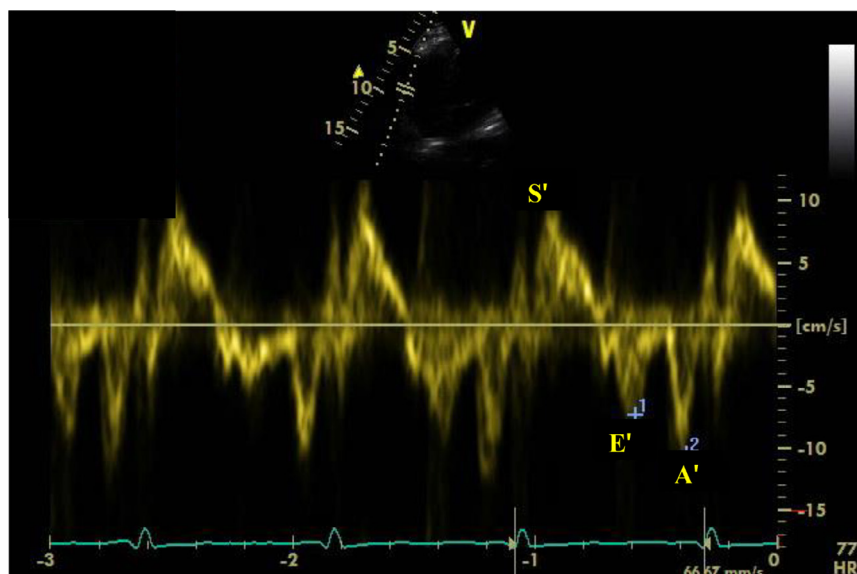


FIG 2. Tricuspid annulus lateral velocity using pulse wave tissue Doppler in apical 4 chamber view.

differences pertaining to the quantitative variables between the groups and for qualitative variables, their non-parametric equivalent or chi-square test is used. To examine the affiliation between the variables, Pearson or Spearman correlation coefficient is used with regard to the normality of the quantitative variables distribution. The Pearson value <0.05 is to be considered noticeable. Also, the available sampling method has been used to collect the samples.

Results

Tables 2-5 contain a summary of the normal distribution of various findings which can be used to facilitate comparative studies. TAPSE, PAP, RVS, and RVFAC are some of the most influential parameters concerning RV systolic function. Moreover, RVD, $DT_{\frac{E}{A}}(T)$, $\frac{E}{E'}(T)$, and $E'(T)$ are some of the most influential parameters concerning RV diastolic function. Using these parameters would lead to more accurate evaluations regarding RV diastolic function appertaining to diabetes, prediabetes, and normal cases. Table 2 represents the normal distribution of echocardiographic findings regarding systolic and diastolic functions of the RV and LV. Considering the average values of TAPSE, PAP, RVS, and RVFAC, there is no noticeable difference regarding these variables between the 3 groups. Moreover, considering the P value, a significant correlation between 3

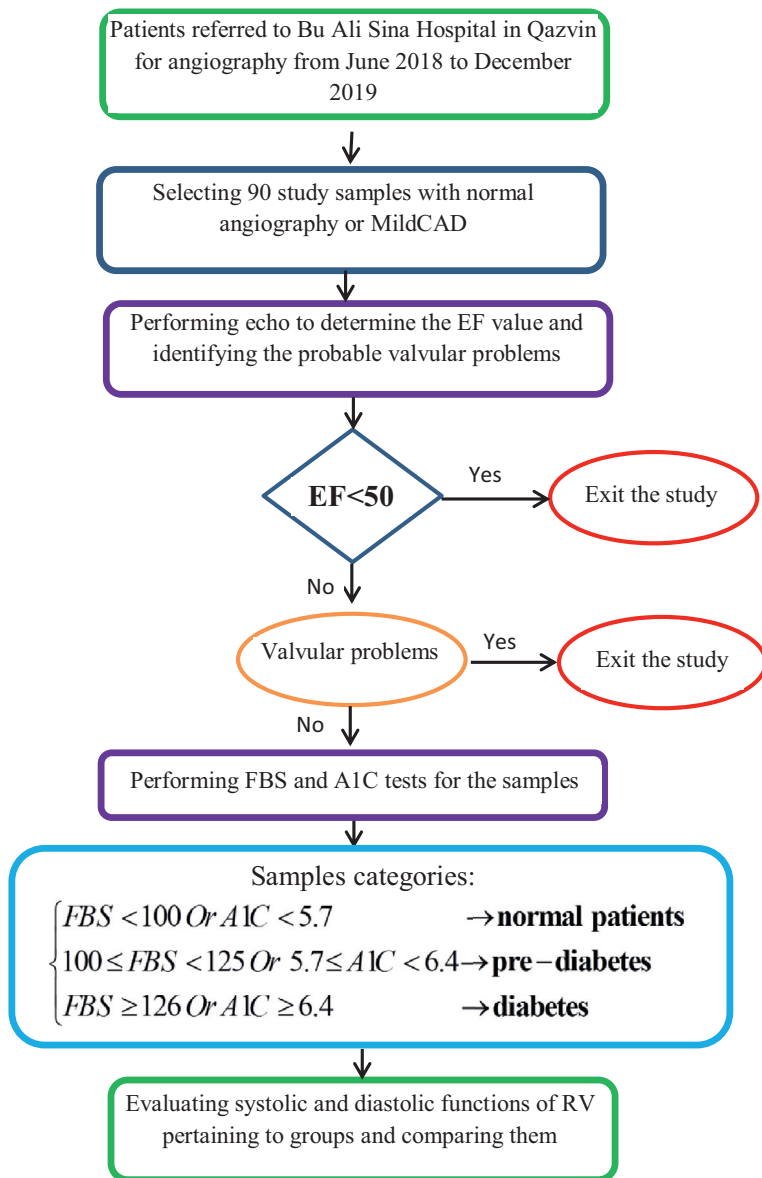


FIG 3. Research flowchart steps.

groups was observed only when taking RAVindex, TRV, HbA1C, $\frac{E}{E'}(T)$, and DT(T) into account. Table 3 represents the normal distribution of Doppler echocardiographic findings (TDI) of the RV function. According to the P value, there was a significant correlation between the groups only when taking $E'(T)$, $A'(T)$, and $\frac{E}{E'}(T)$ into account.

Table 2. normal distribution of echocardiographic findings regarding systolic and diastolic functions of the RV and LV

Variable	DM		Pre DM		Normal		P value
	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	
LVEF (%)	4.729	56.666	3.115	56.433	4.055	56.987	0.867
LVEDD (mm)	3.585	45.20	3.767	46.47	3.875	46.43	0.332
LVESD (mm)	2.646	24.63	2.970	25.07	2.667	24.70	0.808
RVD (mm)	2.764	26.50	2.690	25.93	3.922	26.83	0.543
RAV _{index}	5.164	15.832	6.778	19.622	9.576	21.462	0.014
LAV _{Index}	7.909	24.959	8.469	27.767	8.332	28.263	0.251
TAPSE (mm)	2.773	18.63	4.201	19.07	3.787	19.73	0.501
RVFAC (%)	8.979	55.000	12.094	53.951	7.697	57.144	0.438
TRG (mmHg)	4.063	20.033	4.238	21.970	3.503	19.73	0.082
TRV (m/s)	0.1574	2.173	0.2084	2.300	0.1912	2.200	0.025
PAP (mmHg)	4.118	23.73	4.226	25.00	3.687	23.17	0.200
E(T) (cm/s)	10.268	45.307	7.772	41.210	8.858	41.133	0.129
A(T) (cm/s)	8.769	45.960	13.216	40.800	9.307	40.733	0.097
E _A (T)	0.301	1.020	0.283	1.072	0.305	1.055	0.787
DT(T) (m.sec)	69.964	236.33	62.505	289.03	86.060	255.27	0.023

Table 3. Normal distribution of Doppler echocardiographic findings (TDI) of the RV function

Variable	DM		Pre DM		Normal		P value
	Standard deviation	Average	Standard deviation	average	Standard deviation	Average	
E'(T) (m/s)	1.989	8.405	2.331	8.093	2.482	9.667	0.021
A'(T) (m/s)	2.876	13.557	2.704	12.000	3.248	13.733	0.047
E _E (T)	1.362	5.572	1.470	5.365	1.437	4.522	0.013
RVS (cm/s)	1.311	11.267	2.112	10.753	1.877	11.833	0.072

Table 4. Normal distribution of the basic quantitative properties of 3 groups (diabetes, prediabetes, and normal)

Variable	DM		Pre DM		Normal		P value
	Standard deviation	Average	Standard deviation	average	Standard deviation	Average	
Age	9.684	56.87	10.204	57.87	9.822	56.07	0.780
HbA1C (%)	1.1177	6.280	0.1894	5.900	0.4041	5.153	0.0001
FBS (mg/dL)	73.788	163.27	7.432	109.27	12.493	84.27	0.000
BMI (kg/m ²)	4.592	30.078	5.342	29.127	4.599	28.041	0.272
SBP (mmHg)	13.413	131.57	16.506	119.47	16.449	126.33	0.013
DBP (mmHg)	7.215	81.13	10.450	74.20	10.753	78.57	0.022
Duration DM (year)	3.674	5.233	-	-	-	-	-

Table 5. Normal distribution of the basic qualitative properties of 3 groups (diabetes, prediabetes, and normal)

Variable	DM		Pre DM		Normal		P value
	Percentage	Number of cases	Percentage	Number of cases	Percentage	Number of cases	
Sex (male)	20.0	6	26.7	8	36.7	11	0.349
Sex (female)	80	24	73.3	22	63.3	19	0.348
HTN	73.3	22	40.0	12	50.0	15	0.029
HLP	26.7	8	10.0	3	6.7	2	0.062
FH	3.3	1	3.3	1	0	0	0.600
Smoker	3.3	1	3.3	1	3.3	1	1.000

Table 4 represents the normal distribution of the basic quantitative properties of 3 groups (diabetes, prediabetes, and normal). Considering the P value, there was a significant correlation between 3 groups only when taking HbA1C, SBP, and DBP into account.

Table 5 represents the normal distribution of the basic qualitative properties of 3 groups (diabetes, prediabetes, and normal). Considering the P value, there was a significant correlation between 3 groups only when taking HTN into account.

Figures 4-6 some of the studied variables are represented as examples. Figure 4 represents the DT (T) values for studied samples regarding 3 groups of diabetes, prediabetes, and normal cases which then are compared with standard values of DT (T) > 119 and DT (T) < 242.¹⁴ As it is obvious, a significant number of cases are over 242 which is not acceptable.

Figure 5 represents the $\frac{E}{A}(T)$ values regarding 3 groups of diabetes, prediabetes, and normal cases which then are compared with standard values of $\frac{E}{A}(T) > 0.8$ and $\frac{E}{A}(T), < 2.1$.¹⁴ As it is obvious, $\frac{E}{A}(T)$ value for a few number of cases (18 cases) is less than 0.8 while for the rest of the cases it was not higher than 2.1.

Figure 6 represents the $\frac{E}{F}(T)$ values regarding 3 groups of diabetes, prediabetes, and normal cases which then are compared with standard value of $\frac{E}{F}(T) < 6$.¹⁴ As it is obvious, 6, 6, and 11 number of diabetic, prediabetic, and normal cases, respectively, contain $\frac{E}{F}(T)$ values higher than 6.

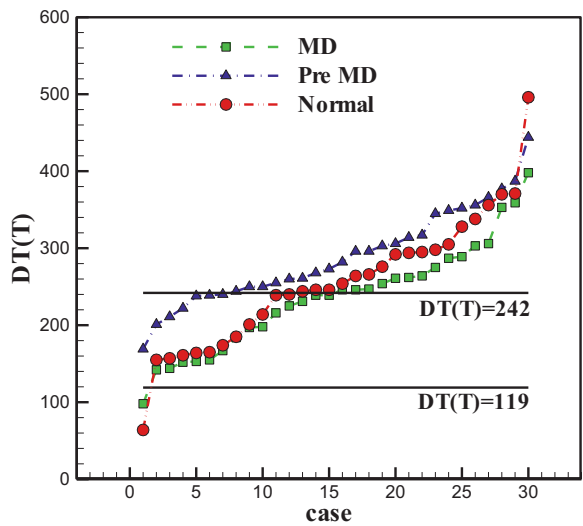


FIG 4. comparing DT (T) values with the standard values regarding the cases in the 3 groups.

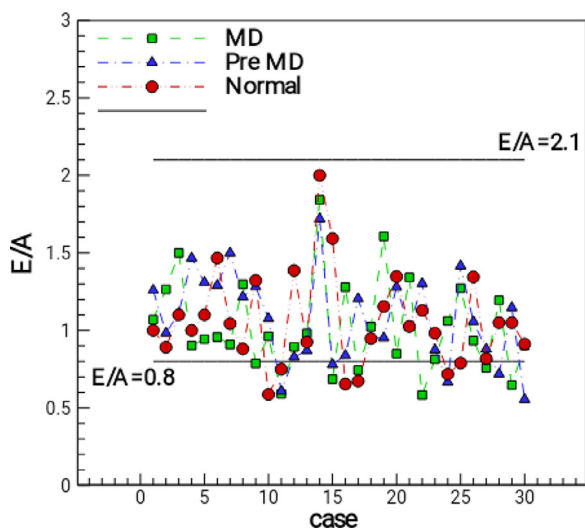


FIG 5. Comparing $\frac{E}{A}(T)$ values with the standard values regarding the cases in the 3 groups.

Discussion

In the present study, among the studied parameters, $\frac{E}{E'}$ and the RA volume between 3 groups (diabetes, prediabetes, and normal cases) had significant differences. There was a noticeable difference between diabetic

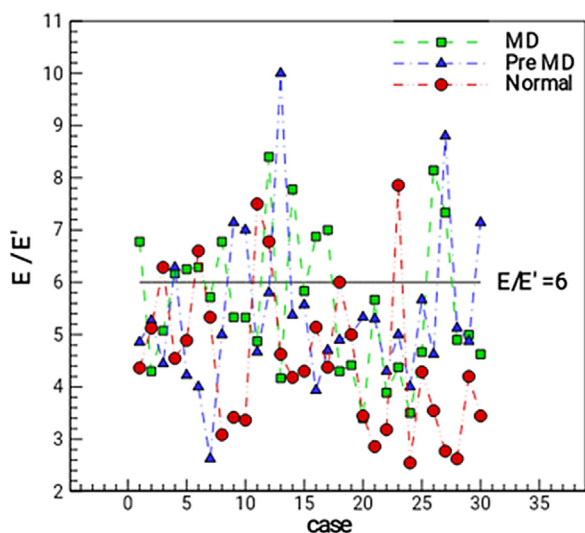


FIG 6. comparing $E/E'(T)$ values regarding three groups of diabetes, prediabetes and normal cases with the standard value.

and normal cases, also between prediabetic and normal cases regarding $\frac{E}{A}$ parameter. The ratio of $\frac{E}{A}$ and the volume or the area of RA has been promising which was issued by most recent studies. There was a noticeable difference regarding RAVindex between diabetic and normal cases which were not issued in any recent studies. Based on 2010 echocardiographic guidelines,¹⁵ in order to evaluate RV diastolic function, the pressure of the right atrium estimated by IVC and its collapse with breathing must be considered. This study employed the same method. Moreover, for all the patients IVC size was estimated normal and less than 2.1 cm with normal collapsibility more than 50% while breathing. There was a noticeable difference regarding E and A between cases with prediabetes and normal cases, while there was no sign of age, sex, and BMI alternation among the groups. Some studies focused on the connection between the RV function and diabetes and prediabetes group of patients. Nevertheless, previous studies had attended to discuss diabetes in normal cases and different ways of evaluating RV. A study which was carried out in 2004, with 27 normotensive patients (DMN group), 36 patients with high blood pressure (DMHT group), and 33 healthy patients in the control group, all suffering from diabetes, led to the conclusion that RV diastolic dysfunction in diabetic patients must be considered when prescribing medication so as to prevent it.² In another study carried out in 2006, the role of echocardiography and other complementary technologies evaluating RV function were investigated. Results have accentuated the precision of MRI in the evaluation of RV function. However, its availability is restricted and it takes a long time to analyze its outcomes. Finally, RV function could be evaluated with pressure–volume loop analysis.⁶ Right ventricle Subclinical and obvious dysfunctions in patients with DM2 were investigated in a study which was carried out by Parsaee et al. in 2012.¹ Results have indicated that RV function could be affected by DM2 in the absence of coronary artery disease, diastolic dysfunction, and pulmonary hypertension.¹ Kowsari et al. have indicated that right ventricular systolic and diastolic functions were impaired in diabetic and prediabetic patients without coronary artery disease.³ The difference between their study and the present study is in the echocardiographic procedure which is Speckle Tracking. Coronary artery disease has also been investigated in many studies by methods other than angiography. In the studies carried out by Parsaee et al.,¹ Kosmala et al.,² and Abdelaziz et al.¹² some methods including treadmill exercise testing methods, echocardiographic stress, electrocardiogram, and echocardiography were employed which were different from angiography regarding sensitivity levels. Thus, the present study is incomparable with other studies due to

the different procedure of performing echocardiography and the exiting method of coronary artery disease from the study. Moreover, this study has presented that the E parameter of the tricuspid was not significantly different between the groups which was like the propositions made by Parsaee and Kowsari.^{1,3} However, the A parameter of the tricuspid seems to have no significant difference between the groups which was unlike the propositions made by Parsaee and Kowsari.^{1,3} In this study, the $\frac{E}{A}$ ratio between the 3 groups was not significantly different, which was also mentioned by kosmala et al.² This finding was different from some other studies.^{1,3,12} Based on the echocardiographic guidelines published in 2010, there is a robust connection between $\frac{E}{A}$ and age so that the ratio of $\frac{E}{A}$ would decrease by 0.1 with A decade increase in the age. Also, inhaling would increase E which will lead to the accretion of the $\frac{E}{A}$ ratio.¹⁵ Tachycardia will lead to an increase in E, although it would cause a relatively larger increase in A, which generally would reduce the overall $\frac{E}{A}$ ratio. Hemodynamic effects must be considered when evaluating the Doppler parameters in a patient. That is why RV is so sensitive about afterload (wall stress) and the preload.¹⁵ Any reduction in the preload would decrease E more than A which would lead to the reduction in the $\frac{E}{A}$ ratio. Based on the mentioned contents, this finding can be due to the effects of hemodynamics on this parameter, especially because studied patients underwent hydration from 12 hours before angiography to 12 hours after angiography to reduce the effects of contrast agent on their kidney which could be effective on the $\frac{E}{A}$ parameter with regard to the changes in the preload. In this study E' and A' parameters were meaningful between normal and pre-diabetic cases which were like the propositions made by previous researches.^{1,3,12} Tissue Doppler parameters have less dependency on the load because any reduction in the preload would reduce E' and A' equally which would cause the $\frac{E'}{A'}$ ratio not to change and not affected by hemodynamic. There was a significant difference regarding $\frac{E}{E'}$ parameter between normal and prediabetic cases and also between normal and diabetic cases (which was like the outcomes presented by.^{1,3}) Based on the echocardiographic guidelines published in 2010, both the tricuspid $\frac{E}{E'}$ ratio and the right atrium volume have a promising correlation with the hemodynamic parameters. RV diastolic dysfunction is an early symptom which is subclinically easy to diagnose in the RV function. Also, most studies have presented that RV diastolic dysfunction usually occurs both before the onset of its systolic dysfunction and the dilatation or hypertrophy of the RV. So considering $\frac{E}{E'}$ parameter which becomes meaningful between normal and diabetic cases and also between normal and prediabetic cases, it could be indicated that prediabetes has affected

the RV diastolic function (as it was effective in the LV diastolic and systolic functions.) According to the mentioned contents, prediabetes like diabetes can cause RV diastolic dysfunction in the future and can be considered as an onset of the RV diastolic dysfunction. Diastolic dysfunction can lead to systolic dysfunction in the future. In previous studies,^{11,16,17} diabetes was effective in the systolic and diastolic dysfunctions of the left ventricle,¹⁵ but in this study it has been presented that diabetes is effective in the RV diastolic parameters including $\frac{E}{E'}$ and RAVindex such that it could be an onset of RV diastolic dysfunction in diabetic patients, leading to an obvious diastolic dysfunction through the time. It may also lead to systolic dysfunctions. Based on the parameters evaluated in the echo, the RV diastolic function is divided into 4 groups (Table 6)¹⁵:

In the present study none of the patients were placed in the Restrictive group and there was not any significant difference between the 3 remaining groups. None of the previous studies had performed a classification like above for the groups of diabetes, prediabetes, and normal cases. Figure 7 presents the frequency of the cases in each of 4 groups.

No significant differences were found in the right ventricular diastolic function groups in the normal, diabetic, and prediabetic cases, also diabetic and prediabetic groups only affect RAV index and $\frac{E}{E'}$ parameters, thus based on both facts, it can be concluded that prediabetes like diabetes is very effective on the onset of diastolic dysfunction. Increasing the number of samples over a longer period could lead to better results obtained from the impact of prediabetes on the RV systolic and diastolic dysfunctions. In this study right ventricular systolic dysfunction was evaluated with regard to TAPSE, RVS, and RVFAC parameters. According to the recorded cases, there was no significant difference in RV systolic function between normal and diabetic and also between normal and prediabetic cases, whilst the study carried out by Kosari would indicate the opposite outcome. Therefore, it can be concluded that the use of new echocardiographic methods such as speckle tracking can be a great help to better identify the RV systolic dysfunction in patients with prediabetes and diabetes. On the other hand, based on the fact that diastolic dysfunction is a background for the occurrence of systolic dysfunction, it can be concluded that more information would have been available provided that there was longer study time.

Table 6. Four groups of RV diastolic function

1 - Normal Function group	$\frac{E}{E'}(T) < 6$, $0.8 < \frac{E}{A} < 2.1$
2 - Impaired Relaxation group	$0.8 > \frac{E}{A}$
3 - Pseudonormalization group	$\frac{E}{E'}(T) > 6$, $0.8 < \frac{E}{A} < 2.1$
4 - Restrictive group	$DT > 120$, $\frac{E}{A} > 2.1$

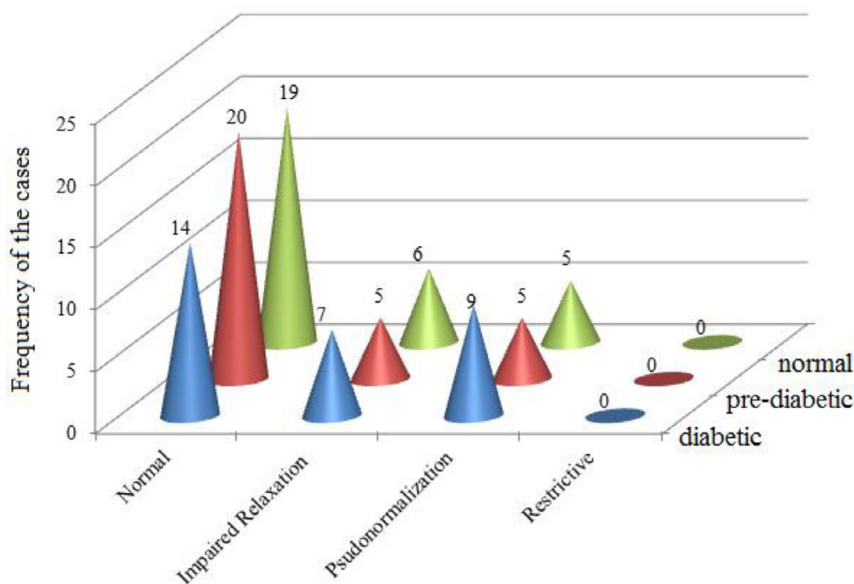


FIG 7. Frequency of the cases in the 4 groups: Normal Function, Impaired Relaxation, Pseudonormalization, and Restrictive.

In this study the mean duration of diabetes was 5 years, however the effect of duration on the RV function has not been evaluated and the patients have not been followed for a longer period so as to obtain RV systolic dysfunction. Evaluations present that diabetes and prediabetes in comparison with the normal group affect the diastolic parameters, therefore prediabetes like diabetes can be a factor in RV diastolic dysfunction.

Restrictions and solutions

One of the possible restrictions for this research is finding compatible and adequate number of patients for the study. It is mandatory to select the diabetic and prediabetic patients with no clinical signs presenting systolic and diastolic heart failure. To solve this issue it is helpful to extend the period of the procedure so as to obtain sufficient samples. Another restriction is the inability to assess the RV function based on 3D and employing Speckle-Tracking methods.

Conclusion

Prediabetes, like diabetes, can be a factor in right ventricular diastolic dysfunction and can lead to systolic dysfunction in the future.

Appendix 1

Appendix 1. Research variables including dependent and independent variables and their definition

Variables	Independent	dependent	Quantitative Continuous variables	Discrete variables	Qualitative Nominal variables	Ordinal variables	Scientific definition
Sex (male, female)	Contextual				✓		Based on patients phenotype
Age			✓				the length of time that a person has lived
BMI (kg/m ²)		✓	✓				Dividing height in meters by body weight in kilograms squared
Hemoglobin % (A1C (HbA1C	✓		✓				Glucose dependent hemoglobin showing average blood sugar over the past three months
LVEF %		✓	✓				Percentage of LV stroke volume
LV end- diastolic diameter (cm)		✓	✓				LV end- diastolic diameter
LV end- systolic diameter (cm)		✓	✓				LV end- systolic diameter
Diameter of the middle of the RV at the end of the RV diastole(cm)		✓	✓				diameter of the right ventricle at heart relaxation half

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Appendix 1. *(continued)*

Variables	Independent	dependent	Quantitative Continuous variables	Discrete variables	Qualitative Nominal variables	Ordinal variables	Scientific definition
TAPSE (cm)		✓	✓				Tricuspid lateral annulus movement
RVS (m/sec)		✓	✓				Systolic velocity of the RV myocardial tissue
E(T) (m/sec) tricuspid		✓	✓				blood flow rate through the tricuspid valve in the ventricular diastole-early
tricuspid A(T) (m/sec)		✓	✓				The velocity of the blood flow through tricuspid valve in ventricular diastole-late
tricuspid E'(T) (m/sec)		✓	✓				The velocity of RV myocardial tissue in the ventricular diastole-early
tricuspid A'(T) (m/sec)		✓	✓				The velocity of RV myocardial tissue in ventricular diastole-late
PAP (mmHg)		✓	✓				pulmonary artery systolic pressure

(continued on next page)

Appendix 1. *(continued)*

Variables	Independent	dependent	Quantitative		Qualitative		Scientific definition
			Continuous variables	Discrete variables	Nominal variables	Ordinal variables	
Systolic blood pressure (mmHg)		✓	✓				Systolic blood pressure
Diastolic blood pressure (mmHg)		✓	✓				Diastolic blood pressure
RVFAC		✓	✓				right ventricular fractional area changes
Diabetes duration (years)			✓				Duration of diabetes
Deceleration time (DT)(msec) tricuspid			✓				Time period needed for the right atrium and right ventricle to equalize during diastole.

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