

Role of Strain in the Early Diagnosis of Diabetic Cardiomyopathy

Papel do Strain no Diagnóstico Precoce da Cardiomiopatia Diabética

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Abstract

Background: Advanced echocardiography using two- and three-dimensional myocardial strain proposes to identify subclinical systolic dysfunction in different clinical conditions. Strain assessment plays an important role in the early diagnosis of diabetic cardiomyopathy in diabetes mellitus (DM). However, the findings of published articles are heterogeneous. Here we conducted a systematic review to analyze the current role of strain assessment in patients with DM. **Methods:** This systematic review of five databases identified 19 studies that used two-dimensional strain and 8 studies that used three-dimensional strain. **Results:** The studies of two-dimensional strain included 1,774 DM patients (mean age, 57.1 years; median age, 55 years; 47.5% women), while those of three-dimensional strain included 488 DM patients (mean age, 55.7 years; median age, 63 years; 51% women). Global longitudinal strain was the myocardial deformation marker that differed most frequently between the DM and control groups. **Conclusion:** Myocardial strain imaging by two- and three-dimensional speckle tracking echocardiography allows the identification of subclinical systolic dysfunction in DM patients, and differences become more marked when associated with risk factors and ventricular remodeling.

Introduction

Diabetes mellitus (DM), among the most prevalent diseases in the modern world, is a risk factor for heart failure that increases mortality, mainly from cardiovascular causes.¹ Cardiovascular complications are the leading cause of death in DM patients,^{2,3} with diabetic cardiomyopathy being characterized by structural and functional cardiac changes without other known factors for the development of myocardial dysfunction, such as coronary heart disease, arterial hypertension, or significant valvular diseases.⁴ Cardiac remodeling in diabetes results from cardiovascular autonomic neuropathy, renin-angiotensin-aldosterone system activation, interstitial myocardial fibrosis, microangiopathy, inflammatory cytokines, and metabolic changes such as hyperglycemia,^{5,6} and its detection requires sensitive diagnostic methods.⁷

Keywords

Diabetes Mellitus, Echocardiography, Ventricular Function.

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The early diagnosis of diabetic cardiomyopathy is clinically relevant, as early lesions may be reversible^{8,9} and therapy can be implemented to prevent cardiovascular disease progression. However, it remains little recognized by clinicians¹ due to the conflicting results of different populations¹⁰ and the need for more sensitive and recently developed diagnostic tools. Left ventricular (LV) diastolic dysfunction was considered the initial sign on Doppler echocardiography.^{11,12} Improved imaging methods such as speckle tracking echocardiography enabled the earlier detection of systolic myocardial dysfunction prior to diastolic dysfunction in asymptomatic subjects.^{13,14}

The incorporation of new techniques such as myocardial strain on echocardiography increased the diagnostic sensitivity of speckle tracking, especially of subclinical myocardial dysfunction, and was validated by magnetic resonance imaging with myocardial tagging and sonomicrometry.¹⁵ The most commonly used parameter is global longitudinal strain (GLS), the mean strain of myocardial segments in the longitudinal direction, a technique that is more reproducible and can identify subclinical LV dysfunction, a better risk predictor than LV ejection fraction (LVEF).¹⁶ Another recent concept is multilayer analysis, which introduced an anatomical aspect into myocardial deformation assessment in which the three LV myocardial layers (endocardium, mesocardium, and epicardium) contribute to more effective contractions in different directions.¹⁷ In contrast, three-dimensional myocardial strain enables a more objective assessment of LV systolic dysfunction without requiring calculations to predict ventricular geometric shape, with the additional benefit of being more reproducible than two-dimensional strain for avoiding marker loss outside the analyzed plane despite requiring high-quality images.¹⁸

Several studies aiming to assess cardiac function in DM patients using two- and three-dimensional strain reported worse myocardial deformation rates compared to controls. However, some such studies were small, heterogeneous, and presented several confounding factors. Thus, a review of the current evidence is necessary to understand knowledge gaps and revisit important issues. The present study aimed to identify whether advanced two- or three-dimensional speckle tracking echocardiography could demonstrate early cardiac lesions secondary to DM and define its current role for assessing DM patients. Thus, here we conducted a systematic review of the use of ventricular strain echocardiography in DM.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched the MEDLINE,



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EMBASE, SCOPUS, and WEB OF SCIENCE databases using the descriptors “diabetic cardiomyopathy” or “speckle tracking” or “myocardial strain/dysfunction” or “ventricular function/dysfunction,” “deformation imaging/analysis,” or “cardiac mechanics/function” and “diabetes” or “diabetic.” The search was limited to articles in humans; published in English, French, Spanish, or Portuguese; and published through January 31, 2022. The selection criteria for the articles were age older than 15 years, inclusion of control group without DM, no established heart disease, and speckle tracking description of the GLS value. Database references were gathered in the Mendeley® application and duplicates were removed. Two researchers (TRWS and RLS) searched the articles separately and agreed on the eligibility of the final selections. First, a broad search identified articles related to the topic by title and abstract screening. The exclusion criteria were a different target population or no control group; the presence of coronary artery disease or other structural disease; use of another imaging method for measuring myocardial deformation such as magnetic resonance imaging or tissue Doppler; no description of the GLS value; and case report, conference presentation, review, and editorial articles.

The articles were subsequently subjected to full-text review to identify those that presented the necessary data and fit the previous requirements. In studies with multiple subgroups of patients or controls, the lowest-risk subgroup was selected (Table 1). The studies were allocated to two- or three-dimensional speckle tracking groups for evaluation. The information extracted from the articles included author, year of publication, brand of equipment, study design, number of cases in the sample, age,

sex, body mass index (BMI), blood pressure levels or diagnosis of hypertension, glycated hemoglobin (HbA1c) value, LVEF, GLS, global radial strain (GRS), and global circumferential strain (GCS) (Table 2). Studies of three-dimensional strain also included global strain area (GSA) (Tables 3 and 4).

Results

We identified 819 references in the electronic databases in the previous five years, excluding 123 duplicates. Of the remaining 696 studies, we obtained 75 full articles for analysis after title and abstract screenings. Another 49 studies were excluded (Figure 1). The review included 26 articles for qualitative analysis, which were classified into two main categories: two-dimensional strain ($n = 19$; Table 1) and three-dimensional strain ($n = 8$; Table 2). Only studies with a control group were included. The articles were mostly published in English, followed by French and Portuguese. Three^{18–20} were prospective studies and the others were case-control studies.

The studies using two-dimensional strain resulted in a sample of 1,774 DM patients (mean age, 57.1 years; median age, 55 years; 47.5% women). A GE Vivid E9 ultrasound machine was most often used in these studies. The studies using three-dimensional strain resulted in a sample of 488 DM patients (mean age, 55.7 years; median age, 63 years; 51% women). All studies used the GE Vivid E9 device except for two that used an Philips iE33 ultrasound system.

Of the 19 analyzed studies, less than half excluded hypertensive patients from the DM group,^{10,18,21–24} most involved type 2 DM (DM2) patients, and only three

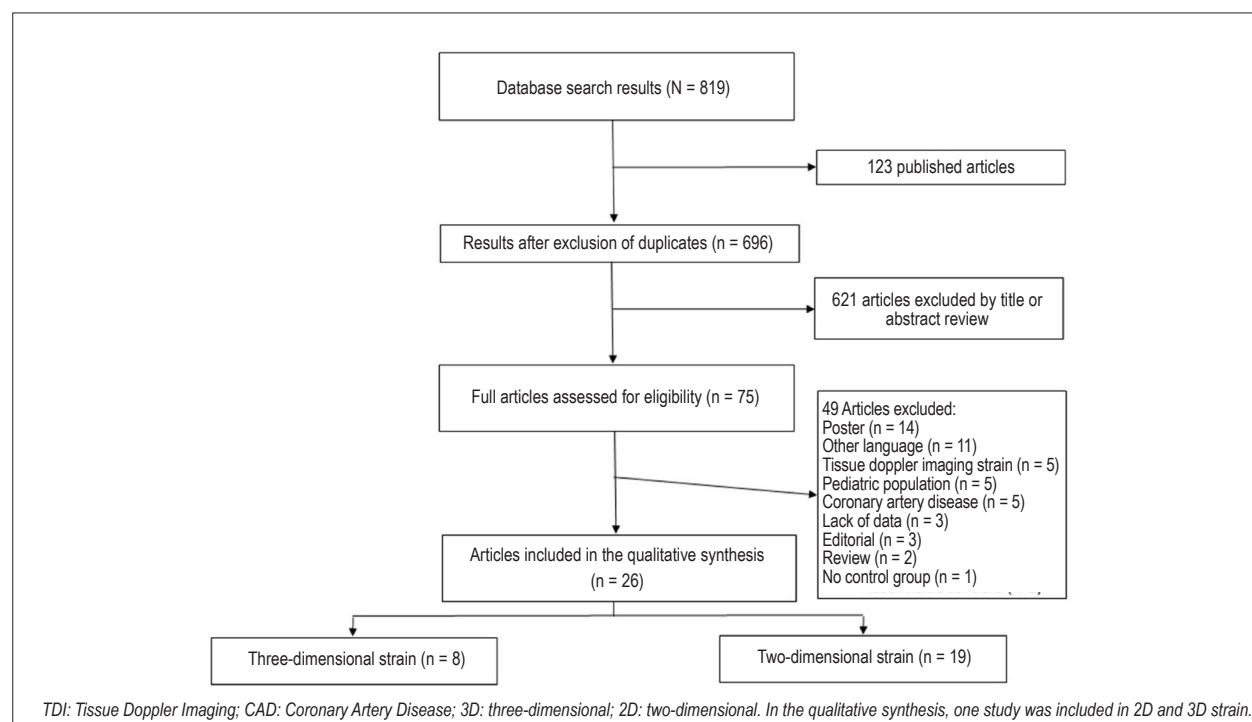


Figure 1 – Flowchart of search and selection of studies evaluating diabetic cardiomyopathy through bidimensional and three-dimensional strain.

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Table 1 – Clinical and demographic data of studies that evaluated diabetic cardiomyopathy using two-dimensional speckle tracking strain.

Author	N	Control	DM type	HbA1c	Control	Age, years (DM)	Age, years (Control)	Women, % (DM)	Women, % (Control)	BMI (DM)	BMI (Control)	SBP (DM)	SBP (Control)
Yamauchi et al. ⁷	192	81	DM2	8.5	Healthy	61	57	48	54	25	22	131	123
Weber et al. ¹⁰	40	40	DM1	8.0	Healthy	33	33	55	55	25	25	110	102
Tadic et al. ¹⁷	48	44	DM2	7.3	Healthy	55	52	48	50	27	26	131	127
Ringle et al. ¹⁸	66	26	DM1	7.7	Healthy	38	35	71	69	24	23	122	121
Ng et al. ²⁰	397	104	DM2	7.3	Healthy	58	50	46	43.3	29	-	141	123
Yang et al. ²¹	47	27	DM2	6.1	Healthy	51	50	32	33	23	23	-	-
Wang et al. ²²	48	50	DM2	10.1	Healthy	54	50	52	50	23	23	127	122
Vukomanovic et al. ²³	50	40	DM2	7.3	Healthy	55	50	48	45	29	24	131	129
Vukomanovic et al. ²⁴	70	80	DM2	7.5	Healthy	52	49	44	43	28	26	126	124
Soufi Taleb Bendiab et al. ²⁵	93	107	DM2 + SAH	-	SAH	61	62	63	53	30	29	158	142
Tadic et al. ²⁶	50	55	DM2 + SAH	7.0	Healthy	56	51	48	47	27	26	145	128
Todo et al. ²⁹	177	79	DM2	8.8	Healthy	61	58	47	57	25	22	131	125
Van Ryckeghem et al. ³⁰	36	23	DM2	6.9	Healthy	62	57	14	48	28	26	149	140
Roberts et al. ³¹	34	17	DM1/DM2	7.8	Healthy	42	41	29	35	27	25	125	121
Li et al. ³²	101	60	DM2	7.6	Healthy	52	54	53	53.3	24	23	123	123
Philouze et al. ³³	44	35	DM2	7.2	Healthy	56	52	41	51	27	24	126	123
Mochizuki et al. ³⁴	103	82	DM	8.6	Healthy	56	55	63	60	23	22	121	117
Jørgensen et al. ³⁶	57	80	DM2	6.1	Healthy	65	65	44	35	26	24	126	123
Stevanovic et al. ³⁹	121	40	DM2	8.2	Healthy	55	53	19	29	28	27	125	122

BMI, body mass index; DM, diabetes mellitus; DM1, type 1 DM; DM2, type 2 DM; HbA1c, glycated hemoglobin; N, number of patients with diabetes; SAH, systemic arterial hypertension; SBP, systolic blood pressure.

Table 2 – Clinical and demographic data from studies that evaluated diabetic cardiomyopathy by three-dimensional speckle tracking strain.

Author	N	Control	DM	HbA1c (%)	Control	Age, years (DM)	Age, years (Control)	Women, % (DM)	Women, % (Control)	BMI (DM)	BMI (Control)	SBP (DM)	SBP (Control)
Wang et al. ⁴¹	40	40	DM2	-	Healthy	66±7	68±8	50	50	24.6±2	23.5±3	128±7	123±9
Wang et al. ⁴⁴	40	40	DM2	6.6±0.6	Healthy	68±8	68±7	50	55	24.9±3	24.4±3	128±9	126±10
Wang et al. ⁴²	38	45	DM2	7.0±0.6	Healthy	61±8	62±7	45	50	24.5±3	24.7±2	127±10	126±7
Luo et al. ⁴³	38	35	DM2	10.4±2.6	Healthy	59±7	58±76	32	32	24.9±2	24.3±2	128±9	107±6
Wang et al. ⁴⁷	40	40	DM2	-	Healthy	66±8	67±8	50	50	24.7±2	25.0±3	128±6	126±7
Wang et al. ⁴⁵	34	40	DM2	-	Healthy	65±7	64±8	50	50	24.0±2	24.5±3	125±8	125±7
Chen et al. ⁴⁶	192	81	DM2	6.1±0.4	Healthy	52±8	50±6	50	49	25.1±2	24.3±2	122±11	119±10
Ringle et al. ¹⁸	66	26	DM1	7.7±1.3	Healthy	37±9	35±7	71	69	24.0±3	23.0±3	121±12	122±9

BMI, body mass index; DM, diabetes mellitus; DM1, type 1 diabetes mellitus; DM2, type 2 diabetes mellitus; HbA1c, glycated hemoglobin; N, number of patients with diabetes; SAH, systemic arterial hypertension; SBP, systolic blood pressure.

analyzed type 1 DM (DM1) cases. In one study,²⁵ the control group consisted of hypertensive patients without diabetes. Some studies evaluated DM patients with versus without hypertension, with versus without associated microvascular complications, or even subgroups in which uncontrolled risk factors were quantified. Another study presented a DM population prior to hospitalization with changed glycemic levels (HbA1c > 10%).²²

Different assessments were studied in this population, such as myocardial work index,^{26,27} myocardial torsion by speckle tracking,²⁸ right ventricular systolic dysfunction by speckle tracking,²⁹ cardiac function during physical activity and exercise

capacity,^{24,30,31} dispersion value between systolic strain peaks,³² heart rate effect,⁷ cardiac function during dobutamine stress echocardiography,³³ heart rate variability,²³ diastolic dysfunction progression,³⁴ and multilayer speckle tracking analysis.^{17,23}

The echocardiographic characteristics of interest here are shown in Tables 3 and 4.

Discussion

The use of new imaging techniques for diagnosing diabetic cardiomyopathy has increased our knowledge through the identification of earlier lesions. Although LV diastolic

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Table 3 – Systolic cardiac function evaluated by two-dimensional speckle tracking strain.

Author	Equipment	LVEF % (DM)	LVEF % (Control)	GLS (DM)	GLS (Control)	p (DM × Control)	GCS (DM)	GCS (Control)	p	GRS (DM)	GRS (Control)	p
Yamauchi et al. ⁷	GE Vivid E9	66±5	66±5	-17.6±3	-20.3±2	<0.0001	-	-	-	-	-	-
Weber et al. ¹⁰	GE S6	72±5	71±5	-21.7±2	-21.0±2	0.21	-	-	-	-	-	-
Tadic et al. ¹⁷	GE Vivid 7	64±4	65±4	-18.8±2	-20.8±2	<0.001	-19.2±2	-21.4±3	<0.001	41.6±8	43.2±8.3	0.001
Ringle et al. ¹⁸	Philips - IE33	60±8	61±3	-18.9±2	-20.5±2	0.0002	-25.4±3	-26.1±3	0.39	36.3±9	37.6±7	0.054
Ng et al. ²⁰	GE Vivid 7/E9	60±5	58±4	-17.3±2	-20.5±2	-	-	-	-	-	-	-
Yang et al. ²¹	GE Vivid E9	58±3	59±2	-17.2±2	-20.2±3	0.04	-20.9±4	-22.1±3	0.06	37.4±12.6	40.3±11.8	0.45
Wang et al. ²²	GE Vivid E9	66±4	62±5	-19.6±2	-22.5±3	<0.0001	-	-	-	-	-	-
Vukomanovic et al. ²³	GE Vivid 7	64±5	63±4	-18.5±2	-21.1±3	<0.001	-18.9±2	-21.9±3	<0.001	37.2±8.1	42.1±8.6	0.007
Vukomanovic et al. ²⁴	GE Vivid 7	64±4	64±3	-18.4±2	-21.6±3	<0.001	-19.5±2.6	-22.0±3	<0.001	37.9±9.4	40.6±10.1	0.094
Soufi Taleb Bendiab et al. ²⁵	GE S6	61±6	62±6	-16.4±3	-17.8±3	<0.0001	-	-	-	-	-	-
Todo et al. ²⁹	GE Vivid E9	66±5	66±5	-17.6±3	-20.5±2	<0.0001	-	-	-	-	-	-
Van Ryckeghem et al. ³⁰	GE Vivid E9	66±8	66±9	-17.0±3	-19.8±2	<0.001	-	-	-	-	-	-
Tadic et al. ²⁶	GE Vivid 7	62±3	63±3	-17.7±2	-21.3±3	<0.001	-18.3±2.3	-22.1±3	<0.001	38.5±9.3	41.8±10.1	0.247
Roberts et al. ³¹	GE Vivid E9	60±4	60±5	-18.6±2	-19.7±2	0.09	-	-	-	-	-	-
Li et al. ³²	GE Vivid E9	64±4	65±4	-19.4±3	-21.22±3	<0.001	-	-	-	-	-	-
Philouze et al. ³³	GE Vivid E95	64±8	64±7	-20.8±2	-20.2±3	NS	-	-	-	-	-	-
Mochizuki et al. ³⁴	GE Vivid E9	67±4	66±5	-20.5±2	-20.5±2	<0.05	-	-	-	-	-	-
Jørgensen et al. ³⁶	GE Vivid E9	65	63	-15.3±2	-15.9±2	0.13	-18.7±5	-18.1±4	0.49	-	-	-
Stevanovic et al. ³⁹	GE Vivid 7	62±4	62±5	-17.5±2	-24.4±2	<0.001	-	-	-	-	-	-

DM, diabetes mellitus; GCS, global circumferential strain; GLS, global longitudinal strain; GRS, global radial strain; LVEF, left ventricular ejection fraction.

Table 4 – Systolic cardiac function evaluated by three-dimensional speckle tracking strain.

Author	Equipment	LVEF % (DM)	LVEF % (Control)	GLS (DM)	GLS (Control)	p (DM × Control)	GCS (DM)	GCS (Control)	p	GRS (DM)	GRS (Control)	p	GSA (DM)	GSA (Control)	p
Wang et al. ⁴¹	GE Vivid E9	61±6	61±5	-17.1±2.6	-18.4±3.0	<0.05	-17.8±2.7	-18.8±3.0	>0.05	49.0±8.9	51.0±9.0	>0.05	-29.1±4.0	-30.2±3.6	>0.05
Wang et al. ⁴⁴	GE Vivid E9	60±7	61±7	-17.0±2.6	-18.9±2.5	<0.01	-17.4±2.5	-18.7±2.9	<0.05	47.7±8.5	51.5±8.9	>0.05	-30.1±3.6	-30.6±4.0	>0.05
Wang et al. ⁴²	GE Vivid E9	58±6	58±6	-17.3±2.4	-19.9±2.6	<0.001	-17.2±2.7	-18.9±0.31	<0.05	47.7±7.9	53.2±10.0	<0.01	-30.2±3.4	-31.0±4.7	>0.05
Luo et al. ⁴³	IE33	68±2	66±3	-17.2±3.0	-20.8±2.8	<0.01	-22.9±3.0	-25.9±3.4	<0.05	-	-	-	-	-	-
Wang et al. ⁴⁷	GE Vivid E9	60±7	60±6	-16.9±2.9	-18.2±2.3	<0.05	-17.6±3.5	-18.1±2.2	>0.05	46.9±9.8	48.5±6.5	>0.05	-29.6±5.5	-30.0±3.2	>0.05
Wang et al. ⁴⁵	GE Vivid E9	60±7	60±7	-17.6±2.1	-18.8±2.7	<0.05	-17.9±2.7	-18.1±3.0	>0.05	49.1±7.9	50.2±9.3	>0.05	-30.7±3.2	-31.2±4.3	>0.05
Chen et al. ⁴⁶	GE Vivid E9	65±8	67±4	-19.3±3.9	-20.1±3.2	>0.05	-19.7±4.9	-19.3±6.3	>0.05	45.4±7.0	45.7±7.5	>0.05	-30.3±5.5	-33.0±6.6	>0.05
Ringle et al. ¹⁸	IE33	60±8	61±3	-17.5±2.0	-19.0±2.0	>0.05	-	-	-	-	-	-	-	-	-

DM, diabetes mellitus; GSA, global strain area; GCS, global circumferential strain; GLS, global longitudinal strain; GRS, global radial strain; LVEF, left ventricular ejection fraction.

dysfunction has traditionally been believed to precede systolic dysfunction, subclinical systolic dysfunction detected by GLS may be the first sign of diabetic cardiomyopathy.¹⁴

GLS is the myocardial deformation marker that most frequently differs between DM and control groups. Some studies established a specific GLS value for the diagnosis of subclinical ventricular dysfunction based on the statistical analysis of the values obtained in the sample. In these studies, the incidence of subclinical ventricular dysfunction was 40–45% in the diabetic population.^{20,35} The fewer studies that used other parameters, such as GCS^{17,23,24,26} or GRS²³, identified myocardial function differences using two-dimensional strain. These differences were not detected using LVEF. Tadic et al.¹⁷

showed a GRS difference only in a DM and hypertension group. Likewise, Jørgensen et al. reported a GCS difference among subgroups of DM patients with more risk factors.³⁶

Multilayer speckle tracking analysis can show differences between DM and control groups.^{17,23,24,37} Despite being a new technology that requires further validation, this tool locates myocardial lesions and detects possible changes early.³⁸ Tadic et al. studied healthy controls, DM2 patients, and/or patients with systemic arterial hypertension (SAH) and reported multidirectional strain change; hypertension as a factor for LV mechanical deterioration; involvement of all myocardial layers due to DM and SAH; and a correlation between glycemic control (fasting glucose and HbA1c), GLS, and LV layer-specific strain.

In the previous five years, only three studies followed the participants. Studies including DM2 patients had larger sample sizes. Stevanovic et al. and Ng et al. followed up more than 100 subjects and demonstrated that GLS was a strong predictor of cardiovascular events in multivariate analysis.^{20,39} Ringle et al. evaluated a group of DM1 patients a mean 37 years of age without cardiovascular risk factors who presented an absolute strain value lower than the control population and a significantly decreased absolute strain value during follow-up; however, no events were observed in the follow-up period. This study showed no correlation between GLS and metabolic status in terms of glycemic control, diabetes duration, or coexisting microvascular complications.¹⁸

Of the 19 articles analyzed, only four^{10,31,33,36} identified no GLS differences and demonstrated subclinical myocardial function reduction attributable to diabetes. These studies analyzed DM1 and/or DM2 patients but with clearly fewer risk factors, such as SAH, overweight and obesity, dyslipidemia, renal function measured by creatinine clearance, lower glycemic levels (HbA1c < 8%), which, when present, were controlled in addition to showing no or smaller differences in LV structural parameters such as ventricular mass index and relative wall thickness. This information is useful for predicting a better prognosis for these patients and encouraging good control of comorbidities.

Several authors studied possible contributors to worsen systolic function in patients with diabetes. Yang et al. studied the relationship between microvascular complications and LV systolic function and reported decreased GLS in the group without complications that was even greater in the group with microvascular complications.²¹ Soufi et al. studied hypertensive patients with and without diabetes and showed that the association of SAH and DM further decreases ventricular systolic function when evaluated by strain and that the two independent variables for this decreased absolute GLS value were DM2 and relative posterior wall thickness.²⁵ Jørgensen et al. designed a study to assess the influence of risk factors in DM patients and reported an association between systolic blood pressure, BMI, HbA1c, and LV structure and function. Thus, risk factors should be weighed when analyzing studies that assess diabetic cardiomyopathy to avoid confounding factors. Regardless, this population has a high prevalence of comorbidities, and poor metabolic control can interfere with cardiac function.

As for glycemic control, Lind et al. analyzed 20,985 DM1 patients and concluded that even after adjusting for other cardiovascular risk factors, the risk of heart failure was still four-fold higher in patients with poor glycemic control than in those with excellent glycemic control and that each 1% increase in HbA1c corresponded to a 30% increase in the risk of developing heart failure.⁴⁰ Li et al. explored the relationship between glycemic control and LV dysfunction in DM2 patients through HbA1c³² and found that LVEF showed no difference; however, ventricular mass index and mitral E-wave velocity differed between the DM and control groups, with a greater difference in the group with worse glycemic control. In addition, there was no GLS difference between the group with good glycemic control and the control group. This study showed a correlation between HbA1c, ventricular

mass index, and E/e' ratio, and GLS. Wang et al.²² showed an intergroup difference in GLS; however, there was already an LVEF difference. This study highlights the poor glycemic control in the DM2 group prior to hospitalization, with an HbA1c value around 10%.

Contrary evidence was reported by studies that showed no difference between DM and control groups with populations with better-controlled risk factors.^{10,18,31,36} Three-dimensional speckle tracking analysis identified a lower absolute GLS value in subjects with diabetes versus controls.^{18,41–46} Depending on the associated risk factor, other parameters also showed differences, such as GCS^{42–46} and GRS.^{42,47} Chen et al. concluded that three-dimensional speckle tracking strain detects LV dysfunction in DM patients with poor glycemic control and that myocardial dysfunction is associated with DM duration and HbA1c.⁴⁶ Wang et al. demonstrated that fasting glucose, dyslipidemia, and BMI were significant risk factors for LV remodeling in DM2 patients. Those with normal ventricular geometry showed differences in only GLS compared to controls, while DM patients with LV remodeling showed lower absolute GLS, GCS, CSA, and GRS values.⁴⁴ Hepatic steatosis is another condition highly prevalent in DM2, being associated with LV remodeling and subclinical ventricular dysfunction; of the three-dimensional strain parameters, GLS presented the most evident change.⁴² Finally, intensive treatment with an insulin pump improved LV systolic function, proving a sensitive and accurate diagnostic technique that could even provide data on the therapeutic effect.⁴³

As previously reported,^{18,48} image acquisition and the analysis of myocardial deformation by three-dimensional speckle tracking was faster than that by two-dimensional speckle tracking; however, high-quality images are required to ensure an accurate strain analysis.

Conclusion

Myocardial strain imaging by two- and three-dimensional speckle tracking echocardiography enables the identification of subclinical systolic dysfunction in DM patients that becomes more marked when associated with risk factors and ventricular remodeling. The introduction of tools like the layer-specific method allows for a broader understanding of myocardial involvement in DM. Despite few prospective studies assessing clinical outcomes, there is evidence of an association between GLS and cardiovascular events in DM patients.

Authors' contributions

Research creation and design:: Silva TRW, Silva RL; Data acquisition: Silva TRW, Silva RL; Data analysis and interpretation: Silva TRW, Martins AF; Statistical analysis: Silva RL; Manuscript writing: Silva TRW, Silva RL, Martins AF; Critical revision of the manuscript for important intellectual content: Silva TRW, Silva RL, Martins A, Marques JLB.

Conflict of interest

The authors have declared that they have no conflict of interest.

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