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Original Research Article

The Effect of Myocardial Scars on Left Ventricular Deformation in Type 2 Diabetes Mellitus following a Myocardial Infarction was Studied using Contrast-Enhanced Cardiac Magnetic Resonance

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Abstract

Objective: Myocardial infarction (MI) and coronary artery disease are both greatly increased by type 2 diabetic mellitus (T2DM). Uncertainty exists on how diabetic cardiomyopathy and MI scars affect myocardium deformation in T2DM patients. The objective was to assess myocardial deformation using cardiac magnetic resonance (CMR) in T2DM patients who had previously experienced a MI and to find out how myocardial scar affected left ventricular (LV) deformation.

Method: At Nalanda Medical College and Hospital, Patna, 200 T2DM patients, comprising 45 with MI (T2DM(MI+)) and 155 without MI (T2DM(MI), as well as 58 normal controls who received CMR scans, were included for one year. Late gadolinium enhancement was used to evaluate myocardial scarring. The LV function and deformation, including the peak systolic strain rate (PSSR), peak diastolic strain rate (PDSR), and LV global peak strain (PS), were compared between these groups. The correlation between myocardial scars and LV distortion was examined using multivariate linear regression and correlation analysis.

Results: When compared to the other groups, the T2DM (MI+) group's LV function and LV global PS, PSSR, and PDSR showed declines. In the T2DM (MI+) group with anterior wall infarction, there was lessened LV deformation ($p<0.016$). Reduced LV global PS (radial, circumferential, and longitudinal directions; $p<0.02$) and LV global PSSR (radial and circumferential directions; $p<0.01$) were associated with increased total LV infarct size and LV infarct mass. LV anterior wall infarction was independently associated with LV global longitudinal PS ($\beta=0.397$, $p=0.005$), and NYHA functional class was independently associated with LV global radial PS ($\beta=0.401$ and $\beta=0.445$, respectively, all $p<0.02$; model $R2=0.36$) and circumferential PS ($\beta=0.338$ and $\beta=0.531$, respectively, all $p<0.02$; model $R2=0.40$).

Conclusion: In T2DM individuals who have had a MI, the amount of myocardial scarring is inversely linked with the LV global PS and PSSR, especially in the circumferential direction. Additionally, specific clinical evaluations should be reinforced because different MI areas have different effects on reducing LV distortion.

Keywords: Biabetes-related Cardiomyopathy, Cardiovascular Disease, Heart Muscle Scars Heart Magnetic Resonance Imaging.

Introduction

Diabetic cardiomyopathy (DCM) is defined as myocardial dysfunction that can cause heart failure and is unrelated to coronary artery disease and high blood pressure [Figure 1]. One of the key signs of early left ventricular (LV) dysfunction before lower LV ejection fraction in DCM is diastolic dysfunction, and poor global longitudinal strain has been linked to cardiovascular events in people with type 2 diabetes mellitus (T2DM)[1]. Contractile dysfunction in DCM is associated with myocardial microvascular dysfunction and remodeling of the extracellular matrix [1].

T2DM is regarded as a major risk factor for coronary artery disease, T2DM patients are at a high risk of MI, and T2DM patients have a poor prognosis. Coronary artery disease and myocardial infarction (MI) are significant causes of global morbidity and mortality. Previous research has shown that the size of the MI and the type of transmural in MI patients have a significant impact on prognosis and survival.

Myocardial scarring affects LV myocardial deformation in patients with prior MI by causing decreased or even conflicting LV wall movement, fibrotic healing of the infarcted area, and compensatory cardiomyocyte hypertrophy in remote infarcted locations [2]. Few studies have examined the effects of myocardial scar on myocardium deformation following MI in T2DM patients with DCM as of yet.

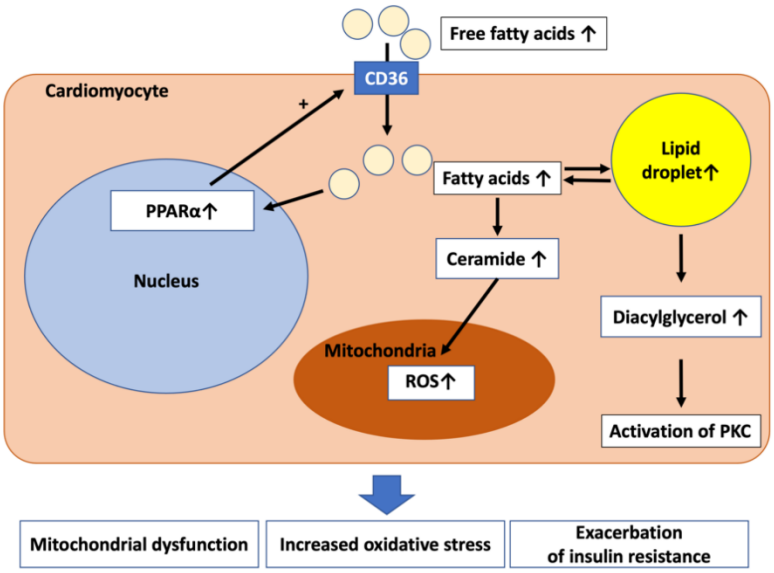

Figure 1: Diabetic Cardiomyopathy

Cardiac magnetic resonance (CMR) imaging, which has been utilized extensively in clinical practice over the past few decades, gives details on a variety of aspects of cardiac anatomy, function, and myocardial tissue. Myocardial deformation has been measured using CMR tissue tracking [3]. The myocardial scar is identified and evaluated with great spatial resolution using the late gadolinium enhancement (LGE) sequence, which also quantifies the MI area [4]. Therefore, the purpose of this study was to assess LV deformation using CMR in T2DM patients who had previously experienced a MI and to look into the impact of the MI scar on LV deformation.

Methods

Study Design: This was a retrospective study carried out at Nalanda Medical College and Hospital, Patna for one year.

Methodology: All patients and healthy controls had their clinical features, family histories, surgical histories, medication histories, and serum biochemical indexes gathered. Within a week following the CMR scan, blood was drawn to measure serum biochemical indices without altering the subject's medication schedule.

In the supine posture, all individuals got CMR scans using body scanners. End-inspiratory breath-holding was done while an ordinary ECG trigger was being used. Following a survey scan, a steady-state free precession sequence was used to capture cine pictures such as long-axis four-chamber views and short-axis two-chamber views. A 10 mL saline flush was administered after an intravenous infusion of 0.2 ml/kg body weight of arogenate Di meglumine at a rate of 2.0–3.5 mL/s. 15-20 minutes after contrast injection, LGE images were taken in the same slice position as the cine imaging. Using a phase-sensitive inversion recovery technique, the pictures were produced.

All CMR data were semi-automatically uploaded to an ofine workstation. Two seasoned radiologists manually defined endocardial and epicardial traces in the sequential short-axis slices at the end-diastolic and end-systolic phases. Epicardial fat was disregarded and papillary muscles were included in the definition of the ventricular cavity. LV functional parameters and LV mass were thereafter automatically calculated. The proportion of LV mass to LV end-diastolic volume (LVEDV) (LVMVR) served as a marker for LV remodeling.

Long-axis 2-chamber, 4-chamber, and short-axis slices were put into the 3-dimensional tissue tracking module for LV myocardial strain characterization. The peak systolic strain rate (PSSR), peak diastolic strain rate (PDSR), and radial, circumferential, and longitudinal peak strain (PS) characteristics of the LV global myocardial strain were automatically recorded. In order to analyses LGE images, LV segment-based analysis was carried out in accordance with the American Heart Association's 16-segment model. When the signal intensity was four standard deviations above the mean intensity of the normal myocardium on the LGE short-axis images, that area was defined as the myocardial scar.

By segmenting the LV wall into the interventricular septum, anterior wall, inferior wall, and lateral wall using the 16-segment model, the extent of the LGE regions affecting them was evaluated. When the results of the two radiologists' independent evaluations of the photos were incongruous, they conferred and came to a consensus.

Sample Size: A total of 200 patients with T2DM were enrolled in this study, comprising 45 with MI (T2DM(MI+)) and 155 without MI (T2DM(MI), as well as 58 normal controls.

Inclusion criteria: Patients with acute MI may have myocardial that is edematous or shocked, which affects the assessment of CMR measures.

Exclusion criteria: Acute or subacute MI patients, severe renal failure, known cardiomyopathy, congenital heart disease, or valvular heart disease, uncontrollable hypertension (systolic blood pressure > 130 mmHg), severe renal failure (estimated glomerular filtration rate, eGFR 40 mL/min), and acute or subacute MI patients.

Statistical analysis: With SPSS, statistical analyses were carried out. For continuous variables, data were presented in the form of mean± standard deviations or median interquartile range, and for categorical variables, frequencies. The following groups

were examined for differences using the one-way analysis of variance test: T2DM(MI+), T2DM(MI), and normal control. Bonferroni's correction for multigroup comparisons determined that p-values <0.016 were statistically significant. In order to determine the connection between infarction and cardiac deformation, Spearman's and Pearson's correlation studies were performed. Continuous variables were correlated using Pearson's method, and the rank correlation was examined using Spearman's method. Additionally, multivariable stepwise linear regression analysis was used to establish a link between infarction parameters and cardiac dysfunction. A stepwise multivariable analysis built on a linear regression model then took variables with a p-value of <0.2 from the univariable studies into account. Statistics were deemed significant at a p-value of <0.04**.**

Results

Out of the 200 T2DM patients, 155 belonged to the T2DM(MI) group (47 [30.6%] men, mean age 55.54±11.81 Years), and 45 to the T2DM(MI+) group (27 [60.7%] males, mean age 61.53±9.10 Years). Local risk factors, metabolic measurements, and prescription drugs. With the exception of a higher proportion of males in the T2DM(MI+) group compared to the T2DM(MI) group, the results showed no statistically significant differences in the baseline characteristics between these groups. In terms of cardiovascular risk factors, individuals in the T2DM(MI+) group were more likely to be current or former smokers (50.4% vs. 28.2%), whereas there was no difference in hyperlipidemia or family history of T2DM across the groups. Between the T2DM(MI+) and T2DM(MI) groups, there were no statistically significant differences in HbA1c or fasting plasma glucose.

21 patients underwent percutaneous coronary interventions and 2 underwent coronary artery bypass grafting operations in the T2DM(MI+) group. 33 individuals had culprit vessels identified, of which 15 (30.42%) had the right coronary artery (RCA), 13 (30.42%) had the left anterior descending coronary artery (LAD), and 5 (13.1%) had the left circumflex coronary artery.

Comparison of the three groups' LV function and deformation

In comparison to the control group, LVESVi (LVESV index) was higher in the T2DM(MI) group. In comparison to the T2DM(MI) and normal control groups, LVESVi and LV mass were higher (all p0.004) in the T2DM(MI+) group. In the meantime, LVGFI and LVSVi were lower in the T2DM(MI+) group compared to the T2DM(MI) and control groups (T2DM(MI+) vs. T2DM(MI): 27.36 (18.11-40.01) vs. 48.98 (44.37-54.32); T2DM(MI+) vs. control: 27.36 (18.11-40.01) vs. 51.

In terms of LV deformation, the T2DM(MI+) group had lower global radial, circumferential, and longitudinal PS values than the T2DM(MI) and control groups (all p <0.002). The T2DM(MI) group's global longitudinal PS (p <0.016) was lower than that of the control group. There was no statistically significant difference between the T2DM(MI) and control groups in terms of global radial PS. The T2DM(MI+) group had significantly lower global radial, circumferential, longitudinal PSSR and PDSR values than the T2DM(MI) and control groups (all p <0.002). With the exception of longitudinal PDSR between the T2DM(MI+) group and the T2DM(MI) group. The circumferential and longitudinal PDSR was lower for the T2DM(MI) group than for the control group (p <0.016).

Analysis of LV infarct features

LV distortion and LGE size are related in T2DM patients who had MI.

The range of LV infarct size and total LV infarct extent in this study were 17.95 (11.06-25.25) and 17.11 (9.56-27.51, respectively). According to **Table 1**, there was a negative connection between growing infarction size and declining LVGFI (all p<0.002) as well as LV global PS in all three directions (all p<0.02) for T2DM(MI+) patients.

Table 1: Analysis of the relationships between LV function, global strain, and myocardial infarction parameters

Criteria	Total LV infarct extent (%)		Enhanced mass (g % of LV)		Enhanced area (mL %of LV)	
	r	P	r	P	r	P
LVGFI, %	-0.532	<0.002	-0.506	<0.002	-0.505	<0.002
PDSR, %						
Radial	0.161	0.286	0.162	0.281	0.171	0.253
Circumferential	-0.234	0.115	-0.221	0.140	-0.217	0.145
Longitudinal	-0.122	0.416	-0.082	0.585	-0.070	0.638
PSSR, %						
Radial	-0.352	0.015	-0.301	0.041	-0.296	0.044
Circumferential	0.532	<0.002	0.524	<0.002	0.527	<0.002
Longitudinal	0.096	0.521	0.105	0.483	0.111	0.464
PS, %						
Radial	-0.454	0.002	-0.436	0.001	-0.434	0.002
Circumferential	0.537	<0.002	0.531	<0.0002	0.532	0.001
Longitudinal	0.394	0.006	0.433	0.002	0.430	0.006

LV global radial and circumferential PSSR was inversely correlated with total LV infarct extent (r= −0.352, p=0.015; r=0.532, p<0.002, respectively), the enhanced mass of LV (r= −0.301, p=0.041; r=0.524, p<0.002, respectively), and enhanced area of LV (r= −0.296, p=0.044; r=0.527, p<0.002, respectively) in T2DM(MI+) patients.

However, there was no significant correlation between the extent of the infarction and the LV global longitudinal PSSR or global PDSR in the three directions (all p>0.04). According to multivariate linear regression analysis, global circumferential PS (β=0.338, p=0.005; and global radial PS (β=0.445, p=0.002, respectively; model R2=0.36) and global radial PS (β=0.338, p=0.005; and β=0.531, p=0.002, respectively; model R2=0.40) were independently associated with NYHA functional class and total LV infarct extent.

LV distortion and LGE area are related in T2DM patients who had MI.

In the T2DM(MI+) group, there were 27 patients with LGE areas involving the interventricular septum, 21 with LGE areas involving the LV inferior wall, 12 with LGE areas involving the LV lateral wall, and 11 with LGE areas involving the LV anterior wall. In the T2DM(MI) group, no LGE regions were found.

For the LGE area in different regions of the LV wall, patients with anterior wall infarction had lower LV global radial PS (anterior vs. non-anterior: 11.90±1.923 vs. 18.44±1.670, p=0.036), circumferential PS (anterior vs. non-anterior: − 8.446±0.7524 vs. − 13.23±0.8777, p=0.033) and longitudinal PS (anterior vs. nonanterior: − 5.288±0.4826 vs. − 8.350±0.6051 p=0.005). Lower LV global longitudinal PS is observed in patients with interventricular septum infarction (interventricular septum vs. non-

interventricular septum: 6.514±0.707 vs. 8.502±0.6701, p=0.042). Additionally, there was an independent relationship between global longitudinal PS and LV anterior wall infarction (β=0.397; p=0.005, model R2=0.15).

Both between- and within-observer variation

The ICCs for intra- and interobserver variability were 0.827- 0.958 and 0.776-0.945 for LV deformation and 0.826-0.894 and 0.881-0.892 for LGE parameters, respectively, indicating agreement between the two methods.

Discussion

T2DM is a chronic metabolic disease that affects several organs, and DCM is mostly to blame for the higher mortality of T2DM patients. T2DM also poses a significant risk for cardiovascular problems such MI and coronary heart disease [5]. The following key findings from this investigation were attained: T2DM (MI) patients have decreased LV longitudinal deformation, whereas T2DM (MI+) patients have decreased deformation in all three directions, especially circumferential deformation; (2) LV global PS and PSSR are decreased in T2DM (MI+) patients, related to the degree of myocardial scarring; (3) anterior wall infarction followed by ventricular septal infarction are more likely to reduce LV deformation in T2DM (MI+) patients. The pathophysiology of DCM is multifaceted and complex, and it has a number of potential causes, including metabolic effects on myocytes, myocardial steatosis, myocardial fibrosis, microangiopathy, and autonomic nerve dysfunction [6, 7]. Because longitudinal myocardial fibres are primarily found in the sub-endocardium, where microvascular ischemia of DCM is most likely to occur, there is a reduction in longitudinal LV deformation in the early stages of the disease. Our findings demonstrate decreased longitudinal PS but retained circumferential and radial PS in T2DM (MI) patients compared to control subjects, which is consistent with other research [8]. However, distortion of the LV global PS in all three directions was reduced in T2DM(MI+) patients, especially in the circumferential rather than longitudinal direction.

We hypothesise that the fibrous matrix replaces the myocardial cells in the scar location following MI and scar formation in T2DM patients, and local ventricular wall movement is diminished or inhibited to variable degrees. Circumferential myocardial fibres are different from longitudinal myocardial fibres in that they are primarily subepicardial in location, which significantly lessens circumferential LV deformation [9]. Additionally, as we have previously shown [10], decreased longitudinal and circumferential PDSR suggests that diastolic dysfunction starts in the early stages of DCM. Common cardiac morphological changes following MI include LV enlargement, especially LVESV, and lower LVEF, which were more significant than the early diastolic functional impairment of DCM.

Because of this, patients with T2DM(MI+) showed lower PDSR and lower PSSR in all three orientations in our study. The best method was currently available for noninvasively assessing cardiac scar tissue after MI is LGE-CMR. It defines the infarct territory of the LV ventricle wall, distinguishes the transmural infarction, and quantitatively assesses the myocardial scar [11]. A negative cardiac remodelling and cardiovascular events are directly correlated with the size and extent of scarring [12]. The presence of scars may potentially be a predictor of the substrates of arrhythmias. Histological analysis has shown that isolated bundles of living myocytes are entangled with strands of fibrous tissue. These live cells have the ability to create reentry circuits in fibrous tissue, which can cause ventricular

tachycardia [13]. In individuals with acute MI, earlier research has linked LV distortion to the severity of the MI [14]. However, the delayed enhancement region of LGE imaging alters following acute MI due to the absorption of myocardial edema and infarction, or infarction core fiber gliosis.

We discovered that myocardial scarring after MI has a significant negative connection with LV radial, circumferential, and longitudinal PS and PSSR on the basis of DCM, which predisposes to myocardial distortion and injury. It shows that following an acute MI, the quality and size of the MI, particularly in the circumferential direction, affect the recovery of LV myocardial systolic function and deformation. Furthermore, we discovered that LV global PDSR in the three directions was lower in T2DM (MI+) patients than in T2DM (MI) patients, but there was no relationship between LV global PDSR and the degree of myocardial scarring. The decline in PDSR may be brought on by scarring. The myocardial metabolic disease may develop as a result of decreased LV function, and hyperglycemia may have an additional effect on diastolic dysfunction, which results in decreased LV PDSR. These hypotheses need to be confirmed through other research.

Limitation

This study has a number of drawbacks. First of all, since this study only involved one site, there might be some biases influencing the findings. Second, no measurements were made of the drug or NT-proBNP in the control group. The medical histories and the physical examination reports, however, were thoroughly examined to make sure they matched the inclusion and exclusion requirements. Thirdly, because our study was a retrospective one with intrinsic design flaws, future follow-up research should focus more on the long-term evolution of T2DM patients following myocardial infarction. This is what we hope to achieve with our upcoming research projects.

Conclusion

This study discovered a significant reduction in LV global circumferential distortion and a higher likelihood of systolic dysfunction in T2DM patients following MI. The LV global PS and PSSR have a negative correlation with the extent of myocardial scarring. Additionally, the reduction of LV deformation is affected differently by MI in various areas. Therefore, in clinical assessments, it is important to pay more attention to MI scarring and the degree of MI involvement in T2DM patients.

Abbreviations

DM: Diabetes mellitus; T2DM: Type 2 diabetes mellitus; DCM: Diabetic cardiomyopathy; CMR: Cardiac magnetic resonance; LGE: Late gadolinium enhancement; LV: Left ventricular; LVGFI: Left ventricular global function index; MI: Myocardial infarction; PDSR: Peak diastolic strain rate; PS: Peak strain; PSSR: Peak systolic strain rate; LAD: Left anterior descending coronary artery; EDVi: End-diastolic volume index; ESVi: End systolic volume index; SVi: Stroke volume index; LVEF: Left ventricle ejection fraction; ICC: Intraclass correlation coefficient.

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