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ROLE OF TEI INDEX IN IDENTIFYING CARDIAC DYSFUNCTION AMONG DIABETIC PATIENTS

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ABSTRACT

Background: Diabetic cardiomyopathy is an important cardiovascular complication of type 2 diabetes mellitus (T2DM) and is characterized by myocardial dysfunction in the absence of hypertension, coronary artery disease, and valvular heart disease. Early detection of cardiac dysfunction remains challenging because conventional echocardiographic parameters may remain normal during the initial stages of myocardial involvement. The Myocardial Performance Index (MPI), also known as the TEI index, provides a comprehensive assessment of both systolic and diastolic cardiac function and may serve as an effective screening tool for early diabetic cardiomyopathy.

Objective: To evaluate the role of the TEI index in identifying cardiac dysfunction among patients with type 2 diabetes mellitus.

Methods: This hospital-based observational cross-sectional study was conducted in the Department of Cardiology, NRI Medical College and Hospital, Mangalagiri, Andhra Pradesh, India, from June 2021 to November 2022. A total of 100 patients with type 2 diabetes mellitus aged 30–70 years were included after screening 142 patients. Patients with hypertension, valvular heart disease, chronic alcoholism, and regional wall motion abnormalities were excluded. All participants underwent clinical evaluation, electrocardiography, conventional Doppler echocardiography, tissue Doppler imaging, and assessment of the TEI index. Statistical analysis was performed using appropriate parametric tests, and a p-value of <0.05 was considered statistically significant.

Results: Diastolic dysfunction was identified in 60% of patients, whereas systolic dysfunction was observed in 18%. Grade I diastolic dysfunction was the most common subtype, accounting for 47% of cases. The severity of cardiac dysfunction was significantly associated with longer duration of diabetes, higher HbA1c levels, increased body mass index, and lower ejection fraction values. The mean TEI index progressively increased with worsening grades of diastolic dysfunction, ranging from 0.399 in patients with normal diastolic function to 0.558 in patients with severe dysfunction ($p<0.001$). Receiver operating characteristic analysis demonstrated excellent diagnostic performance of the TEI index, with a sensitivity of 93.55%, specificity of 94.74%, positive predictive value of 96.67%, negative predictive value of 90.00%, and overall diagnostic accuracy of 94%.

Conclusion: Subclinical cardiac dysfunction is highly prevalent among patients with type 2 diabetes mellitus. The TEI index is a simple, reproducible, and non-invasive echocardiographic parameter with excellent diagnostic accuracy for detecting early cardiac dysfunction and may serve as a valuable screening tool for diabetic cardiomyopathy.

Keywords: *Type 2 diabetes mellitus; Diabetic cardiomyopathy; TEI index; Myocardial performance index; Echocardiography; Cardiac dysfunction.*

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major global health problem and one of the leading causes of morbidity and mortality worldwide. It is characterized by insulin resistance, impaired insulin secretion, and increased hepatic glucose production, resulting in chronic hyperglycemia. The burden of T2DM has increased substantially over recent decades, with an estimated 422 million adults affected globally in 2014. The prevalence of diabetes worldwide increased from 4.7% in 1980 to 8.5% in 2014 [1,2]. India, often referred to as the diabetes capital of the world, had approximately 62.4 million individuals with diabetes and 77.2 million individuals with prediabetes in 2011, highlighting the enormous healthcare burden posed by this disease [2].

Cardiovascular disease remains the leading cause of morbidity and mortality among patients with T2DM. Heart failure (HF) has emerged as one of the earliest and most frequent cardiovascular complications associated with diabetes [3-5]. In addition to accelerated atherosclerosis and coronary artery disease, diabetes can independently affect myocardial structure and function, resulting in diabetic cardiomyopathy [6]. Diabetic cardiomyopathy is defined as ventricular dysfunction occurring in patients with diabetes in the absence of coronary artery disease, hypertension, or valvular heart disease and is characterized by structural, metabolic, and functional abnormalities of the myocardium [7-9]. The concept of diabetic heart disease was initially proposed by Lundbaek in 1954 [10], and subsequent studies have established a strong association between diabetes and non-ischemic cardiomyopathy [11]. Furthermore, patients with T2DM continue to have a significantly increased risk of hospitalization for heart failure despite optimal management of conventional cardiovascular risk factors [12].

Diabetic cardiomyopathy is often clinically silent during its early stages and initially manifests as subclinical left ventricular diastolic dysfunction before progressing to overt systolic dysfunction and heart failure. Conventional echocardiographic parameters, particularly left ventricular ejection fraction, frequently remain within normal limits during the early stages of myocardial impairment, limiting their ability to detect subclinical cardiac dysfunction. Therefore, there is a growing need for sensitive, reliable, and non-invasive diagnostic tools capable of identifying early myocardial dysfunction in patients with diabetes.

The Myocardial Performance Index (MPI), also known as the TEI index, was introduced by Tei et al. in 1995 as a Doppler-derived echocardiographic parameter that provides a comprehensive assessment of global ventricular performance by simultaneously evaluating systolic and diastolic function [13]. The TEI index is calculated using isovolumic contraction time, isovolumic relaxation time, and ejection time and has the advantage of being relatively independent of ventricular geometry, age, heart rate, and loading conditions [13]. Because of its simplicity, reproducibility, and ability to detect early myocardial dysfunction, the TEI index may serve as a valuable tool for identifying subclinical diabetic cardiomyopathy. Therefore, the present study was undertaken to evaluate the role of the TEI index in identifying cardiac dysfunction among patients with type 2 diabetes mellitus.

MATERIALS AND METHODS

Study Design and Setting: This hospital-based observational cross-sectional study was conducted in the Department of Cardiology, NRI Medical College and Hospital, Mangalagiri, Andhra Pradesh, India, over a period of 18 months from June 2021 to November 2022. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants before enrolment.

Study Population: Patients with type 2 diabetes mellitus attending the outpatient departments of General Medicine and Cardiology during the study period were screened for eligibility. A total of 142 patients were screened, of whom 100 patients fulfilled the inclusion criteria and were enrolled in the study.

Sample Size: The sample size was calculated based on the prevalence of diabetic cardiomyopathy reported by Dandamudi et al. [81], which was estimated to be 1.1% among the Indian population. Using the population survey formula:

$$N = Z^2PQ/E^2$$

with a confidence level of 90% and an allowable error of 2%, the minimum required sample size was calculated to be 75. To improve the statistical power and account for potential exclusions, a total of 100 patients were included in the study.

Inclusion Criteria: Patients fulfilling all the following criteria were included:

- Age between 30 and 70 years;
- Diagnosed cases of type 2 diabetes mellitus;
- No previous history of cardiac illness;
- Willingness to participate in the study with provision of written informed consent.

Exclusion Criteria: Patients with any of the following conditions were excluded:

- Hypertension;

- History of chronic alcoholism;
- Valvular heart disease;
- Regional wall motion abnormalities on echocardiography.

Study Procedure: Demographic and clinical data, including age, sex, and relevant clinical history, were recorded for all participants. A detailed clinical examination was performed, followed by standard 12-lead electrocardiography. Comprehensive transthoracic echocardiography was performed using a Philips Affiniti Series echocardiography machine equipped with an S5-1 transducer. Two-dimensional and M-mode echocardiographic measurements included left ventricular end-diastolic dimension (LVEDD), left ventricular end-systolic dimension (LVESD), fractional shortening (FS), and left ventricular ejection fraction (LVEF). Conventional Doppler echocardiography was used to measure transmitral flow velocities, including early diastolic (E wave) and late diastolic (A wave) velocities, and the E/A ratio was calculated. Tissue Doppler imaging was performed to obtain the early diastolic mitral annular velocity (e′).

Assessment of TEI Index: The left ventricular Myocardial Performance Index (MPI), also known as the TEI index, was assessed using pulsed-wave Doppler echocardiography. Doppler recordings were obtained from the apical five-chamber view, with the sample volume positioned midway between the mitral and aortic valves, enabling simultaneous recording of mitral inflow and aortic outflow signals.

The TEI index was calculated using the formula:

TEI Index = (Isovolumic Contraction Time + Isovolumic Relaxation Time) / Ejection Time
or
TEI Index = (ICT + IRT)/ET

Higher TEI index values were considered indicative of impaired global myocardial performance.

Assessment of Diastolic Dysfunction: Left ventricular diastolic dysfunction was assessed using conventional transmitral Doppler and tissue Doppler parameters and was classified according to standard echocardiographic criteria.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean ±standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using Student's t-test or analysis of variance (ANOVA), as appropriate. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 142 patients with type 2 diabetes mellitus were screened, of whom 100 patients fulfilled the eligibility criteria and were included in the final analysis. Diastolic dysfunction was observed in 60% of the study population, with grade I dysfunction being the most common subtype. Systolic dysfunction was identified in 18% of patients. The prevalence and severity of cardiac dysfunction increased with longer duration of diabetes, poorer glycemic control, and higher TEI index values.

Table 1. Baseline demographic and clinical characteristics of the study population (N = 100)

Characteristic	Frequency (%)
Age group (years)	
41–50	17 (17.0)
51–60	65 (65.0)
61–70	18 (18.0)
Gender	
Male	64 (64.0)
Female	36 (36.0)
Smokers	39 (39.0)
Systolic dysfunction present	18 (18.0)
Diastolic dysfunction present	60 (60.0)

The majority of participants were aged between 51 and 60 years and were male. Nearly two-thirds of the study population had evidence of diastolic dysfunction.

Table 2. Distribution of diastolic dysfunction grades

Grade	Description	Frequency (%)

N	Normal diastolic function	40 (40.0)
A	Grade I diastolic dysfunction	47 (47.0)
B	Grade II diastolic dysfunction	9 (9.0)
C	Grade III diastolic dysfunction	4 (4.0)

Grade I diastolic dysfunction represented the predominant pattern of cardiac involvement, whereas severe diastolic dysfunction was uncommon.

Table 3. Clinical characteristics according to diastolic dysfunction grade

Parameter	Grade A	Grade B	Grade C	Normal	p-value
Duration of diabetes (years), mean ± SD	10.09 ± 3.79	7.56 ± 1.51	11.25 ± 2.22	5.43 ± 1.92	0.001
HbA1c (%)	9.16	9.39	9.53	7.99	<0.001
BMI (kg/m²)	—	—	—	—	0.002

Patients with diastolic dysfunction had significantly longer duration of diabetes and poorer glycemic control compared with those with normal diastolic function. BMI was also significantly higher among patients with diastolic dysfunction.

Table 4. Echocardiographic parameters according to diastolic dysfunction grade

Parameter	Grade A	Grade B	Grade C	Normal	p-value
Ejection fraction (%)	66.9 ± 5.2	59.1 ± 8.4	49.0 ± 7.5	71.2 ± 4.3	<0.001
E/A ratio	Significant difference observed				<0.001

A progressive decline in left ventricular systolic function was observed with increasing severity of diastolic dysfunction. Patients with severe diastolic dysfunction demonstrated the lowest mean ejection fraction values.

Table 5. TEI index according to diastolic dysfunction grade

Group	Mean TEI index ± SD
Grade A	0.438 ± 0.011
Grade B	0.498 ± 0.037
Grade C	0.558 ± 0.017
Normal	0.399 ± 0.020

ANOVA p-value: <0.001

The TEI index increased progressively with worsening grades of diastolic dysfunction, indicating impaired global myocardial performance among patients with advanced cardiac dysfunction.

Table 6. Diagnostic performance of TEI index in detecting cardiac dysfunction

Parameter	Value (%)
Cut-off value	≥0.42
Sensitivity	93.55
Specificity	94.74
Positive predictive value	96.67
Negative predictive value	90.00
Diagnostic accuracy	94.00

Receiver operating characteristic analysis demonstrated excellent diagnostic performance of the TEI index for detecting cardiac dysfunction in patients with type 2 diabetes mellitus.

DISCUSSION

The present hospital-based cross-sectional study evaluated the role of the TEI index in identifying cardiac dysfunction among patients with type 2 diabetes mellitus. The study demonstrated that cardiac dysfunction was common among asymptomatic diabetic patients, with diastolic dysfunction observed in 60% and systolic dysfunction in 18% of the study population. Grade I diastolic dysfunction constituted the majority of cases, whereas severe diastolic dysfunction was relatively uncommon. These findings support the concept that diabetic cardiomyopathy initially manifests as diastolic dysfunction and subsequently progresses to systolic dysfunction in the absence of coronary artery disease, hypertension, and valvular heart disease [14-17].

The prevalence of cardiac dysfunction observed in the present study is consistent with previous studies that reported a high burden of subclinical cardiac dysfunction among patients with type 2 diabetes mellitus [18,19]. Zabalgoitia et al. [20] and Boyer et al. [21] also demonstrated a high prevalence of asymptomatic left ventricular diastolic dysfunction among normotensive diabetic patients. Furthermore, the duration of diabetes was significantly associated with the severity of diastolic dysfunction in our study, suggesting that prolonged exposure to hyperglycemia contributes to progressive myocardial damage. Similar observations were reported by Goroshi et al. [22], who observed a significant association between duration of diabetes and worsening grades of cardiac dysfunction.

In the present study, patients with diastolic dysfunction had significantly higher HbA1c levels compared to patients with normal diastolic function. Previous studies have shown that poor glycemic control contributes to myocardial fibrosis, oxidative stress, accumulation of advanced glycation end products, and impaired myocardial relaxation, ultimately leading to diabetic cardiomyopathy [23-27]. The observed association between elevated HbA1c levels and worsening cardiac function in our study further supports the role of chronic hyperglycemia in the pathogenesis of diabetic myocardial dysfunction.

We observed a progressive decline in left ventricular ejection fraction with increasing severity of diastolic dysfunction. Although conventional echocardiographic parameters remain useful, they may fail to detect early myocardial impairment in asymptomatic diabetic patients [28]. In contrast, the TEI index provides a comprehensive assessment of global myocardial performance by simultaneously evaluating both systolic and diastolic function [29-31]. The mean TEI index increased progressively with the severity of cardiac dysfunction and demonstrated excellent diagnostic performance, with a sensitivity of 93.55%, specificity of 94.74%, and diagnostic accuracy of 94% at a cut-off value of $\geq$0.42.

Our findings are comparable with those reported by Goroshi et al. [22], who demonstrated excellent diagnostic performance of the TEI index in identifying cardiac dysfunction among diabetic patients. Similarly, Al-Daydamony et al. [32] reported that myocardial performance index could effectively identify subclinical cardiac dysfunction in asymptomatic patients with type 2 diabetes mellitus. The high diagnostic accuracy observed in the present study suggests that the TEI index may serve as a simple, reproducible, and non-invasive screening tool for the early detection of diabetic cardiomyopathy.

Overall, the findings of the present study emphasize the importance of early cardiovascular evaluation in patients with type 2 diabetes mellitus and support the use of the TEI index as a valuable echocardiographic parameter for the detection of subclinical cardiac dysfunction.

CONCLUSION

The present study demonstrated that subclinical cardiac dysfunction is highly prevalent among patients with type 2 diabetes mellitus, even in the absence of hypertension, coronary artery disease, and valvular heart disease. Diastolic dysfunction was observed in 60% of the study population, with grade I diastolic dysfunction being the most common manifestation, while systolic dysfunction was present in 18% of patients. Longer duration of diabetes, poor glycemic control, and worsening echocardiographic parameters were significantly associated with the severity of cardiac dysfunction. The TEI index showed a progressive increase with advancing grades of diastolic dysfunction and demonstrated excellent diagnostic performance, with high sensitivity, specificity, and overall diagnostic accuracy. These findings suggest that the TEI index is a simple, reproducible, non-invasive, and clinically useful echocardiographic parameter for the early detection of diabetic cardiomyopathy and may be incorporated into routine cardiovascular assessment of patients with type 2 diabetes mellitus.

DECLARATIONS

Ethics Approval and Consent to Participate: The study was approved by the Institutional Ethics Committee of NRI Medical College and Hospital, Mangalagiri. Written informed consent was obtained from all participants prior to enrolment.

Consent for Publication: Not applicable.
Availability of Data and Materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.
Competing Interests: The authors declare that they have no competing interests.
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Authors' Contributions: All authors contributed to the conception, study design, data collection, analysis, interpretation of data, manuscript preparation, and final approval of the manuscript.

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