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Original Article

Myocardial Performance Index (Tei Index): A simple tool to identify cardiac dysfunction in patients with diabetes mellitus

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ABSTRACT

Background: Cardiac dysfunction is the major cause of morbidity and mortality in diabetes. Myocardial Performance Index (MPI/Tei Index) includes both systolic and diastolic time intervals to assess the global cardiac dysfunction. Our aim was to assess the MPI in patients with type 2 diabetes.

Material and methods: This hospital-based analytic observational study was performed in the tertiary care center. The conventional Doppler parameters, tissue Doppler-derived E/E' and MPI, were measured in all patients.

Results: 100 patients with type 2 diabetes were included in the study. 65 patients showed diastolic dysfunction, 33 with Grade I diastolic dysfunction, 23 with Grade II diastolic dysfunction, and 14 patients with Grade III diastolic dysfunction. The conventional Doppler showed abnormality in 44% of patients (33 patients with Grade I and 14 patient with Grade III). 23 patients were in Grade II diastolic dysfunction (12 patients showed reversal E/A on valsalva maneuver and 11 patients showed abnormality in tissue Doppler-derived E/E' , $E/E' > 15$). MPI with cut-off 0.36 was found to have 94% sensitivity, 100 specificity, and 94% PPV for the detection of cardiac dysfunction. MPI negatively correlated with systolic dysfunction ($\rho = 0.455$, $p < 0.001$) and positively correlated with grade of diastolic dysfunction ($\rho = 0.832$, $p < 0.001$) and NYHA grading of dyspnea ($\rho = 0.872$, $p < 0.001$)

Conclusions: MPI as a single parameter can be used for assessment in diabetic cardiac dysfunction.

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1. Introduction

Cardiac dysfunction is the major cause of morbidity and mortality in diabetes.¹ Most commonly the cardiac dysfunction in diabetes is caused by the coronary atherosclerosis.

But the epidemiological and clinical data show that diabetes mellitus independently increases the risk for cardiac dysfunction and heart failure.^{2–5} Diabetic cardiomyopathy was first reported in 1972 by Rubler.⁴ It is characterized by the development of diastolic dysfunction at the early stage,

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followed by systolic dysfunction in the absence of coronary artery disease, hypertension, or significant valvular heart disease.

Cardiac dysfunction in diabetes can manifest as both systolic as well as diastolic dysfunction, and routinely ejection fraction and conventional Doppler parameters are used for its evaluation. Ejection fraction is a less sensitive parameter in early systolic dysfunction and cannot be used routinely in asymptomatic patients.⁶ The sensitivity for the detection of diastolic dysfunction by conventional Doppler parameters is decreased by pseudonormalization pattern in Grade II diastolic dysfunction. This calls for the use of tissue Doppler-derived indices, i.e., E/E' for differentiation.

Myocardial Performance Index (MPI/Tei Index), which includes both systolic and diastolic time intervals to assess the global cardiac dysfunction was used by Tei and his co-workers in 1995.⁷ Tei Index uses the measurement possible on flow wave Doppler and is as sensitive as the tissue Doppler measurements. The index is mainly used in amyloidosis, dilated cardiomyopathy, ischemic heart disease, and congestive heart failure.

Our aim was to assess the MPI in patients with type 2 diabetes without hypertension, regional wall motion abnormality, chronic alcoholism, and valvular heart disease.

2. Material and methods

This hospital-based analytic observational study was performed in the tertiary care center. Patients with type 2 diabetes were screened for inclusion. All the subjects were interviewed, examined, and investigated as per the predesigned proforma, and the study was approved by the institutional ethics committee. Fasting lipid profile, blood urea and serum creatinine, fasting and post-meal blood sugar, and 12-lead ECG were done in all study subjects.

2.1. Echocardiographic protocol

Their echocardiographic indices were evaluated serially using PHILLIPS HD11XE with frequency of 4.2 MHz.

2.1.1. Transmitral flow Doppler measurement

For recordings of the mitral inflow velocity pattern, the sample volume of the pulsed Doppler was placed between the tips of the mitral leaflets in the apical four-chamber view. From the

transmitral recordings, the following measurements were carried out: peak E velocity in meters per second (peak early transmitral filling velocity during early diastole), peak A velocity in meters per second (peak transmitral atrial filling velocity during late diastole), and deceleration time in milliseconds (time elapsed between peak E velocity and the point where the extrapolation of the deceleration slope of the E velocity crosses the zero baseline). The definitions published by the Canadian consensus on diastolic dysfunction by echocardiography were used to classify diastolic function as follows: normal, impaired relaxation, pseudonormal, and restrictive pattern.⁸ To distinguish subjects with normal diastolic function from those with a pseudonormalized pattern of ventricular filling TDI derived $E/E' > 15$ and valsalva maneuver were used.

2.1.2. Tissue Doppler measurement

TDI of the mitral annulus was obtained from the apical four-chamber view. A 1.5-mm sample volume was placed sequentially at the medial mitral annulus. Early diastolic velocity E' was measured and E/E' was calculated (Fig. 1).

2.1.3. MPI measurement

Doppler time intervals were measured from mitral inflow and left ventricular outflow Doppler tracings, as described by Tei and co-workers⁷. The interval 'a' from cessation to onset of mitral inflow is equal to the sum of isovolumic contraction time (ICT), ejection time (ET), and isovolumic relaxation time (IRT). ET 'b' is derived from the duration of the left ventricular outflow Doppler velocity profile. The sum of ICT and IRT was obtained by subtracting b from a. The MPI was calculated as shown in Fig. 1: $(a - b)/b$.

2.2. Statistical analysis

All demographic, echo parameters were presented as mean \pm SD. Categorical variables were expressed in actual number and percentage. Age, duration of diabetes, and all echo parameters were compared between different groups by performing unpaired t-test for normalized data; Mann-Whitney test was performed for non-normalized data. Categorical variables were compared by chi-square test. Receiver operating characteristic (ROC) curve was used to derive cut-off value for the MPI to detect cardiac dysfunction. All the tests were two sided; p -value < 0.05 was considered as statistically significant. Pearson correlation test was used to

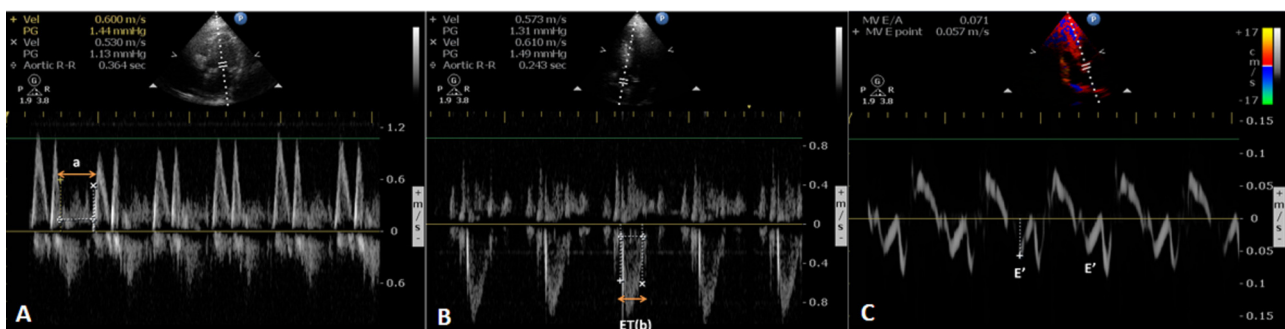


Fig. 1 – (A and B) Measurement of MPI and is calculated by $(a - b)/b$ and (C) tissue Doppler-derived E' .

correlate between MPI and different echocardiographic parameters and NYHA class of breathlessness. Statistical software SPSS version 20 was used for statistical analysis.

3. Results

A total of 145 patients were screened for inclusion; of that, 30 patients with hypertension, 2 with valvular lesion, and 3 patients with chronic alcoholism were excluded. 110 patients underwent echocardiographic evaluation; 10 patients were excluded from the study because of regional wall motion abnormality. Baseline characteristics of 100 patients with diabetes are shown in Table 1.

70% of the patients were found to have diastolic dysfunction; 25% of the patients were found to have reduced systolic function in the form of ejection fraction less than 50%.

Depending on diastolic dysfunction, patients were divided into four groups:

- Group A with no diastolic dysfunction ($n = 30$),
- Group B with Grade I diastolic dysfunction ($n = 33$),
- Group C with Grade II diastolic dysfunction ($n = 23$)
- Group D with Grade III diastolic dysfunction ($n = 14$).

Comparison of different echocardiographic parameters is shown in Table 2. On ROC curve analysis (Fig. 2), MPI showed area under curve as 0.948, with cut-off 0.36, and was found to have 94% sensitivity, 100 specificity, and 94% PPV for the detection of cardiac dysfunction. MPI negatively correlated with systolic dysfunction ($\rho = 0.455$, $p < 0.001$) and positively correlated with grade of diastolic dysfunction ($\rho = 0.832$, $p < 0.001$) and NYHA grading of dyspnea ($\rho = 0.872$, $p < 0.001$)

4. Discussion

The MPI is an easily performable, recordable and reproducible parameter by flow Doppler. The standardization of MPI is not required as number of studies have documented that the MPI is independent of arterial pressure, heart rate, ventricular geometry, atrioventricular valve regurgitation, afterload, and

Table 1 – Baseline characteristics of patients ($n = 100$).

Age (yrs)	53.28 ± 8.8
Gender (F/M)	62/38
Duration diabetes (yrs)	5.01 ± 3.4
BMI	26.4 ± 2.13
SBP	116.2 ± 14.5
DBP	82.1 ± 8.6
Fasting blood sugars	119.93 ± 22.86
HbA1c	7.8 ± 1.6
T. Triglyceride	134 ± 24.8
T. Cholesterol	177.6 ± 16.2

preload in patients who are in a supine position.^{7,9–12} We compared the index with conventional Doppler-derived parameters.

4.1. Conventional Doppler parameters in diabetes

The conventional Doppler showed abnormality in 44% of patients (33 patients with Grade I and 14 patient with Grade III). 23 patients were in Grade II diastolic dysfunction (12 patients showed reversal E/A on valsalva maneuver and 11 additional patients showed abnormality in tissue Doppler-derived E/E', E/E' > 15).

The incidence of diastolic dysfunction in patients with type 2 DM on conventional Doppler parameters was comparable to other studies.^{13,14} The tissue Doppler-derived E/E' has additionally detected dysfunction in 11% of the patients, which increased diastolic dysfunction to 70%, which was comparable to the study by Boyer et al.¹⁵ Boyer et al. had used the tissue Doppler in addition to the valsalva maneuver to identify the cardiac dysfunction. For the detection of cardiac dysfunction, relying on a single parameter is not possible. In our study, in contrast to Boyers et al., the reliability of MPI alone for detection of cardiac dysfunction was equal to that of combining TDI and conventional Doppler parameters.

4.2. MPI in diabetes

LV systolic as well as diastolic dysfunction induces impaired relaxation (prolongation of IRT). The fact that both phases of LV function are simultaneously reflected in the diastolic

Table 2 – Comparison of echocardiographic parameters between groups.

	Group A ($n = 30$)	Group B ($n = 33$)	Group C ($n = 23$)	Group D ($n = 14$)	Group A vs. B p value	Group A vs. C p value	Group A vs. D p value
Age (yrs)	48.4 ± 11.08	51.96 ± 6.67	58.13 ± 6.66	58.85 ± 6.90	0.1, NS	<0.001, HS	<0.001, HS
Duration of DM (yrs)	5 ± 1.5	5.31 ± 2.38	7.86 ± 3.26	7.07 ± 3.02	<0.001, HS	<0.001, HS	<0.001, HS
LA (mm)	28.4 ± 1.6	34.69 ± 3.10	36.13 ± 4.59	39.78 ± 2.99	<0.001, HS	<0.001, HS	<0.001, HS
EF (%)	58.8 ± 1.64	64.2 ± 11.7	53.69 ± 15.38	37.28 ± 11.96	0.016, S	0.076, S	<0.001, HS
E (m/s)	0.92 ± 0.11	0.72 ± 0.17	0.93 ± 0.19	1.05 ± 0.24	<0.001, HS	0.6, NS	0.012, S
A (m/s)	0.74 ± 0.06	0.90 ± 0.17	0.76 ± 0.17	0.55 ± 0.21	<0.001, HS	0.569, NS	<0.001, HS
E/A	1.22 ± 0.57	0.81 ± 0.16	1.23 ± 0.15	2.09 ± 0.74	<0.001, HS	0.699, NS	<0.001, HS
DT (ms)	210 ± 36.5	222 ± 49	190 ± 40	150 ± 19	<0.125, NS	0.125, NS	<0.001, HS
a	0.372 ± 0.048	0.375 ± 0.046	0.399 ± 0.075	0.436 ± 0.09			
b (ET)	0.3 ± 0.046	0.259 ± 0.035	0.244 ± 0.058	0.25 ± 0.059			
MPI	0.24 ± 0.23	0.45 ± 0.130	0.6 ± 0.119	0.680 ± 0.2	<0.001, HS	<0.001, HS	<0.001, HS
E/E'	9.49 ± 6.42	11.81 ± 3.9	16.39 ± 2.69	21.75 ± 8.58	<0.001, HS	<0.001, HS	<0.001, HS

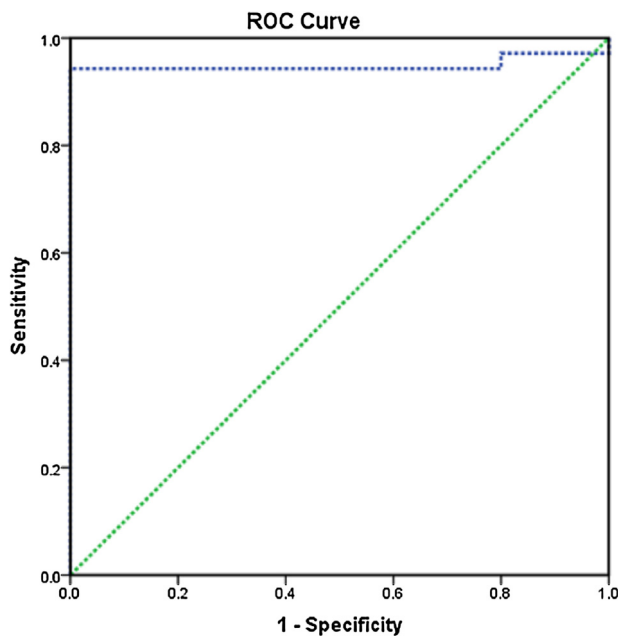


Fig. 2 – Receiver operating characteristic curve for MPI to detect cardiac dysfunction, AUC = 0.948.

parameter of the index (IRT) renders the index sensitive in the identification of impaired relaxation.^{16,17} Thus, MPI has a close correlation with diastolic hemodynamic indices of relaxation and appears superior to conventional diastolic parameters in the detection of impaired relaxation. MPI in our study group was significantly elevated in all grades of diastolic dysfunction. In patients with pseudonormalization of diastolic dysfunction, prolongation of MPI can be explained by the shortening of ET as compared to normal group (Table 2). MPI in our study effectively differentiated the pseudonormalization from normal and it prolonged as degree of diastolic dysfunction increases.

4.3. Pseudonormalization of MPI

A debate exists regarding the ability of the index to reflect the severity of LV diastolic dysfunction in more advanced stages of diastolic dysfunction (pseudonormalization or restrictive physiology), especially in cases with preserved systolic function.^{18,19} In our study, Grade III diastolic dysfunction (restrictive physiology) showed prolongation of MPI; this can be explained by the fact that in most of the patients in Grade III diastolic dysfunction, patients were associated with severe systolic dysfunction (EF = 37.28 ± 11.96%). When severe systolic dysfunction exists, a significant increment (worsening) of the quotient ICT/ET (due to prolongation of ICT and shortening of ET) is induced, which not only counterbalances the short IRT, but also increases the index value.

4.4. MPI and systolic dysfunction

Because of the potent systolic parameters that contribute to the MPI, such as ICT and ET, the index detects with reliability current alterations of LV systolic function. Index in our study

showed a strong inverse relation with ejection fraction, the higher the value of the index, the lower the ejection fraction, and vice versa. The results were comparable to other studies.^{12–16}

5. Conclusions

MPI as a single parameter can be used for assessment in diabetic cardiac dysfunction.

6. Limitations of the study

Sample size was a major limitation in our study. We have not included normal subjects as control group, but with that limitation also, the index was able to differentiate the abnormal cardiac dysfunction with good sensitivity and specificity.

Conflicts of interest

The authors have none to declare.

REFERENCES

- Boudina S, Abel ED. Diabetic cardiomyopathy revisited. *Circulation*. 2007;3213–3223.
- Garcia MJ, McNamara PM, Gordon T, Kannel WB. Morbidity and mortality in diabetics in the Framingham population. Sixteen year follow up study. *Diabetes*. 1974;23:105–111.
- Kannel WB, Hjortland M, Castelli WP. Role of diabetes in congestive heart failure: the Framingham study. *Am J Cardiol*. 1974;34:29–34.
- Fein FS, Sonnenblick EH. Diabetic cardiomyopathy. *Cardiovasc Drugs Ther*. 1994;8:65–73.
- Zarich SW, Nesto RW. Diabetic cardiomyopathy. *Am Heart J*. 1989;118:1000–1012.
- Edvardsen T, Helle-Valle T, Smiseth OA. Systolic dysfunction in heart failure with normal ejection. *Prog Cardiovasc Dis*. 2006;49:207–214.
- Tei C, Ling LH, Hodge DO, et al. New index of combined systolic and diastolic myocardial performance: a simple and reproducible measure of cardiac function—a study in normals and dilated cardiomyopathy. *J Cardiol*. 1995;357–366.
- Rakowski H, Appleton C, Chan KL, et al. Canadian consensus recommendations for the measurement and reporting of diastolic dysfunction by echocardiography: from the Investigators of Consensus on Diastolic Dysfunction by Echocardiography. *J Am Soc Echocardiogr*. 1996;9:736–760.
- Moller JE, Sondergaard E, Poulsen SH, Appleton CP, Egstrup K. Serial Doppler echocardiographic assessment of left and right ventricular performance after a first myocardial infarction. *J Am Soc Echocardiogr*. 2001;14:249–255.
- Tei C, Dujardin KS, Hodge DO, Kyle RA, Tajik AJ, Seward JB. Doppler index combining systolic and diastolic myocardial performance: clinical value in cardiac amyloidosis. *J Am Coll Cardiol*. 1996;28:658–664.
- Nearchou N, Tsakiris A, Stathakopoulos D, Loutsidis K, Skoufas P. A new Doppler index combining systolic and diastolic myocardial performance. Behavior and significance during hospitalization of patients with acute myocardial infarction. *Hellenic J Cardiol*. 1999;40:486–496.

12. Moller JE, Poulsen SH, Egstrup K. Effect of preload alternations on a new Doppler echocardiographic index of combined systolic and diastolic performance. *J Am Soc Echocardiogr.* 1999;1065–1072.
13. Zabalgoitia M, Ismaeil MF, Anderson L, Maklady FA. Prevalence of diastolic dysfunction in normotensive, asymptomatic patients with well-controlled type 2 diabetes mellitus. *Am J Cardiol.* 2001;87:320–323.
14. Poirier P, Garneau C, Bogaty P, et al. Impact of left ventricular diastolic dysfunction on maximal treadmill performance in normotensive subjects with well-controlled type 2 diabetes mellitus. *Am J Cardiol.* 2000;85:473–477.
15. Boyer JK, Thanigaraj S, Schechtman KB, Pérez JE. Prevalence of ventricular diastolic dysfunction in asymptomatic, normotensive patients with diabetes mellitus. *Am J Cardiol.* 2004;93:870–875.
16. LaCorte JC, Cabreriza SE, Rabkin DG, et al. Correlation of the Tei index with invasive measurements of ventricular function in a porcine model. *J Am Soc Echocardiogr.* 2003;16:442–447.
17. Tei C, Nishimura RA, Seward JB, Tajik AJ. Noninvasive Doppler-derived myocardial performance index: correlation with simultaneous measurements of cardiac catheterization measurements. *J Am Soc Echocardiogr.* 1997;10:169–178.
18. Nearchou N, Tsakiris A, Tsitsirikos M, et al. Tei index as a method of evaluating left ventricular diastolic dysfunction in acute myocardial infarction. *Hellenic J Cardiol.* 2005;46:3542–3557.
19. Bruch C, Schmermund A, Dages N, Katz M, Bartel T, Erbel R. Tei-index in coronary artery disease – validation in patients with overall cardiac and isolated diastolic dysfunction. *Z Kardiol.* 2002;91:472–480.